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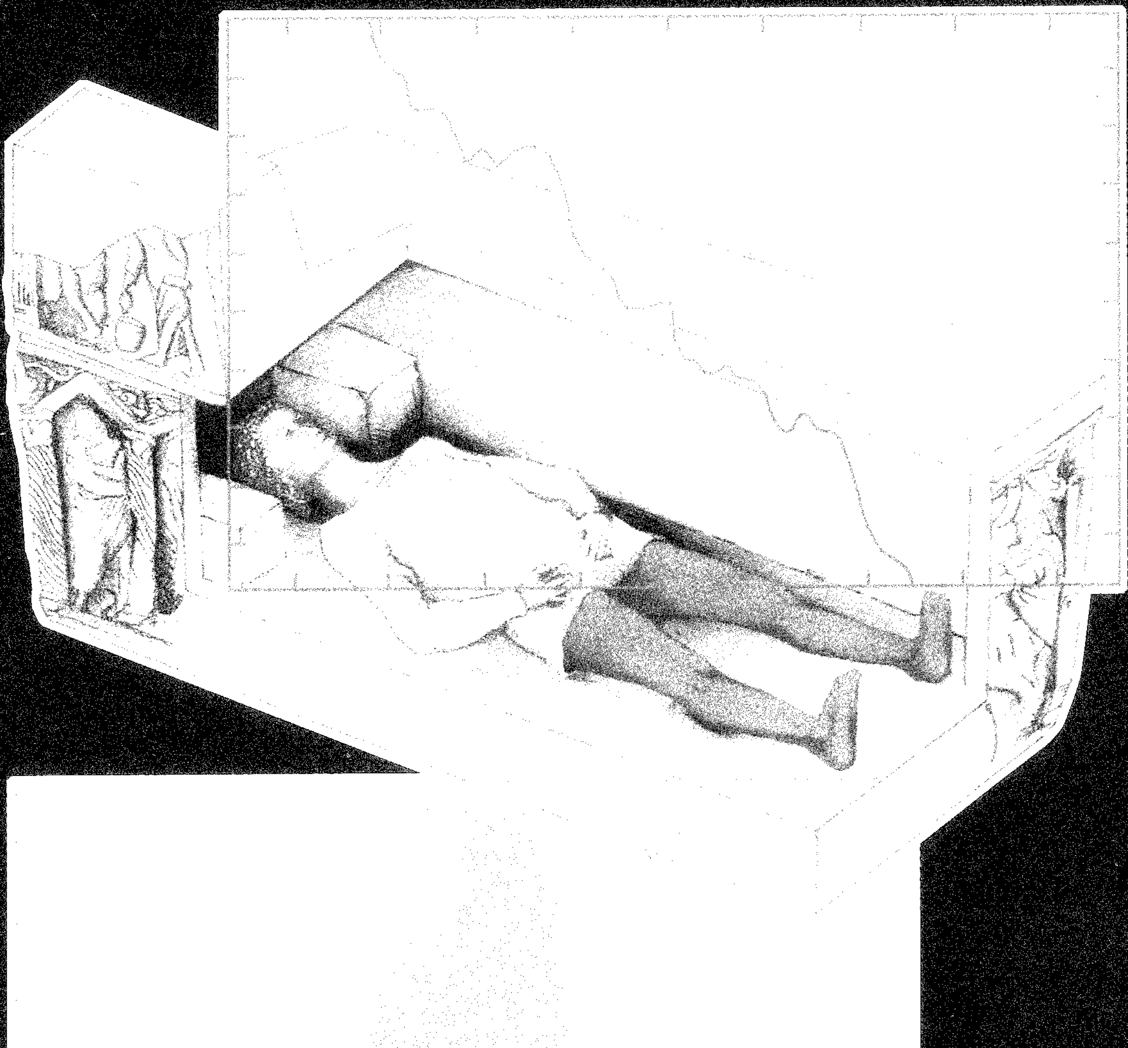
3ème Congrès International
3rd International Symposium
Lyon 6 - 10 avril 1998



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Actes publiés sous la direction de

Jacques EVIN, Christine OBERLIN, Jean-Pierre DAUGAS et Jean-François SALLES

1999

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PREFACE

La datation archéologique est l'une des applications les plus connues de la méthode du carbone-14. Mais pour que les dates ^{14}C soient fiables et qu'elles puissent être utilisées avec clarté, certaines règles précises doivent être appliquées et c'est de la concertation entre les utilisateurs et les spécialistes de la mesure que viennent les progrès en la matière.

Il est donc logique que les uns et les autres éprouvent le besoin de se réunir pour confronter leur expérience et faire connaître leurs résultats. Pour cela, l'organisation de congrès périodiques internationaux sur le thème "Archéologie et ^{14}C" a paru nécessaire lorsque la méthode de datation par le carbone-14 a été reconnue comme un des outils essentiels de l'archéologie.

Deux congrès ont déjà eu lieu dans les années 80 à Groningen (Pays-Bas) et il était devenu nécessaire que le troisième soit organisé car d'importants progrès méthodologiques en radiocarbone ont été faits depuis et, dans le même temps, les archéologues ont révisé la chronologie de nombreuses civilisations de l'Histoire et de la Préhistoire.

Ayant une longue expérience et une longue collaboration dans le domaine des datations et de l'étude des sites archéologiques, les trois organismes lyonnais, le Centre de Datation par le Radiocarbone, la Maison de l'Orient Méditerranéen et le Service Régional de l'Archéologie, se sont proposés pour organiser ce troisième congrès qui a eu lieu du 6 au 10 avril 1998 à Lyon. Les organisateurs souhaitent que le présent ouvrage ait la plus large diffusion tant auprès des laboratoires de datation qui pourront étendre le champ de leur application à l'archéologie qu'auprès des archéologues qui y trouveront de nombreux exemples d'application de la méthode et de nombreuses synthèses chronologiques basées sur de grands ensembles de résultats, spécialement dans les domaines les plus d'actualité au tournant du siècle.

Cet ouvrage publie 72 communications, conférences et rapports de groupes de travail, présentés lors de ce 3ème Congrès International.
Ces textes se regroupent suivant cinq thèmes couvrant les principaux aspects de l'application du radiocarbone à l'archéologie depuis le Paléolithique supérieur jusqu'au Moyen-Age. En chacun des domaines, des contributions des laboratoires de radiocarbone de toutes les régions du monde font état des dernières données acquises tant en méthodologie que par l'accumulation d'un grand nombre de dates radiocarbone.

Ce congrès a bénéficié des aides de la Commission Européenne (Dg. X), de la Sous-Direction de l'Archéologie du Ministère de la Culture, du Conseil Général du Rhône, du Conseil Régional de Rhône-Alpes (programme ARASSH), du Ministère des Affaires Etrangères, du Ministère de l'Enseignement Supérieur (M.S.U.), du Centre National de la Recherche Scientifique, des Universités Lyon 1 et 2 et de l'Ecole Nationale Supérieure CPE.

Le comité organisateur de ce congrès était constitué de :
- Jacques EVIN et Christine OBERLIN, Centre de Datation par le Radiocarbone, CNRS et Université Claude-Bernard Lyon 1, Villeurbanne,
- Jean-Pierre DAUGAS et Michel PRESTREAU, Service Régional de l'Archéologie de la région Rhône-Alpes, Lyon,
- Jean-François SALLES, Maison de l'Orient Méditerranéen, Lyon.

Le comité scientifique, qui est devenu le comité de lecture pour la publication des présents Actes, était constitué de, outre les précédents :
Robert CHENORKIAN (Aix-en-Provence), Gabrielle DEMIANS D'ARCHIMBAUD (Aix-en-Provence), Henri-Paul FRANCFORT (Paris), Alain GALLAY (Genève), Jean GUILAINE (Paris), Robert HEDGES (OXFORD), Loïc LANGOUËT (Rennes), Danièle LAVALLEE (Paris), Philippe LEVEAU (Aix-en-Provence), Wim MOOK (Gröningen), Christian STRAHM (Freiburg-im-Brisgau), Jean-Philippe RIGAUD (Bordeaux), Mark VAN STRYDONCK (Bruxelles), Hélène VALLADAS (Paris) et Hessel WATERBOLK (Gröningen).

Chaque article a été soumis à deux relecteurs, voire à trois en cas de désaccord entre les deux premiers. La vérification du contenu des textes a été assurée par Anne LANDOIN (Lyon) et la maquette du volume des présents Actes (montage PAO) a été réalisée par Gaëlle LE PAGE (Rennes), dans le cadre du Pôle Editorial d'Archéologie de l'Ouest (UMR 6566).

J. EVIN, C. OBERLIN, J.F. SALLES et J.P. DAUGAS

Lyon 1998

3rd International Symposium

14C and Archaeology programme

Lyon-1998

Liste des participants

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Actes du colloque « C14 Archéologie », 1998, p. 7-9.

CONFÉRENCE INAUGURALE

*Jacques EVIN**

Chers Collègues,

Je suis très heureux de prendre la parole pour le premier exposé de cette conférence sur le radiocarbone et de vous saluer, ici réunis, mes collègues spécialistes du radiocarbone et mes collègues spécialistes d'archéologie. Je crois être, à beaucoup de titres, l'un des vôtres, m'étant toujours plu à être le physicien dans les conférences d'archéologie et le géologue et l'archéologue dans les réunions regroupant les spécialistes du radiocarbone. Au cours de tous les colloques internationaux de radiocarbone j'ai bien remarqué que les archéologues, ou même seulement ceux qui s'intéressent un peu à l'archéologie, sont très minoritaires. En effet l'archéologie n'est pas la principale préoccupation des « radiocarbonistes ». Dans leurs congrès les communications la concernant sont infiniment moins nombreuses que celles portant sur les technologies, la calibration ou le cycle naturel du carbone :

- les technologies de mesure : comment mesurer au plus exact la teneur en ^{14}C,
- la calibration : comment ajuster au mieux le calendrier radiocarbone au calendrier normal,
- l'environnement et le cycle du C-14 : comment utiliser cet extraordinaire marqueur naturel qu'est le radiocarbone pour comprendre les processus complexes qui ont régi les climats des temps glaciaires ou ceux de l'interstade Holocène que nous vivons depuis 10 000 ans.

Mais, après tout, il est logique que les chercheurs soient plus préoccupés de savoir si l'ère industrielle ou atomique va changer le climat que de connaître la chronologie de la vie de nos ancêtres.

Cette archéologie, qui fait peu recette auprès des "radiocarbonistes", c'est elle qui nous rassemble aujourd'hui comme elle a rassemblé pour la première fois, à Chicago, il y tout juste un demi siècle, quelques archéologues autour d'un certain Libby venu leur exposer les possibilités de la méthode dont il venait de jeter les bases et qui lui valu le prix Nobel quelques années plus tard.

Cette Archéologie, c'est bien elle qui a le plus fait connaître cette méthode de datation auprès du grand public comme l'illustrait la photo des trois premiers objets archéologiques datés, reproduite sur livré jubilaire du fondateur de la méthode.

Je ne vais pas reprendre ici tout l'historique de la méthode. Il y a quelqu'un ici qui a vécu, presque dès ses débuts, cette méthode, et qui en a été un de ses principaux promoteurs depuis 40 ans, c'est notre collègue Harm Tjalling Waterbolk qui reprendra cet historique vendredi soir lorsque, nous tous, après cette semaine de congrès, nous y aurons ajouté une page, qui, je l'espère, sera une page bien remplie.

Si mon laboratoire s'est trouvé toujours très en liaison avec les archéologues, si nous, ma collègue Christine Oberlin et moi, nous sommes toujours enrichis à leur contact et si, je l'espère, nous avons pu apporter une certaine contribution à leur discipline, je crois qu'il n'en a pas toujours été de même pour tous les laboratoires ou tous les instituts d'archéologie. Peut-être que l'histoire des rapports entre l'archéologie et la méthode du Radiocarbone peut se résumer à cette boutade « je t'aime, moi non plus ». N'a-t-on pas vu trop souvent les physiciens trop sûrs de leurs résultats et les archéologues trop sûrs de leurs systèmes. Mais comme toujours le temps et l'honnêteté des uns et des autres ont fini par faire « prendre la mayonnaise ». Pour illustrer cette longue quête d'une efficace collaboration je voudrais prendre en premier un exemple qui nous a touché de près, nous archéologues et "radiocarbonistes" français et lyonnais : je veux parler de la datation des peintures pariétales.

Tout le monde connaît ces très célèbres peintures de Lascaux, découvertes en 1940 et étudiées par l'Abbé Breuil. Il les attribuait au Périgordien, c'est-à-dire au milieu du Paléolithique Supérieur et ne s'est guère soucié de leur âge. Le Radiocarbone n'ayant pas encore été découvert on ne pouvait d'ailleurs pas avoir grande idée de

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cet âge. 10 ans plus tard, en 1951, paraissait la première liste de dates qui comprenait un petit article sur la datation d'un échantillon provenant de Lascaux. Le commentaire disait brièvement que cette mesure datait le niveau d'occupation de la grotte. Les archéologues ne firent aucun cas de ce résultat et l'abbé Breuil le déclara trop récent. Deux datations du laboratoire de Saclay confirmaient peu après ce chiffre mais pendant longtemps plus personne ne parla de datations absolues des oeuvres d'art et, tout à fait indépendamment de toute chronologie chiffrée, une théorie sur l'évolution de l'art fut proposée. En ce domaine l'archéologie et la ^{14}C s'ignoraient totalement, évidemment parce qu'il était alors impossible de dater directement les traces carbonées.

22 ans plus tard, en 1973, j'eus la chance de pouvoir effectuer la première datation de peinture sans que puisse être mise en doute le rapport entre la matière carbonée datée et la peinture. L'archéologue avait pu récolter sur le sol au milieu d'un peu de peinture orange, reste de la palette du peintre, un seul petit charbon qui aurait été facilement daté par un accélérateur, mais le principe de cette technologie de mesure si révolutionnaire n'ayant pas encore été imaginé ; je mesurais ces petits charbons avec la meilleure précision possible et je fus satisfait d'obtenir cette date de 21000 BP à +/- 800 ans près. Je fus surtout bien heureux de constater que cette date était, comme on le dit souvent, « dans la plage de temps attendue ». En cette occurrence c'est l'archéologie qui était pilote en chronologie et je devais trouver ce résultat sinon c'était ma mesure qui était remise en cause.

Encore à peu près 20 ans après on découvrait près d'ici les grottes de Cosquer et de Chauvet et nous pouvions recevoir, nous à Lyon, des échantillons provenant des foyers au sol et Mme Valladas de Gif-sur-Yvette, des fragments de matières carbonées issues des peintures ou des mouchage de torche. Les résultats, tous autour de 30 000 BP pour les plus anciens, n'étaient pas du tout ceux qui étaient attendus. Eh bien, le temps étant passé, la méthode et la technique de mesure ayant indubitablement fait leurs preuves aux yeux des archéologues, c'est toute l'interprétation de l'évolution de l'art qui sera changée.

Est-ce à dire que les archéologues doivent avoir maintenant une confiance sans borne dans les résultats annoncés par les physiciens. Il va être question dès ce matin, en début du congrès, de la calibration : comment les chiffres que nous obtenons par la mesure de la teneur en radiocarbone doivent-ils être ajustés pour correspondre à la réalité des années calendaires. Lorsque cette correction n'était pas encore bien connue, il s'est heureusement trouvé des gens pour dire que la méthode du radiocarbone n'était pas adaptée à la résolution de certains problèmes archéologiques. Ils avaient raison ceux qui, très tôt, se sont aperçu que la forte variation des écarts entre les dates ^{14}C et les dates en années réelles masquait certaines données bien établies par l'étude des industries. Je me souviens de discussions sur les datations BP du Néolithique final en Languedoc qui faisaient se succéder à un rythme trop rapide pour leur épanouissement les civilisations Ferrières, Fontbouïsse et Chalcolithique. Ce scepticisme des archéologues se justifiait car la calibration a montré que ces phases culturelles avaient en réalité duré moitié plus de temps que ne l'indiquaient les dates radiocarbone non corrigées.

C'était aussi une réaction raisonnable, celles des climatologues ne pouvant admettre que la période froide du Dryas récent, responsable d'une forte réavancée glaciaire et datée de 10 100 à 10 400 BP, n'ait duré que 300 ans, alors qu'on va jusqu'à lui attribuer maintenant un millénaire puisqu'il y a un large plateau dans la courbe de correction justement autour 10 100 BP.

C'est donc une chance pour les spécialistes du radiocarbone d'être mis, par les « lecteurs du terrain », en face d'une contradiction qui les force à revoir et préciser leur résultats. On souhaiterait qu'il en soit toujours ainsi et que ni le "radiocarboniste" ni l'archéologue ne se laisse guider sans esprit critique par les affirmations de l'un ou de l'autre, mais que chacun apporte sa spécificité au bâti de la chronologie. Pour illustrer ceci je vais faire un petit retour sur une période que nous n'aborderons pas au cours de ce colloque, car il n'était pas possible de s'arrêter sur tout les époques : je veux parler de la fin du Paléolithique Supérieur.

Chaque archéologue se souvient des civilisations Magdaléniennes qui se succédaient comme des pelures d'oignon : Magdalénien 0, I, II, III, IV, V, VIA et VIB se remplaçant les unes après les autres, en même temps que des interstades se produisaient tous les 1 000 ans, entre 20 000 et 10 000 B.P. L'archéologue croyant sans réserve dans la précision des datations, attendait qu'elles classent chaque niveau de chaque site dans un canevas rigide. Toutes les datations que nous avons faites n'ont pas confirmé cette manière de voir et nous avons cru mettre en évidence bien des contemporanéités entre différentes phases culturelles car nos ensembles de dates ont montré de large recouvrement. Mais avions nous raison, puisque nous ne pouvions pas corriger nos dates BP ? Ces apparentes contemporainéités sont peut-être dues aux fluctuations de la production du ^{14}C et les archéologues ont, peut-être à cause de nous, abandonné trop vite leur première manière de voir. Ce problème ne peut pas être résolu à l'heure actuelle tant est grande l'incertitude sur les détails de la courbe de calibration pour cette période puisqu'elle n'est encore fondée que sur quelques datations U/Th. Nous le savons maintenant, de grands plateaux perturbent les IXèmes et Xèmes millénaires avant notre ère. Les millénaires des « derniers chasseurs » ont peut être eu une atmosphère encore plus perturbée en teneur en ^{14}C. Il nous faudrait pouvoir dater finement de bonnes séries stratigraphiques et être aidé par un bon schéma typologique. Donc, pour le tardiglaciaire, nous, "radiocarbonistes", nous avons plus à attendre des géologues et des archéologues que l'inverse.

La situation est complètement différente pour les périodes plus récentes où la courbe de correction est connue en détail. La méthode de datation peut donner la plénitude de ses possibilités. On l'utilise fort bien pour dater de grands événements archéologiques tels que les premiers peuplements, ou les premières apparitions de technique. Plusieurs séances illustrent cela et je n'ai pas à insister.

Je voudrais pour finir en venir sur la précision que l'on peut attendre de la méthode lorsque l'on se trouve dans la période la plus récente.

Pendant de nombreuses années le ^{14}C a été uniquement considéré comme une méthode réservée à la préhistoire : dans sa nouvelle édition un dictionnaire archéologique bien connu la définit encore ainsi. Pourtant un laboratoire comme le nôtre, qui autrefois datait surtout des échantillons du Néolithique ou du Paléolithique, est maintenant amené à consacrer une part très importante de ses activités à dater des objets de moins de 1 000 ans. Nous aurions tous, mes collègues et moi, des quantités d'exemples où le C-14 est venu contribuer à authentifier les restes de tel roi ou de telle princesse, vérifier telle légende, confirmer telle relique où la date est exactement conforme à ce qu'affirmait la tradition ou infirmer celle de telle autre où la date est complètement différente de ce qui était attendu.

Ayant l'embarras du choix pour illustrer la grande précision que l'on peut attendre de la méthode pour le Moyen Âge, je choisis un étude récente qui pour moi est l'exemple presque parfait de la collaboration entre les archéologues, les "radiocarbonistes" et des spécialistes des autres disciplines de l'archéométrie. Il s'agit de la datation des ossements d'une sépulture collective d'une partie de la dynastie des Comtes de Toulouse. Accolé au mur extérieur de la basilique Saint-Sernin, un sarcophage contenait, pensait-on depuis presque un millénaire, les restes du plus célèbre d'entre eux, Guillaume Taillefer, né vers 970 et mort en 1035, après une vie glorieuse, comme celle de son jeune contemporain Guillaume le Conquérant. L'ouverture du coffre a curieusement montré la présence des restes de 20 individus différents dont, à la base un comte, au squelette complet, reconnaissable à quelques morceaux d'habit rouge. Cet individu était remarquablement conservé et on a même pu reconstituer son visage et savoir qu'il était mort d'une tumeur derrière l'oeil. 5 datations ont été effectuées, une par notre collègue Robert Hedges d'Oxford, les autres par nous. Il s'agissait de mettre une date sur divers ensembles osseux que les anthropologues avaient pu distinguer, de tenter de retrouver si l'un d'entre eux pouvait correspondre à Guillaume Taillefer qui ne pouvait être ce comte, mort à 35 ans environ. Je n'ai pas le temps de détailler l'interprétation archéologique mais on passe du schéma classique à l'hypothèse d'interprétation grâce à la contribution de toutes les disciplines, de l'épigraphie à l'anatomie, de l'analyse des tissus à l'étude du paysage urbain par les pollens. Au bout de l'étude, chef d'oeuvre d'interdisciplinarité, une bonne part de l'histoire de la famille a été en partie élucidée. Dans cette affaire quelle a été la contribution du ^{14}C ? Elle fut essentielle parce qu'elle a déblayé le terrain et ordonnancé les ensembles osseux. En son absence aucune interprétation fiable n'était possible car on avait même pensé que les derniers individus dataient du XVIIIème siècle.

Satisfaction donc de l'apport de notre technique pour cette période pourtant si souvent bien documentée avec seulement un petit doute que les spécialistes apprécieront. Après tout, avec une telle précision des analyses à +/-30 ou +/-40 ans et des pics de probabilités focalisés sur 20 ans, est-ce que nous ne donnons pas une précision trop grande tant que nous ne connaissons pas le cycle du carbone dans les os au cours de la vie d'un homme ? Il faudrait que des anatomistes nous apportent cette précision. Est-ce que cette teneur en radiocarbone des os du comte que nous avons mesurée et qui nous fait situer son décès très près de l'année 950, ne correspond pas, en réalité au Carbone 14 de la matière carbonée qu'il a ingéré 20 ans avant sa mort et que celle-ci ne date que de l'an 970. D'après les historiens nous changeons alors de comte et nous avons peut-être à faire au père de Guillaume Taillefer et non pas à son grand père ! La question reste ouverte et des problèmes de ce type seront évoqués demain dans le rapport du groupe de travail dirigé par notre collègue Marc van Strydonck. J'en terminerai là sur cet exemple si spectaculaire que tous laboratoires voudrait pouvoir avoir à étudier chaque jour mais qui n'est malheureusement pas si fréquent.

Illustrant ainsi certains aspects de la méthode appliquée aux temps les plus anciens de nos ancêtres artistes peintres, à ceux un peu plus récents des derniers chasseurs, aux premiers agriculteurs, j'ai terminé sur nos proches parents, les hommes du Moyen Âge. Pour monter tout l'édifice de la chronologie de l'histoire de l'Homme, pour édifier la pyramide des dates les « dateurs », comme des tailleurs de pierre, apportent des éléments plus ou moins bien façonnés. C'est à l'archéologue de faire le maçon et d'édifier la pyramide, sans mortier si les pierres sont très bien ciselées, avec le mortier de l'interprétation, si le matériel est peu précis. Avec le développement de la recherche en radiocarbone la tour ^{14}C que nous montons prend de plus en plus bonne figure. Certes l'immeuble ne dépassera sûrement jamais le 50ème étage (ou millénaire), tandis que ceux construits par la thermoluminescence, l'Uranium-Thorium ou le Potassium-Argon, avec leur portée qui se chiffre en centaines de milliers d'années ou en millions d'années, montent beaucoup plus haut dans le ciel de l'infini des temps. Mais notre petite maison « Carbone 14 » a des bases bien solides et est de mieux en mieux entretenue. Nous tous, que le radiocarbone réunis ici cette semaine nous allons y contribuer et, quant à moi, depuis plus de trente ans que j'y travaille dans mon petit bâtiment, j'y ai trouvé beaucoup de plaisir.

Nous allons avoir toute cette semaine de nombreuses communications au cours desquelles nous regretterons peut-être de ne pas en savoir plus sur la chronologie, de ne pas avoir une méthode plus précise, de ne pas comprendre parfaitement bien le cycle du radiocarbone. Peut-être que certains regrettent que cet isotope n'est pas une période de 55 710 ans, ou qu'il n'y ait pas 15 ou 20 isotopes radioactifs harmonieusement répandus dans la nature avec chacun une période différente. Et pourtant, quelle chance nous avons actuellement de pouvoir disposer de nos moyens chronométriques. Avec l'arrivée de l'an 2000, la mode est à la rétrospective : pensons à ce qu'avaient nos prédécesseurs à la fin du XIXème siècle avant la découverte de la radioactivité.

Pour illustrer cela nous avons accepté avec plaisir la communication de Messieurs Schoeneich et Corboud qui vont nous repousser 130 ans en arrière dans les problèmes de chronologie. Je vous prie donc de les écouter avant que nous allions fêter le début de ce congrès par une première petite tasse de café à 115 % N.B.S. en ^{14}C. Après celle-ci la présidence de la séance sera assumée par notre collègue Wim Mook, ce qui fera la continuité avec les deux premiers congrès « Archéologie et C-14 », dont il a été l'organisateur.

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CONFÉRENCE DE CLOTURE : ARCHAEOLOGY AND RADIOCARBON DATING 1948-1998 : A GOLDEN ALLIANCE

*H. Tjalling WATERBOLK**

INTRODUCTION

In this concluding lecture I want to look back at the relationship between archaeologists and radiocarbon scientists. My point of view will be that of an old world archaeologist and highly personal. The beginning of this relationship seems clear enough : it was a lecture on a new dating method given in January 1948 by the Chicago physicist and future Nobel Prize winner Willard F. Libby (1909-1980) at a Viking Fund Supper Conference in New York City (Taylor, 1987). The attendance consisted of some thirty archaeologists and anthropologists and at least one geologist. In those days such conferences were regularly organized by the legendary Paul Fejos, the Director of Research for the Viking Fund, which in 1951 would become the well-known Wenner Gren Foundation for Anthropological Research. A few months before, the Viking Fund had rendered financial assistance to the dating project, which up to that time had only by the University of Chicago.

Under the guidance of Harold Urey - himself a Nobel Prize winner - Libby had been working on the project since 1946 (Arnold and Schuch, 1992). The Chicago archaeologists Robert J. and Linda Braidwood remember - in a letter to the author of March 2, 1998 - that sometime in the summer or early fall of 1947 they were invited to attend a small luncheon at the Faculty Club where they heard about the new method from Urey and Libby themselves. They don't remember who else was at the luncheon, "probably Thorkild Jacobson, then the head of the Oriental Institute and a few from the Anthropology Department, such as Sol Tax and Robert Redfield - none still living to ask - And when Urey spoke as though the system was all ready to be tested and Libby demurred, saying there were still certain things to be ironed out, Urey was positive that this was only a minor thing and Libby could easily overcome any such trifles". Soon afterward the Braidwoods left for a field expedition in Iraq where they remember collecting snail samples for Libby.

At the New York meeting, which the Braidwoods could not attend, the slide projector was run by James R. Arnold, a physical chemist who had joined the project in November 1947 on the basis of the Viking Fund grant. At this occasion Libby was still cautious. He "emphasized that the method was not yet proven, and particularly made the point that isotopic enrichment might be required, with its attendant disadvantages of small throughout of samples and large required sample size. Also to many archeologists present his efforts to make the principles of the method understood were difficult to grasp. But as I recall he was not at all discouraged by the reception he got." (Arnold, in a letter to the author of April 6, 1998).

THE YEARS 1948-1953

The New York meeting, now exactly 50 years ago, was the first introduction of the new method to the world of archaeology at large. It marks the beginning of what one might call a golden alliance.

As sequel to the meeting the American Anthropological Association and the Geological Society of America set up a joint 'Committee on Radioactive Carbon 14', which was to help Libby in finding suitable samples of known historical age. Members of the committee were the archaeologists Frederick Johnson (chairman), Donald Collier and Froelich Rainey and the geologist Richard Foster Flint.

After a preliminary publication in March 1949 (Libby, Anderson and Arnold, 1949), Arnold and Libby published in December 1949 a series of seven measurements of samples of known age from AD 600 to 2700 BC (Arnold and Libby, 1949). In early 1949 Libby felt confident enough to start dating samples of unknown, prehistoric age.

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The committee requested ten individuals to collect material for this purpose. Each person represented a particular region or chronological issue. For the old word, Robert J. Braidwood had to deal with Mesopotamia and Hallam L. Movius with Scandinavia and western Europe. Braidwood wrote an article on the new method in the American Journal of Archaeology (Braidwood *et al.*, 1950). Movius covered Europe by papers in Antiquity (Movius, 1950a) and - in french - in l'Anthropologie (Movius 1950b).

Quickly the news spread around the world. The widely read British journal Antiquity mentions the discovery in the Editorial of its September 1949 issue. Among the first places outside the U.S. where laboratories were set up were Copenhagen and Groningen. I happen to have some personal recollections relating to the events in both cities. In October 1949 I stayed as a student in palynology and archaeology for a couple of weeks at the pollen laboratory of the Danish Geological Survey at Copenhagen under the guidance of Johannes Iversen. At that time Iversen was the world's leading palynologist, known for his fondamental work on pollen identification, the recognition of the influence of Neolithic man on the natural vegetation and the nature of the Late Glacial vegetation. In his pollen diagrams he identified two slightly warmer periods, the Bölling and the Alleröd oscillations, before the final warming up of the climate at the beginning of the Postglacial period. The cold period between the Alleröd oscillation and the Postglacial, the so-called Younger Dryas period, could be equated with the last advance of the glaciers in Fennoscandia. This advance had been dated by the geochronologist G. de Geer by counting varve sequences in meltwater lakes in front of the shrinking glaciers. The dates of this advance could therefore be transferred to the Younger Dryas zone in the pollen diagrams of sediments outside the formerly glaciated zone. The Alleröd pollen zone had already been recognized at the Upper Palaeolithic sites of Meiendorf and Stellmoor near Hamnburg. In 1948 it was round in the northem part of the Netherlands. Apparently it was a synchronous phenomenon over large parts of Europe, with an estimated date of c. 9800 - c. 8800 BC.

Peat of Alleröd age would therefore ideally be suited for checking the validity of the new dating method over a time range more than twice as long as the Egyptian samples that American museums could offer. A widely experienced quaternary geologist, such as Richard Foster Flint, an active member of Libby's committee, would realize this. It is certainly no accident that the first sample from Europe to be dated in Chicago was from a peat layer with birch remains from the upper part of the Alleröd pollen zone in a profile from Wallensen in the German Weser Bergland. The date, C-337: 11044 +/- 500 (Libby 1965), was according to expectation and is still perfectly acceptable. The sample had been submitted by the palynologist F. Firbas, who added a note on the very satisfactory result to his famous book 'Waldgeschichte Mitteleuropas', part 2, of 1952.

It was during my stay at Copenhagen that Flint visited Iversen's laboratory in the company of the Danish nuclear physicist, Hilde Levi. I do remember the commotion caused by this visit, though being a foreign student at the lab I was of course not in any way personally involved. But in retrospect this visit by Flint must have played a key role in the establishment, about a year later, of a radiocarbon laboratory at Copenhagen, where of course nuclear physics at that time had earned great international prestige through the work of Niels Bohr. Samples from an Alleröd peat layer at the clay brickwork of Ruds Vedby were in due course measured and as the results (Iversen, 1953) turned out to be according to expectation it was for any quaternary geologist and palynologist in Europe obvious that the method was fundamentally correct. Subsequently other new laboratories used the Ruds Vedby samples as an interlaboratory check (e.g. British Museum, Stockholm, Uppsala).

Back home in Groningen my professor A.E. van Giffen, had been alerted by professor H.W. Aten, a physics colleague at Amsterdam. Aten had recently visited the United States and most certainly had met Urey, with whom he had closely collaborated in the thirties (information W.G. Mook). Van Giffen immediately took steps to introduce the method at his university by urging a brillant young professor of biophysics, named Hessel De Vries, to build a dating apparatus for him. As we all know, De Vries started to develop the method of counting the radioactivity of carbon in the form of the gas carbon dioxyde. His method has replaced the solid carbon dating method of Libby which soon began to suffer from the nuclear fall-out resulting from the atomic bomb tests.

As a test sample De Vries used a large stump of an oak tree, excavated in 1950 by Van Giffen as part of a wooden building below the floor of the medieval church of Saint Walburg in Groningen. In May 1952 he produced his first date Gro-000 : 850 +/- 200. As Libby had got a quite different result (C-621 : 2221 +/- 200) - through Movius he had already obtained a piece of Van Giffen's wood - further measurements were done by De Vries with slightly varying results that were only much later understood (Lanting, 1990). One reason for the variability in the dates obtained by De Vries lay in the fact that at that time possible age differences within the wood were not yet recognized. Another reason was that the wood growth fell within a period with serious calibration difficulties. The wood of the Saint Walburg stump has been used as a check sample by many laboratories starting to work in the fifties (Arizona, Hanover, Heidelberg, Copenhagen, Lamont, London, Lund, Trondheim, Uppsala, Victoria). This illustrates the close cooperation between the radiocarbon scientists in the pioneer phase and the central position of De Vries in their network. "Libby was much gratified by the rapid spread of the method to other laboratories in Europe and around the world, and he had a particularly high regard for De Vries (though it was hard for him at first to accept the deviations from the simple decay curve which De Vries was the first to discover)" (Arnold, in litt.). De Vries died in 1959. Libby left Chicago in 1954. He was awarded the Nobel Prize in 1960.

Among the first archaeological samples to be routinely dated by De Vries were charcoals from cremations in Bronze Age barrows excavated by my colleague assistant Willem Glasbergen, for whom I was doing the analysis of pollen samples. These barrows had interesting peripheral structures such as timber cercles, ditches and batiks, but they were very poor in finds and thus hard to date by traditional means. In May 1953 the expected age and the sequence of barrows suggested by the pollen content were confirmed by radiocarbon dates. For us, the new method had proved its validity (Waterbolk, 1983). Only much later I realized that the introduction of radiocarbon dating meant that pollen analysis lost its monopoly as a dating tool for the prehistory of northern Europe, which it had had for a quarter of a century.

EXPANSION 1953 - c. 1965

In dealing with the following years I will mainly follow a suggestion by Paul Damon (1992) and divide the history of radiocarbon dating in three phases. The first lasts until c. 1965. The second phase ends with the publication in 1986 of the Calibration issue of the journal Radiocarbon. We are living in the third phase. Mainly on the basis of the adress lists in Radiocarbon I have prepared a graph indicating the number of active laboratories with 5 years intervals. In the first phase falls the rapid expansion, first in the USA and Canada, soon after also in Western Europe, Australia and New Zealand. In 1960 41 laboratories were already active. The second phase sees a gradual further growth to a total of 114 laboratories in 1985. In the third phase there is no further increase in the total number of laboratories. A drastic decrease in the USA and Canada from 39 in 1985 to 20 in 1995 is compensated by a spectacular growth in Eastern Europe and Asia.

My graphs only indicate the number of active laboratories. Many laboratories were however only active for a limited period. For example from the 36 laboratories active in 1960 only 14 were still operating in 1996. Equally, of the 60 new laboratories listed in 1970 there are only 30 left in 1996. All in a total of nearly two hundred laboratories may at some stage have produced radiocarbon dates.

The fifties and early sixties did not only witness an explosive growth of the number of laboratories, it also was the period of technical innovations, increasing insight in the fundament of the method and international agreements on procedures and reporting. Let me recall a few developments that have a direct bearing on the archaeological interpretation of radiocarbon dates.

One of the first things we had to learn was that one of the fundamentals of the method, the constancy of the radioactivity of living matter, was not quite correct. There was the 'Suess-effect', showing us that the influence of the combustion of fossil coal and oil since the industriel revolution had been of such a magnitude that recent plant material could not simply be used for comparison. The radiocarbon people round a way out by the distribution of an artificial 'recent' standard, made available by the American National Bureau of Standards. Then there was the 'De Vries-effect' : before the industriel revolution the radioactivity of living matter was not constant but showed variations. These had been round by comparing the radiocarbon ages of tree rings of known historical age. This discovery, at first of course considered to be a serious draw-back, was the beginning of a line of research that has lead to the calibration possibilities that now are available. Next, there was the problem of the not exactly known half-life of carbon 14. Here the radiocarbon people round a way out by agreeing to calculate all radiocarbon dates on the basis of the so-called Libby-half life. It was also decided to use the year 1950 as the standard reference year. Every lab was given its own code designation and we were asked to always use the dates in combination with these code designations. The first date-lists were published in journals such as Science and Nature. For these lists the '*Radiocarbon* Supplement' of the American Journal of Science was founded in 1959. Its name was changed to 'Radiocarbon' in 1961. The date-lists became highly standardized. We started to work with 'conventional' radiocarbon dates in years 'BP' with a one sigma error, of which we knew that they were not quite accurate in terms of calendar years but which were of enormous help in bringing an independent order to the increasing multitude of archaeological and environmental data. Finally I should mention the process of isotopic fractionation, which was round to be responsable for errors that with some types of plants and with animals living in special environments could be considerable. However, they could be corrected by measuring in a mass spectrometer the $^{12}C/^{13}C$ ratio. This soon became a standard element in the dating procedure.

Looking back on this pioneer decade it is clear that many early dates needed to be corrected as more and better information on the effect of the factors mentioned became available. The Groningen lab switched in 1963 from Gro-numbers to GrN-numbers and indicated different corrections for various series of dates already published. In the course of time other labs too came with corrections.

Of course one should look upon the defects of the early measurements as unavoidable in the development of a new method. For some people, however, the successive corrections added to a basic feeling of discomfort with a dating method so alien to their field. In particular the statistical nature of the determinations was for many people difficult to handle. At the same time, natural scientists could not understand why this should be so. In America the claim to be able to measure time before the calculated date of the Creation was for some religions circles reason enough to reject the method. However, opposition came also from the geologist Ernst Antevs. In the words of Arnold, "He was by far the most sucessful of the experts in estimating the dates of sites and periods in the southwestern U.S., but he had been rather far off in his earlier career (like most everyone else) in dating glacial periods in the northeast. So he kept writing papers proposing that ^{14}C dating was good for dry climates but not for wet." In central Europe a strong resistance was found among professional archaeologists, who did not want their humanistic field to be intruded by natural science methods, which were beyond their control. Their eloquent spokesman was Vladimir M. Milojcic, a German archaeologist of Yougoslav birth, who in a series of articles in the years 1957-1977 fulminated against the method. In an obituary by one of the leading German archaeologists of that time, Joachim Werner from Munich, one can see how far his influence has reached. According to Werner Milojeie "was able thoroughly to disenchant the magie key that one thought one had for dating all carbon-containing samples to the exact year". In this way he "performed for prehistoric archaeology a service which cannot yet fully be evaluated, and encouraged it to stick to the reasoned use of the methods indigenous to its own field of study". Personally I remember vividly the discussion between Milojcic and the British archaeologist Renfrew at the international prehistoric congress of Belgrade in 1970, where both demonstrated considerable acting abilities. At another occasion I discussed in more detail the background of the resistance against radiocarbon dating in Central Europe (Waterbolk, 1983).

Among the early promotors of radiocarbon dating in Europe we find the leading palynologists Firbas in Göttingen, Godwin in Cambridge, Iversen in Copenhagen, Mitchell in Dublin, Overbeck in Kiel and Welten in Berne, and the geologist Zeuner in London. Archaeologists were in fact a relative minority and of a special kind : Bandi in Berne, Blanc in Rome, Clark in Cambridge, Van Giffen in Groningen, Giot in Rennes, Schwabedissen in Schleswig (later Cologne). All of them had a particular interest in the environmental aspects of archaeology and they were used to cooperate with natural scientists. Interestingly, the first editors of the *Radiocarbon* Supplement were the palynologist Deevey and the geologist Flint. They were joined by the archaeologist Irving Rouse in 1963.

CONSOLIDATION c. 1965 - c. 1985

Halfway through the sixties one might say that radiocarbon dating had overcome its childhood diseases and entered a quiet period of further technical sophistication and routine dating. This does not mean that it was a dull period. For archaeology most important was the increasing prospect of the possibilitv of calibrating conventional radiocarbon dates. In the White Mountains on the California/Nevada border, at an altitude of more than 4000 metres, living specimens of a pine, Pinus aristata, were found with an age over 4000 years. Combining the tree ring sequences of these living trees with those of dead trunks in the same area finally produced an unbroken tree ring sequence back to 6700 BC. Long series of radiocarbon dates from bidecal blocks from this sequence were measured by Hans Suess and showed the natural long term variations of the atmospherie ^{14}C content, as well as clear hints of the short term variations superposed on the long term variations, such as had been observed by de Vries as early as 1958. Further progress came when a number of European dendrochronologisis in close cooperation managed in 1984 to build up an unbroken ring sequence of European oak wood over the last 7000 years. Now much more material was available and samples for dating could be taken that covered only one to three years each. Also some laboratories were now able to measure with a much higher precision than Suess could. The long term variations in the natural carbon content were confirmed and the De Vries - effect - resulting in Suess' famous 'wiggles' - became firmly established. All this meant that it now became possible to calibrate conventional radiocarbon dates that fall within the range covered by the unbroken tree ring sequence. Unfortunately the nature of the 'wiggles' is such that calibration does not always give an unambiguous result. After various trials by different laboratories the appearance of the special calibration issue of Radiocarbon 1986 was a true break-through. All archaeologists started to run to 'their' radiocarbon lab for advice on how to calibrate their dates. As a result we now have a few slightly different computer programs for this purpose, and the last word on this matter is not yet said.

The 'wiggles' turned out to have one advantage : by the technique of 'wiggle-matching' one could connect floating dendrochronologies with a high degree of accuracy. This technique has been and is still being used in the process of building up a calibrated radiocarbon time scale. The technique can also be used for getting accurate dates for stratified series of samples from materials other than tree rings.

In 1980 the number of active dating laboratories in the world had grown to 106, most still in the USA and Western Europe, but now also Eastern Europe, Asia, Africa and South America were participating. Australia and New Zealand had been active from the beginning. As the number of radiocarbon dates of archaeological samples grew confidence in them had increased and radiocarbon dating had become a standard element in archaeological research procedures. In 1977 Lanting and Mook could in their book summarize all 700 radiocarbon dates relating to the archaeology of the Netherlands. Their chronological scheme of periods and subperiods is still valid. Other examples could be mentioned where radiocarbon for the first time has permitted the construction of a solid background for a discussion of cultural affinities and origins of innovations. Most spectacular perhaps were the new views on the origins of food production in south-west Asia and the spread over Europe which appeared to have taken place at a much earlier date than was thought before. No less important were the results obtained by radiocarbon dating for the study of such themes as the spread of megalithic burial customs, the origin of metallurgy and the relation between the various Beaker cultures. Radiocarbon dating plays also a vital role in modern studies of the Upper Palaeolithic and Mesolithic periods.

Yet there was also reason for some concern. Sometimes dates were obtained that were far off from what was expected that the deviation could not be explained by the statistical nature of the measurements. On the one hand many of these problems were caused by uncertainties in the association of the samples with the event one wants to date. Wood might have been reused, a grave pit might have been dug at a place where a fire has been burning at a much earlier date than the burial, etc. In such situations it is the sample submitter who should carefully reconsider the find circumstances. He may meet with some surprises. For example, dates of organisms living in certain aquatious environments, such as large rivers - and their predators! -, may suffer from unexpected reservoir effects (Lanting and Van der Plicht, 1996).

With the increased precision of the measurements and the need for integrating tree ring dates from various laboratories the necessity for a systematic study of the reproductibility of radiocarbon dates was also felt in the world of radiocarbon scientists. Organized by the Scottish laboratory 20 different labs formed an international study group who agreed to measure a series of tree ring samples from ages only known to the organizers. The first results (Baxter, 1983) gave much to think. Some laboratories had systematic offsets in their date production of a magnitude of up to 200 years in either younger or older direction. Others had a much wider spread in their results than statistics alone could explain. In general the high-precision laboratories came better off than the others. Apparentlv they had a general better control over their procedures. We may safely assume that those labs that had a bad performance - they remain anonymous - are now doing better. For us, however, this exercise means that there may be considerable differences in the accuracy of the dates and we must especially reckon with this phenomenon if we are using in our analysis dates produced by different laboratories in different stages of their development. A more precise date - a date with a small statistical error - need not necessarily be more accurate - closer to the true calendar age (after calibration) - than a date with a large statistical error ! It certainly would be wrong to discard all dates that were produced more than twenty years ago !

This international replicate study is another example of the close cooperation between radiocarbon scientists. The main vehicles for this cooperation are the international congresses that are held every three years since 1956 - there had also been meetings in 1954 and 1955 - and the journal Radiocarbon. The last congress, the 16th, was held last year in Groningen. To begin with that in Copenhagen in 1954 I have taken part in eight of these congresses and I was coorganizer of the meeting in Groningen in 1959. I have always been deeply impressed by the efficacy of this very loose and informal organisation where in a spirit of cooperation and friendly competition research prestige goes hand in hand with influence on current affairs without bureaucratic intervention of whatever kind. To have been a member of the international radiocarbon community has been a most gratifying experience for me.

AMS-DATING

Now I must say a few words on the development of the spectacular new method of dating samples by accelerator mass spectroscope (AMS). The method was developed by the Rochester group of nuclear physicists in 1977 and had with some research groups reached a stage of routine by about 1980. The advantages over radioactive decay counting are considerable.- a reduction in counting time to less than two hours and a reduction in the sample size by a factor thousand. Single cereal grains, tiny fragments of precious tissues or wooden objects and even individual palaeolithic cave paintings can now be dated. Precision is fairly good, but not yet comparable to that of the high-precision radiometric labs. The main error source is the stability of the machine. In 1980 some 20 laboratories were exploring or applying the method. From 1979 onwards the radiocarbon congresses had sections on AMS-dating. In addition the AMS people have had their own triannual congresses since 1978. Since 1986 the journal *Radiocarbon* publishes adress lists of AMS-laboratories. Their number has increased from 8 laboratories with code designations in 1986 to 20 in 1995. Although one would expect that the pretreatment of very small samples might cause unforeseen problems this does not appear to be the case. It is the Oxford laboratory with its active policy has taken the lead in demonstrating the many new possibilities opened up for archaeology. If AMS-dates reach the same degree of precision as the best radiometric dates one could foresee a complete take-over by the new method, as some AMS people have predicted (e.g. Gove, 1992).

Yet there is one impeding factor : the costs of buying and maintaining a dedicated accelerator are at least 50 times as high as those for a radiometric set-up. And although many more samples can be counted per year, the costs per sample will remain higher.

DEVELOPMENTS SINCE 1985

From my graph it is obvious that the present period is one of unrest, compared to the preceding phase. There is no simple explanation for the ongoing changes. We must realize that radiocarbon dating is not only important for archaeology but also for geology, palynology, climatology, oceanography, hydrology, geophysics, medicine and environmental studies. Some laboratories are only incidentally dating archaeological samples whilst others just concentrate their activities on our field. The decrease in radiometric laboratories in the USA, for example, may partly be explained by the establishment of commercial radiometric and AMS laboratories and does not necessarily mean that the total dating capacity for archaeology in that country has decreased.

My graph shows that many new radiometric laboratories are being set up in Asia and Eastern Europe. On one hand, this is a gratifying development, but there are some risks involved. It will take a long time before these new laboratories will reach the same degree of technical sophistication and build up the same experience as the old labs and we may be afraid that the corpus of existing radiocarbon dates, which as I mentioned includes doubtful dates from the pioneer period will be polluted by another wave of inaccurate dates from laboratories that start publishing them before they have full control of all the technical pit-falls. I have come across some dreadful examples.

I should also direct a word of warning towards my archaeological colleagues in these countries. World archaeology can only truly profit from radiocarbon dating if the archaeologists handle the dates obtained in a correct way. They should for example always realize that the dates determine the time of death of the sample material, and that there may be a considerable difference with the time of the burial or the construction or destruction of the house with which the sample material is round associated. They should also consider the certainty of association between the sample and the event one wants to date. Never should they forget that out of three dates one will be outside the error range added to the date. Series of dates that mutually make sense are always better than single dates. A calibrated bad date remains a bad date. That the date is according to expectation is certainly not a proof of its accuracy ! Archaeologists should never reject dates that are not according to expectation without having tried to find an explanation for the anomaly, first by reconsidering the find circumstances and only in the last instance by approaching the lab. It is also highly important that they should study the nature of the sample material, its botanical or zoological identity, the possibility of its beeing a mixture of material of different age, the number of growth years contained in the sample, the possibility of the sample being contaminated by older or younger material like humus, etc. They should always realize that the radiocarbon date is a statistical determination. The pretreatment of the sample undergoes in the laboratory will hardly ever remove all contaminants completely. The archaeologists should therefore realize the possible effect of such residual contaminants. This is particularly important for samples from the Palaeolithic period. Archaeologists should be aware that every radiocarbon date is a unique measurement of the carbon 14 activity or the carbon- 14 content of a unique sample. They should therefore be very reluctant to lump series of dates together and calculate mean values. Archaeologists should also realize that there are differences in quality of the date output of the laboratories in the various stages of their development. And so on and so forth.

In the course of the years I have done my best to improve the archaeological use of radiocarbon dates. Others have done the same. Yet the archaeological literature if still full of incorrect handling of radiocarbon dates. Of course I realize that there will allways be new users of radiocarbon dates who underestimate the problems that might be involved. I do hope that the present congress will have a positive effect in this respect.

INTERNATIONAL CONGRESSES

At the normal triannual radiocarbon congresses archaeological applications have always played a subordinate role. It is understandable that in the course of lime meetings were organized to review the chronometric data with regard to special areas or problems, often in cooperation with geologists and environmental students. Such meetings for example took place in 1980 (Cauvin and Sanlaville, 1981) and in 1986 (Aurenche *et al.,* 1987) in Lyon and in 1991 in Tucson (Bar-Yosef and Kra, 1994), all with an emphasis on southwestern Asia and the Levant, certainly an area where archaeology has profited enormously from radiocarbon dating. In Groningen we organized in 1981 and 1987 international meetings with the purpose to bring together archaeologists and radiocarbon scientists with a special interest in archaeology and without any geographic or thematic restriction. This formula has been taken over by our hosts today.

The 1981 congress (Mook and Waterbolk, 1983) brought the first news of the results of the international tree ring replicate studies. It also showed the new perspectives opened up by AMS-dating. The progress of the European work on dendrochronology was another item. Many papers were devoted to the treatment of difficult sample types. Our 1987 conference (Mook and Waterbolk, 1990), held just afler the 1986 calibration issue of Radiocarbon had appeared, had a large section on calibration problems. The work on the dendrochronology of European oak had made spectacular progress : a continuons sequence of over 9000 years was reported. Other papers were devoted to the comparison of the dating performance of now as many as 56 laboratories, including some AMS stations. Encouraging results of AMS-dating were presented. At both meetings we were somewhat disappointed by the relatively small attendance of archaeologists. Now at Lyon we have been informed of calibration possibilities for the full 40.000 years for which radiocarbon dating is valid. In contrast to both previous meetings where the discussion of general problems dominated we now have had large sections on the results of radiocarbon dating for the archaeology of certain periods and regions. Among the latter we find South America and Africa represented for the first time. AMS-dating is now firmly established. It has opened up fantastic possibilities, as the work on the palaeolithic rock paintings (Valladas *& al.,* this volume) has shown.

If we compare for the three meetings the geographic origin of the authors of papers in the proceedings and the areas of application interesting differences can be observed. The location in western Europe explains why in all three congresses the majority of papers have an origin in that area and deal with its archaeology. For the rest there are only differences. Asia was not represented in 1981, but appeared in 1987. The present congress differs from both Groningen meetings by a mutch stronger representation of Asia and Eastern Europe, and by the presence for the first time of research reports relating to South America and, especially, Africa. The parallel with the pattern shown by the changes in the distribution of the laboratories over the various regions is obvious. The Lyon congress has demonstrated that radiocarbon dating is well on its way to become a truly international tool in archaeology.

A GOLDEN ALLIANCE

At the beginning of this lecture I spoke of a golden alliance between radiocarbon dating and archaeology, between physicists and archaeologists. The word alliance suggests a close relationship between efforts and profits on both sides. I need not argue that archaeology has profited enormously from the efforts of the radiocarbon scientists. So have other branches of science. This benefit is not only a matter of receiving useful chronometric data, but goes much further. It encompasses a general better understanding of the methods and procedures of the natural sciences. It is widely recognized that radiocarbon did not only improve chronology in archaeology but had also a profound influence on the character of the discipline as a whole. The 'New Archaeology' movement of the seventies with its claim for the use of rigorous scientific methods in archaeology is but one illustration.

But what was our own contribution ? At first glance we may feel embarrassed by this question, but at closer inspection our role should not be belittled. There are the decisive moves of Paul Fejos and the Viking Fund, there is the first committee of assistance for Libby with people like Braidwood and Movius, both leading men in their f'ields. The committee selected samples of known age and screened the first 'unknowns'. Many laboratories in the world were set up and financed by the joint efforts of archaeologists, palynologists and geologists. In a later stage archaeology provided the floating dendrochronologies of woods excavated in the prehistoric lake-side settlements of Switzerland and South-Germany, which have played such a vital role in the construction of the long European dendrochronology. By confronting the radiocarbon scientists with anomalous results, by coming with all kinds of difficult samples, we stimulated them to improve their methods of sample pretreatment and to study reservoir effects. Above all, I think that through our intensive contacts we confronted them with another scientific world, for which I am sure they are very grateful. We built a small bridge over the gap between the 'two cultures' which divide modern society.

NOTE

An early version of the paper was commented upon by J.N. Lanting and W.G. Mook. The english text was improved by A. Brindley. Written information was kindly given by R.J. Braidwood and J.R. Arnold.

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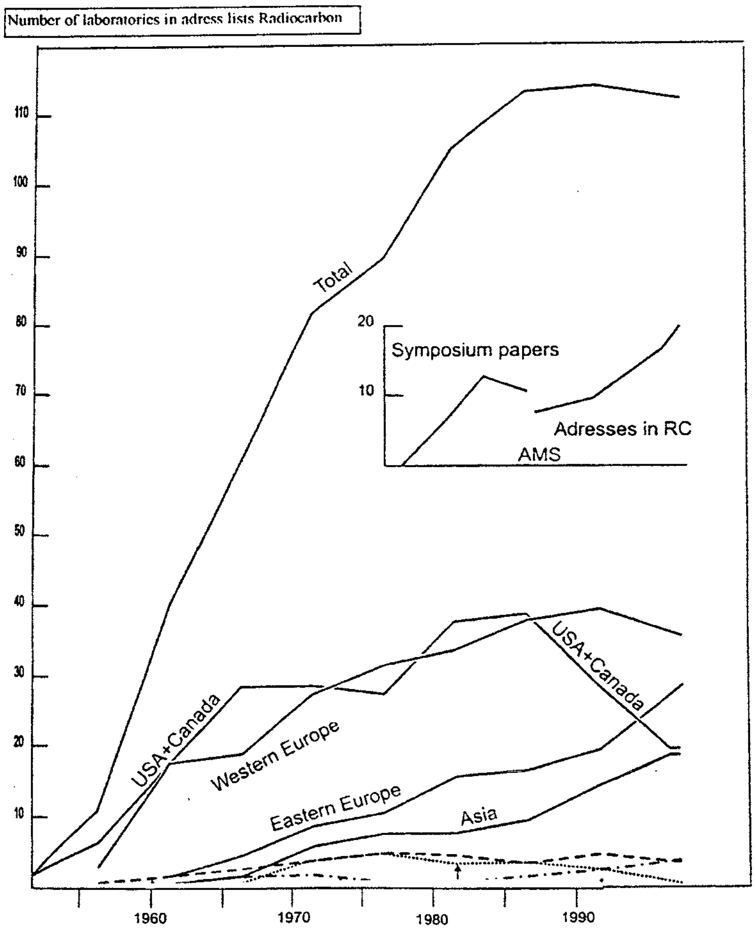

LES MATERIAUX DE DATATION

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DIRECT RADIOCARBON ACCELERATOR MASS SPECTROMETRIC DATING OF THE EARLIEST POTTERY FROM THE RUSSIAN FAR EAST AND TRANSBAIKAL

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Abstract : We demonstrate the use of a stepwise heating technique to measure the ages of organic-tempered pottery from seven Initial Neolithic sites from the Russian Far East and Transbaikal. Pottery samples were first subdivided into interior and exterior parts and then combusted to carbon dioxide using both copper oxide (CuO) and oxygen gas (O_2) as oxidants. Stepwise combustions were made at 400°C and 800°C. In addition, bulk samples were combusted at 1000°C. We obtained a total of 45 measurements on 9 pottery samples. The results can be summarized as follows : 1) the ^{14}C ages of the 800°C fractions are generally older than the 400°C fractions, consistent with the findings of Delque Kolic (1995) ; 2) the ^{14}C ages from the interior of the pot shards are generally older than the ages of exterior portions ; and 3) the percent carbon yield in the 400°C combustion is higher on average when O_2 is used as the oxidant while a similar yield is only obtained for the 800°C combustions with CuO. The dates determined here allow us to assign preliminary age ranges for the Gromatukha culture (10,400 to 13,300 ^{14}C yrs BP), the Novopetrovka culture (9,300 to 9,800 ^{14}C yrs BP), and the Primorye Neolithic (9,000 to 10,800 ^{14}C yrs BP).

Résumé : Nous montrons que l'utilisation d'une nouvelle technique de chauffage par palier permet de mesurer les âges de poterie à dégraissant organique, en provenance de sites néolithiques de l'Est de la Russie et de la région Transbaïkal. Les échantillons de céramiques ont été divisés en deux parties, l'intérieure et l'extérieure. Ces échantillons ont été brûlés avec, comme oxydants, de l'oxyde de cuivre (CuO) et de l'oxygène. Les combustions ont été faites à 400°C et à 800°C et, pour la plupart, un complément de combustion à 1000°C. Nous avons obtenu au total 45 résultats pour 9 échantillons différents. L'ensemble des résultats peut être résumé de la manière suivante : - 1. Les ^{14}C âges des fractions brûlées à 800°C sont généralement plus vieux que ceux des fractions brûlées à 400°C, en agrément avec les conclusions de Delque-Kolic (1995). - 2. Les ^{14}C âges des parties intérieures des tessons sont plus anciens que ceux des parties extérieures ; - 3. Le pourcentage du carbone extrait par la combustion à 400°C est plus important quand l'oxydant est le gaz oxygène et un rendement comparable avec le CuO est obtenu seulement à 800°C. Les dates qui sont déterminées ici, nous permettent d'attribuer des plages d'âges préliminaires pour la culture Gromatukha, de 10 400 à 13 300 BP, pour la culture Novoptrovka, de 9 300 à 9 800 BP et pour le Néolithique de Primorye, de 9 000 à 10 800 BP.

Key-words : Pottery, radiocarbon dating, Accelerator Mass Spectrometry, Initial Neolithic, Russian Far East, Transbaikal, East Asia.

Mots-clés : Poterie, datation radiocarbone, Spectrométrie de Masse avec Accélération, Néolithique ancien, Russie extrême orientale, Transbaïkal, Asie Orientale.

INTRODUCTION

In recent years we have studied the radiocarbon (^{14}C) chronology of Neolithic cultures in the Russian Far East which are often represented by the presence of clay-fired wares. Both AMS and conventional decay counting techniques have been used to date charcoal from these cultural layers (Kuzmin *et al.*, 1994). The radiocarbon AMS dates fall within the interval ca. 10,350-13,260 ^{14}C yrs BP (Kuzmin *et al.*, 1997) from the earliest Neolithic sites in the lower Amur River basin, Gasya and Khummi. This data supports the premise that some examples of Russian Far East pottery are older than 10,000 ^{14}C yrs BP.

The earliest Neolithic sites in the Russian Far East and Transbaikal regions are comprised of four principal archaeological cultures : the Osipovka culture, in the lower Amur River basin ; the Gromatukha and Novopetrovka cultures, in the middle Amur River basin; and the Ust-Karenger culture in the Vitim River basin (Vetrov, 1992 ; Khlobyistin, 1996). The ages of the Osipovka and Ust-Karenga cultures are greater than 10,000 ^{14}C yrs BP. Other neolithic cultures in the Russian

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Far East, such as the Rudnaya culture in the Primorye (Maritime) Province, are known to be much younger, around 8,400 ^{14}C yrs BP (Kuzmin and Jull, 1998). Initial age estimates of the Russian Far East and Transbaikal are given in table 1.

To establish a tentative chronology for these sites we have directly dated pot shards using the ^{14}C method. We attempted to date the organic temper as the source of carbon. We describe below a stepwise combustion technique which is aimed at isolating this source of carbon and minimizing carbon contained in the clay minerals. This work follows the efforts of Johnson *et al.*, (1988), Evin *et al.*, (1989), Hedges *et al.*, (1992), and Delque Kolic (1995), who studied the nature of organic material in clays and the feasibility of directly dating pottery.

1 - BACKGROUND & SIGNIFICANCE

East Asia is the area where the earliest pottery in the world has been found to date. Sites that have been previously studied are in such dispersed areas as Japan, China, and the Russian Far East. These are summarized in table 2. Establishing a clear chronology of this vast region will contribute to our understanding of human adaptation to the natural environment in the Late Glacial-Early Holocene period between 14,000-8,000 ^{14}C yrs BP. Furthermore, this information is important in constructing theories about the origin and spread of ceramics technology at this time. A current theory expressed by Aikens and Higuchi (1982) suggests that the source of the ceramics technology found in Japan was located in the East Asian mainland, and was introduced via the Korean Peninsula. However, there is still a lack of solid evidence from both Northeast China and the Korean Peninsula which would allow us to firmly reconstruct this theory of pottery expansion (Nelson, 1993).

The chronology of these events is further complicated by characteristically poor stratigraphy. Repeated occupation episodes within a single Initial Neolithic site in the Russian Far East may be up to 3,000-5,000 years. It is difficult to distinguish between these episodes due to the absence of simultaneous sedimentation or due to post-depositional mixing and compression. This problem emphasizes the need for a technique to date the pottery directly.

2 - METHODS

We used the Accelerator Mass Spectrometer (AMS) technique to study the individual carbon components of our early Russian pottery samples. In total, nine pottery samples were studied. We initially measured radiocarbon ages on bulk samples. These were pretreated with a standard acid-alkali-acid (AAA) pretreatment and then combusted on a vacuum line with CuO at approximately 1000°C for 10 minutes. The nine samples were then divided into exterior and interior subsamples. We expected that the interior portions of the pottery would be relatively rich in temper, as compared with the exterior portions. Temper is the organic material which is mixed with the clay to fire the pottery. In some of our samples

Culture & Region	Sites	^{14}C ages BP	References
Gromatukha & Novopetrovka Cultures *Middle Amur River Basin*	Gromatukha Novopetrovka Ust-Ulma	10,000-11,000 9,000-10,000	1) Derevianko & Okladinkov, 1977; Derevianko & Petrin, 1995. 2) Derevianko & Zenin, 1995
Osipovka Culture *Lower Amur River Basin*	Gasya Khummi	13,000 13,300	3) Derevianko & Medvedev, 1995
Rudnaya Culture *Primorye/Maritime Province*	Chernigovka	8,400	4) Kuzmin & Jull, 1998
Ust-Karenger Culture *Upper Vitim River, Transbaikal*	Ust-Karenga	11,200	5) Vetrov, 1985

Table 1 : Neolithic Cultures and sites of the Russian Far East with ^{14}C dates.

Japan	China	Far East Russia
Incipient Jomon Culture in the Southern Japanese Islands Kyushu Island at Fukui site: 12,400+350 BP (GaK-949) 12,700+500 BP (GaK-950) Shikoku Island at Kamikuroiwa site: 10,085+320 BP (I-943) 12, 165+600 BP (I-944)	Huang He (Yellow River) & Liao River: 7,000 BP (1) Southern Yangtze River: 10,700-11,300 BP (1) Miaoyan site: 13,700 BP(2) Xianrendong site: 14,600 BP (2)	Osipovka Culture in the Russian far east Lower Amur River Basin: 12,960 BP
Morlan, 1967	1) Chang, 1986; 1992 2)Yuan et al. 1995; MacNeish & Libby, 1995	Okladnikov & Medvedev, 1983

Table 2 : Early sites with ceramics in East Asia.

it was possible to see plant material within the clay matrix, however, these organics were so tightly bound with the clay that we could not physically separate them from the clay. We also hypothesized that the interior portions of the samples were relatively free from contamination.

We sampled the shards by scraping off fine flakes and powder from the exterior surfaces, and then sampled from the middle or interior portion of the shard. Both fractions were pretreated with the standard AAA technique. The first eight fractions were packed in 9 mm quartz tubes and combusted with CuO. These were placed on a vacuum line, evacuated and combusted with a furnace at 400°C for one hour. The carbon gas was then extracted and the sample was combusted again at 800°C for 30 minutes. The sample tube was not removed from the vacuum apparatus between extractions. The remaining samples were combusted using the same type of vacuum line and controlled temperature combustions, but with oxygen gas as an oxidant rather than CuO.

3 - RESULTS & DISCUSSION

The dates from the bulk samples ranged from 9,000 to 12,800 ^{14}C yrs BP. These dates correspond well with previous charcoal dates from these sites. In order to understand the experimental data we need to compare the temperature fractions for each carbon component. Then we can compare the carbon components in the interior and exterior subsamples at the different temperature fractions.

Where both the 400°C and 800°C fractions were measured on interior subsamples the ^{14}C ages were younger at the lower temperature (fig. 1). Since the higher temperature fractions were older we felt this could be interpreted as contamination by older carbon being released from the clay minerals, as shown by Delque Kolic (1995). In support of this theory the exterior samples also gave older ^{14}C ages at the higher 800°C fraction, where both temperatures fractions were measured (fig. 2). Due to low graphite yields and other problems we were only able to directly compare three data points between the interior and exterior subsamples burned at 800°C. However, the general trend suggests that the interior subsamples have older ^{14}C ages at the higher temperature (fig. 3). The data from the interior subsamples burned at 400°C also generally reflect older ^{14}C ages than those of the exterior subsamples (fig. 4). We assume that the interior subsamples will be less susceptible to post-depositional contamination and give better age estimates for the pottery. However, the older ^{14}C ages for the interior subsamples at both temperature fractions does not correspond to our original thesis. This data reflects the fact that the carbon composition (from percent yield) of the two subsamples were more variable than we had assumed. In some cases the exterior subsamples actually contained more carbon than their interior counterparts (tab. 3).

An interesting result from our experiment was the comparison of yields between combustions using CuO and oxygen. Comparing average carbon yields, most of the carbon was liberated at 800°C using CuO while combustions using oxygen liberated most of the carbon at 400°C (fig. 5). This result indicates that oxygen gas is a more efficient oxidant than CuO at the lower temperature. We feel that it is a superior oxidant when combusting organic material within a clay matrix at these low temperatures.

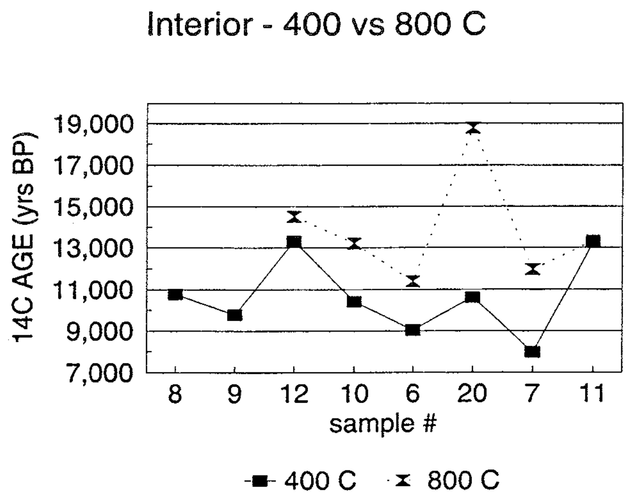

Fig. 1 : ^{14}C ages of interior subsamples at 400°C and 800°C.

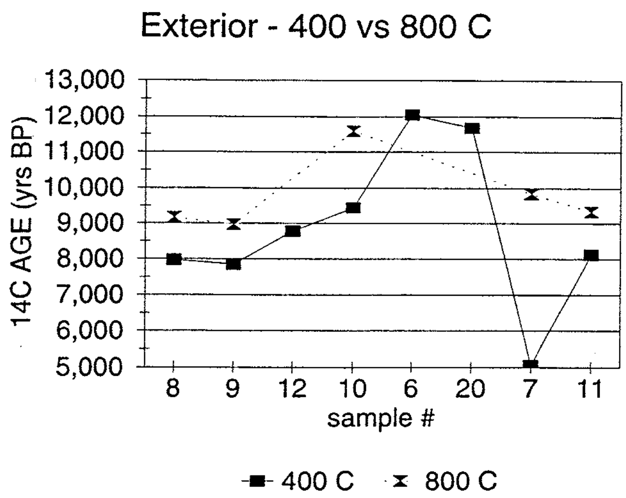

Fig. 2 : ^{14}C ages of exterior subsamples at 400°C and 800°C.

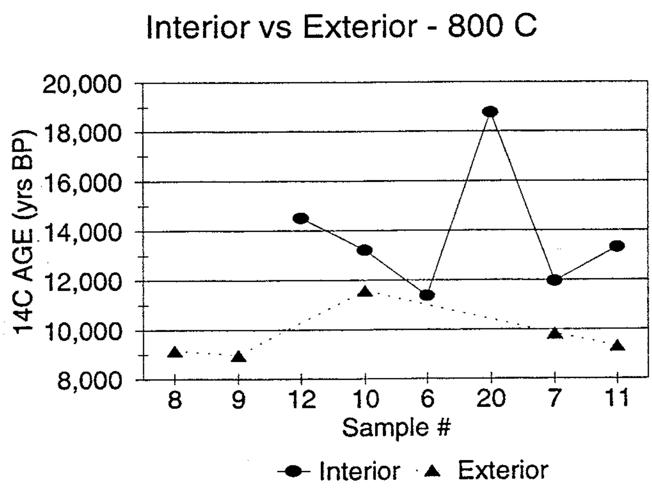

Fig. 3 : ^{14}C ages of interior and exterior subsamples at 800°C.

Site sample	AA #	Lab #	oxidant	Temp (°C)	subsample	%C yield yield	δ13C(‰)	^{14}C age (yrs BP) ± 1σ
Khummi (4)	20932	Z280B	CuO	800	interior	2.0	-26.9	11,915±80
		Z281B	CuO	800	interior	0.5	-24.8	9,555±85
		T5959	Cuo	1000	bulk	2.4	-27.6	12,010±100
	13391	V11294			charcoal			10,340±110
	13392	V11295			charcoal			13,260±100
Gasya (6)	20934	Z282A	CuO	400	interior	0.6	(-25.0)	9,020±65
		Z283A	CuO	400	exterior	1.5	(-25.0)	12,050±95
		Z282B	CuO	800	interior	3.4	-26.0	11,375±75
		Z283B	CuO	800	exterior	1.6	-26.6	10,260±90
		T5960	CuO	1000	bulk	4.9	-26.4	11,905±80
	13393	V11296			charcoal			10,875+-90
		LE-1781*			charcoal			12,960+-120
Ust-Ulma (7)	20935	T6886	CuO	400	interior	1.3	-29.0	8,900±90
		T6887	CuO	400	exterior	0.8	-28.8	9,620±75
		Z284B	CuO	800	interior	1.1	-28.1	11,960±100
		Z285B	CuO	800	exterior	0.9	-27.6	9,835±70
		T5961	CuO	1000	bulk	3.1	-28.7	12,590±80
Chernigovka (8)	20936	Z286A	oxygen	400	interior	1.1	(-25.0)	10,770±75
		Z287A	oxygen	400	exterior	0.8	(-25.0)	7,975±65
		Z286B	oxygen	800	interior	1.5	-29.2	9,350±75
		Z2867B	oxygen	800	exterior	0.6	(-25.0)	9,160±65
		T5962	CuO	1000	bulk	3.4	-28.1	9,020±65
Novopetrovka (9)	20937	Z288A	oxygen	400	interior	1.9	-30.3	9,765±70
		Z289B	oxygen	400	exterior	1.3	-29.2	7,855±95
		Z288B	oxygen	800	interior	1.2	-30.6	10,570±80
		Z289C	oxygen	800	exterior	0.1	-27.7	8,970±100
		T5963	CuO	1000	bulk	4.6	-30.0	9,285±65
Novopetrovka *Gromatukha layer* (10)	20938	Z290A	oxygen	400	interior	0.4	-27.3	10,400±70
		Z291A	oxygen	400	exterior	1.0	-26.9	9,440±110
		Z290C	oxygen	800	interior	0.1	-24.9	13,210±130
		Z291C	oxygen	800	exterior	0.1	-25.8	11,580±110
		T5964	CuO	1000	bulk	0.4	-25.8	11,720±95
Gromatukha (11)	20939	Z282A	oxygen	400	interior	1.4	-26.8	13,240±85
		Z292C	oxygen	400	exterior	2.5	-26.8	8,130±60
		Z293A	oxygen	800	interior	0.3	-27.2	13,320±200
		Z293C	oxygen	800	exterior	1.0	-27.2	9,325±65
		ZT5965	CuO	1000	bulk	1.0	-27.9	12,830±120
Gromatukha (12)	20940	Z294A	oxygen	400	interior	0.6	-28.6	13,310±110
		Z295A	oxygen	400	exterior	2.7	-27.1	8,770±60
		Z294B	oxygen	800	interior	0.3	-27.2	14,510±240
		Z295B/A	oxygen	800	exterior	1.7	-27.9	9,375±75
		T5966	CuO	1000	bulk	1.3	-27.1	11,500±90
Ust-Karenga (20)	21378	Z296A	oxygen	400	interior	1.0	-27.5	10,600±110
		Z297A	oxygen	400	exterior	0.5	-28.3	11,675±75
		Z296C	oxygen	800	interior	0.1	-25.3	18,780±230
		Z297B	oxygen	800	exterior	0.4	-26.2	8,150±65
		Z296A	CuO	800	interior		-27.0	10,840±75
		Z297B/A	CuO	800	exterior	0.4	-27.4	9,625±70
		T5967	CuO	1000	bulk	2.3	-28.8	12,245±85
		GIN-8066*			charcoal			11,240±180
		GIN-8067*			charcoal			10,750±60

*conventional date from decay counting

Tab. 3 : AMS radiocarbon results for pottery and associated charcoal from the Russian Far East and Transbaikal.

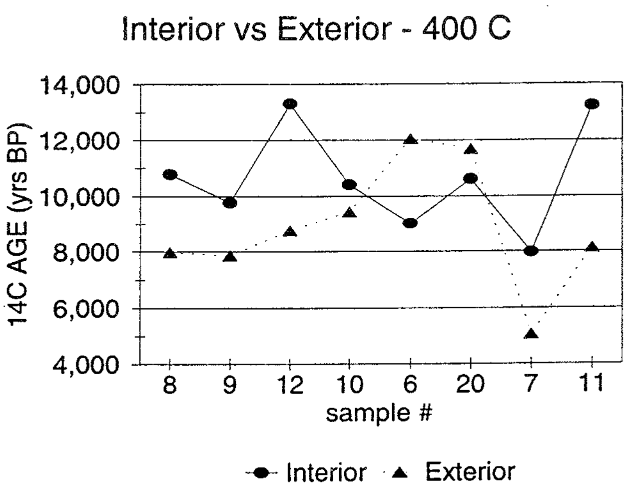

Fig. 4 : ^{14}C ages of interior and exterior subsamples at 400°C.

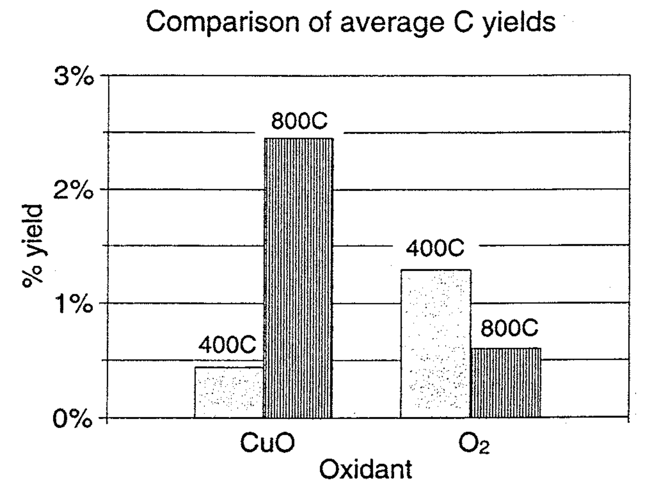

Fig. 5 : Comparison of average carbon yields for samples combusted at 400°C and 800°C with CuO and oxygen.

4 - CONCLUSIONS

In total we obtained 45 ^{14}C measurements from the pottery samples (tab. 3). In reviewing the data three observations can be made : 1) the ^{14}C ages of the 800°C fractions are almost always older than those of the 400°C fractions ; 2) the ^{14}C ages of the interior subsamples of the shards are generally older than the ages of the exterior portion of the shards ; and 3) the percent carbon yield for the combustion of our pottery is higher at 400°C with oxygen, while a similar yield is only obtained at 800°C using CuO.

From this study of the direct AMS dating of pottery we can conclude that the low temperature fraction (400°C) on the carbon-rich portions of pottery, combusted with oxygen, presently provides our best estimate of the age of the ceramics. However, more studies need to be done in order to improve the carbon extraction techniques from such complex sources, and especially to reduce and refine the combustion temperature limits where possible.

As for the archaeological implications of our study, the results obtained correspond well with other archaeological data for the Russian Far East Neolithic. The chronology is still preliminary and will require further work to refine our age estimates. The consistency between pottery dates and charcoal dates, where both are available, is promising. Thus, we can assign preliminary age ranges for the Gromatukha culture at 10,400-13,300 ^{14}C yrs BP, and the Novopetrovka culture at 9,300-9,800 ^{14}C yrs BP. We do not yet have dates from low temperature oxygen combustions for the lower Amur river basin and the Osipovka culture. However, we could assign an approximate age range of 9,000-13,000 ^{14}C yrs BP in combination with charcoal age controls. For the Primoye or Maritime Province with the Rudnaya culture we have a preliminary age estimate of 9,000-10,800 ^{14}C yrs BP. And finally, Ust-Karenger culture from the Vitim River in the Transbaikal we have a very tentative age of 10,500-11,300 ^{14}C yrs BP using charcoal controls.

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NOUVELLE INTERPRÉTATION CHRONOLOGIQUE DES SITES DE FEUDVAR (Serbie) ET POPESTI (Roumanie) A PARTIR DE DEUX SÉRIES DE DATATIONS ^{14}C

*Nona PALINCAS**

Résumé : Deux évènements archéologiques, mis en évidence dans deux sites situés à 500 km de distance, en Serbie et en Roumanie, étaient jusqu'à présent considérés, principalement par l'interprétation archéologique, comme très éloignés dans le temps, bien que l'on ait obtenu pour eux 16 datations radiocarbone toutes situées autour de 3300 BP. Un examen rigoureux des échantillons datés et des intervalles de dates après calibration montre qu'en réalité ils ne peuvent s'être produits que peu de temps l'un après l'autre (au plus un siècle et demi), ce qui remet en cause la chronologie de certaines industries du Bronze dans la région du Bas Danube.

Abstract : Two archaeological events, which took place in two sites located at about 500 km from each other in Serbia and Romania, where considered as separated by a large time space while they gave 16 ^{14}C dates, all close to 3300 BP. A new careful examination of the dated materials and time ranges after calibration demonstrates that they may almost be contemporaneaous or separated by a maximum of 150 years. This makes the chronology of the Bronze Age industry in the Low Danube region questionable.

Mots-clés : Datation radiocarbone, Roumanie, Serbie, Age du Bronze.

Key-words : Radiocarbon dating, Romania, Serbia, Bronze Age.

INTRODUCTION

La basse vallée du Danube est riche en sites de l'Age du Bronze à partir desquels on peut suivre l'évolution et l'extension de plusieurs phases culturelles, telles que les cultures « Vatina » et « Zutor Brdo-Gârle Mare » et le groupe culturel « Fundeni-Govora », en particulier dans les sites de Feudvar (Nord de la Serbie), Cârna et Popesti (Sud de la Roumanie) (fig. 1). Les rapports chrono-typologiques entre ces phases culturelles sont résumés dans la figure 2 où l'on voit que la liaison entre les industries du site le plus occidental (Fendvar) et celles du site le plus oriental (Popesti) est faite par l'analyse des industries représentée à la nécropole de Cârna.

Récemment furent sucessivement publiées deux paires d'articles concernant le site de Feudvar (Görsdorf, 1992 ; Roeder, 1992) puis concernant le site de Popesti (Fischer, 1996 ; Palincas, 1996). Ces 4 articles donnent chacun une série de datations radiocarbone (tab. I et fig. 3) et l'on peut constater que les 16 dates ^{14}C sont toutes très proches de 3300 BP et que la majorité d'entre elles se regroupent autour de la valeur 3200 BP.

Cette homogénéité des résultats met en évidence un important problème de chronologie et de durée des phases culturelles car toutes les dates du site de Feudvar proviennent de son plus ancien niveau archéologique, tandis que celles de Popesti datent une phase culturelle contemporaine d'un de ses niveaux les plus récents.

Aussi, pour réviser la chronologie de ce site de Feudvar à la lumière de ces résultats, il importe d'abord d'examiner avec attention les deux séries de dates en critiquant leur matériel daté, puis de revoir l'interprétation archéologique dans chacun des sites. On pourra alors en déduire quel fut en fait l'apport des datations radiocarbone et quelles nouvelles propositions de chronologie peuvent être faites.

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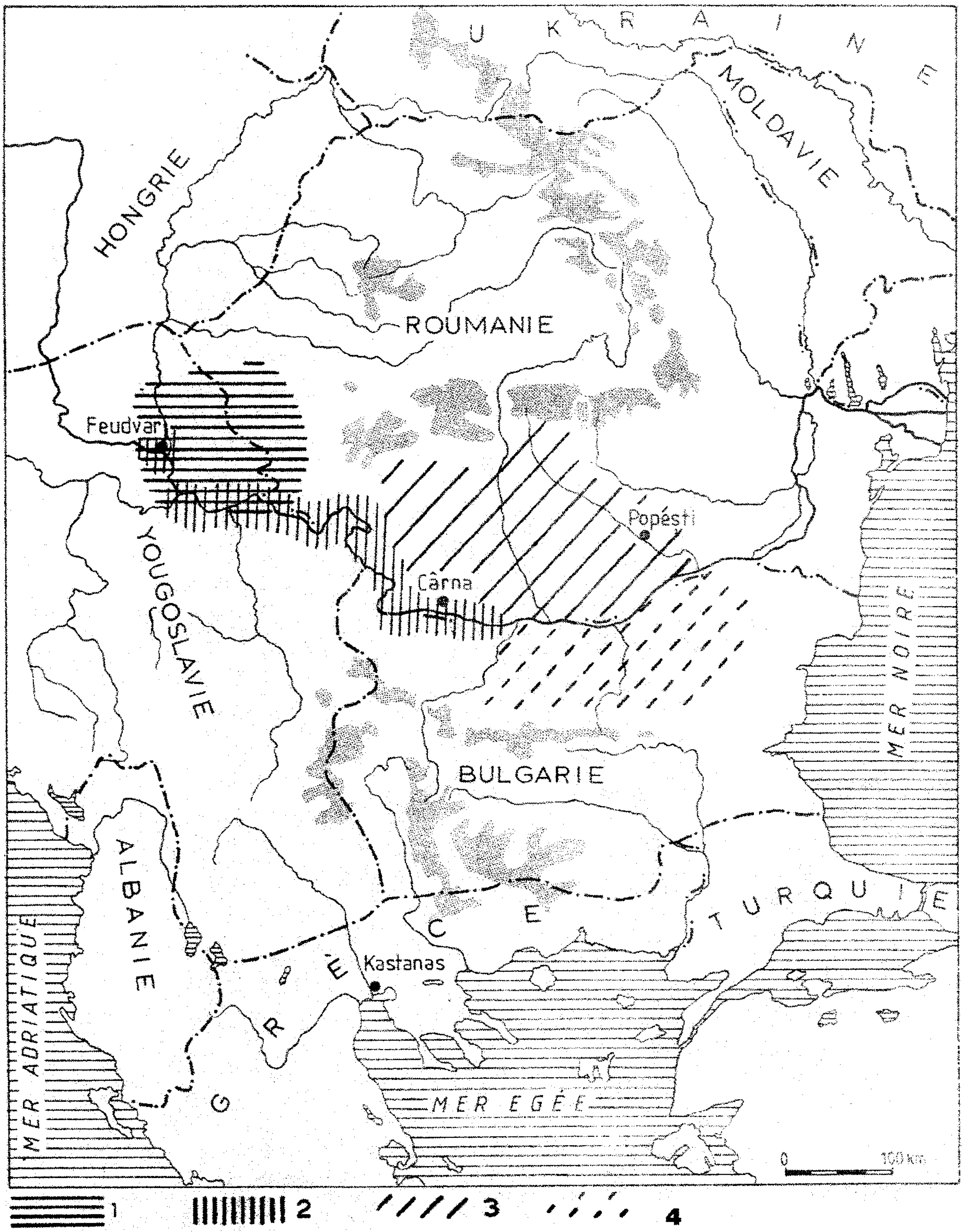


Fig. 1 : Localisation des sites : 1 - extension de la culture Vatina ; 2 - extension de la culture Zutor Brdo - Gârla Mare ; 3 - extension certaine du groupe culturel Fundeni - Govora ; 4 - extension possible du groupe culturel Fundeni - Govora.

LES DATATIONS RADIOCARBONE DES SITES DE FEUDVAR ET POPESTI

- Un ensemble de résultats donnant des dates BP très régroupées

Les éléments essentiels pour chaque date disponible pour les deux sites sont donnés dans le tableau 1. On constate l'homogénéité de la série puisque les dates extrêmes (Bln-4142 : 3445 +/- 50 BP et Bln-4135 : 3160 +/-70) sont mutuellement dans leurs marges d'erreur de deux déviations standard, ce qui est statistiquement normal pour une série de 16 analyses.

Exception faite de Bln-4142, Bln-4264 et Bln-4267, tous les intervalles de date obtenus par convertion en années réelles sont recouvrants avec une plage de temps commune, approximativement, de 1650 à 1450 avant J.-C.

Ce premier examen permet seulement d'affirmer que les évènements datés ne peuvent être que contemporains ou très proches dans le temps ou, en tout cas, sûrement pas écartés de plus de deux siècles.

Si ces deux évènements ne sont pas contemporains, c'est celui du site de Popesti qui est le plus récent.

- Les datations du site de Popesti

Le site de Popesti est une forteresse bâtie au Bronze tardif.

Quatre prélèvements y ont été effectués pour des datations radiocarbone mais deux d'entre eux (B-6104 et B-6106) ont donné des datations avec des marges statistiques importantes car respectivement de +/- 100 et +/- 150 ans. Elles conduisent à des intervalles de dates en années réelles beaucoup trop larges pour être significatifs, ce qui amène à négliger ces deux résultats dans la suite du raisonnement.

Les deux autres prélèvements correspondent à deux phases d'occupation du site :

- l'un (l'échantillon B-6104) provient d'une couche de remplissage appartenant à la phase la plus récente (une habitation du type culturel «Zimmicea-Plodiv»). Comme elle se trouve en position secondaire, sa date présente peu d'intérêt pour cette étude ;
- l'autre (l'échantillon B-6105) provient de la phase

Site	Date radiocarbone	Date BP	Contexte archéologique	Matériel	Intervalle calibré av. J.C.
Feudvar	Bln 4142	3445+/-50	mur	jeune frêne	1890 - 1620
	Bln 4140	3290+/-60	mur	orme; charbon de bois	1690 - 1420
	Bln 4135	3160+/-70	mur	gros frêne	1610 - 1220
	Bln 4264	3420+/-50	toiture	jeune saule	1880 - 1530
	Bln 4266	3365+/-70	toiture	charbon de bois ?	1880 - 1500 (99 %);
	Bln 4267	3385+/-50	toiture	saule ou peuplier; jeune	1770 - 1520
	Bln 4268	3255+/-50	toiture	jeune saule ou peuplier;	1640 - 1410
	Bln 4270	3255+/-50	toiture	saule ou peuplier; jeune arbre; charbon de bois	1640 - 1410
	Bln 4131	3235+/-40	sur le sol en terre battue; sous la couche d'incendie	bouillie carbonisée;	1610 - 1410
	Bln 4160	3230+/-50	sur le sol en terre battue; sous la couche d'incendie	orge carbonisée	1620 - 1400
	Bln 4161	3245+/-40	sur le sol en terre battue; sous la couche d'incendie	blé carbonisé	1610 - 1420
	Moyenne pondérée de Bln 4131, Bln 4160 et Bln 4161	3238+/-25			1530 - 1420
Popeşti	B-6103	3270+/-30	fortification Zimnicea - Plovdiv;	chêne;	1620 - 1440
	B-6104	3210+/-100	fortification Zimnicea - Plovdiv;	chêne;	
	B-6105	3200+/-30	fortification Fundeni - Govora;	branche ou jeune tronc de chêne;	1520 - 1410
	B-6106	3250+/-150	fortification Fundeni - Govora;	chêne	

Tab. 1 : Liste des dates ^{14}C provenant de « Westliches Haus » de Feudvar et de la fortification de Popesti.

ancienne de construction de la fortification. C'est le résultat le plus intéressant, car il date le groupe culturel «Fundeni-Govora», archéologiquement comparable à la dernière phase du site de Feudvar.

La date du dernier échantillon (3200+/-30 BP) reste donc la seule à prendre en considération non seulement parce qu'elle a une marge statistique réduite mais surtout en raison de la nature et de la position du prélèvement. En effet il s'agit d'une branche ou d'un jeune tronc de chêne extrait d'une structure en bois correspondant à la première construction du site. Certes, les analyses anatomiques du bois ont mis en évidence des traces de champignon, ce qui pourrait laisser supposer l'emploi d'un tronc ancien, mais comme la région a toujours été riche en forêt, il est bien plus probable que le développement des champignons a eu lieu postérieurement à la construction de la forteresse. On est donc en mesure de penser que ce prélèvement permet de situer dans l'intervalle 1520 à 1410 avant J.-C. l'édification de la forteresse, en faisant abstraction des derniers cernes de croissance de l'aubier de l'arbre qui n'ont probablement pas été conservés.

Ainsi pour le site Popesti, sur les quatre analyses effectuées, seule la date B-6105 reste suffisamment étayée pour servir de base à la démonstration.

- Les datations du site de Feudvar

Le site de Feudvar est constitué essentiellement par les restes superposés de plusieurs habitations appartenant à des époques différentes, dont trois phases d'occupation d'une maison dite « Westliches Haus » appartenant à la culture «Vatina» (Urban, 1991). Au dessus on trouve encore une couche contenant, parmi d'autres restes d'habitation, de la céramique identique à celle du groupe « Zuto Brdo-Gârla » (Hänsel et Medovic, 1994) lequel est considéré comme correspondant, du point de vue archéologique, au groupe « Fundeni-Govora » présent dans le site de Popesti (Palincas, 1996). Les résultats de onze prélèvements ont été publiés, mais tous proviennent uniquement du niveau le plus ancien de la maison. Les deux niveaux supérieurs de celle-ci et la couche supposée contemporaine du site de Popesti, ne sont donc pas directement datés par le radiocarbone.

Les onze échantillons ont trois origines différentes :

- trois proviennent des murs à partir de gros ou de petits poteaux. Mais on doit noter une certaine incohérence des trois résultats car, contrairement à ce qui pouvait être attendu, c'est la date issue du gros poteau qui est la plus récente de tout l'ensemble (Bln-4135) alors que celle d'un jeune frêne est la plus ancienne. Devant cette incertitude et avec le risque de réemploi de matériel ancien, on préfère ne pas prendre en compte ces prélèvements provenant du mur.
- cinq proviennent de la toiture dont quatre à partir de jeunes arbres. Toutefois les quatre résultats s'étagent entre environ 3400 et 3250 BP ce qui ne permet pas de situer avec précision la date de construction de cette maison, la plage de date, après correction, s'étendant sur 450 ans : de 1880 à 1410 av. J.-C. Ce dernier intervalle serait bien sûr réduit si on faisait la moyenne pondérée de ces quatre résultats, mais cela impliquerait de supposer aucun réemploi de matériel ancien lors de la contruction de la toiture.
- enfin trois échantillons provenant de restes de nourriture recueillis sur le sol en terre battue de la maison. Comme il est peu probable que ces grains de blé ou d'orge carbonisés ou que ces restes de bouillie aient été conservés longtemps dans la maison, la datation de ces matériaux à courte vie permet de situer dans le temps la destruction de la première phase de la « Wesliche Haus ». De plus comme ces trois échantillons sont très certainement les témoins du même évènement archéologique, on est en droit d'effectuer la moyenne des trois datations et ainsi d'obtenir une plus grande précision statistique. On obtient 3283 +/- 25 BP et, en définitive, on peut donc affirmer que la première phase de la maison occidentale du site de Feudvar a été détruite par un incendie entre 1530 et 1410 avant J.-C.

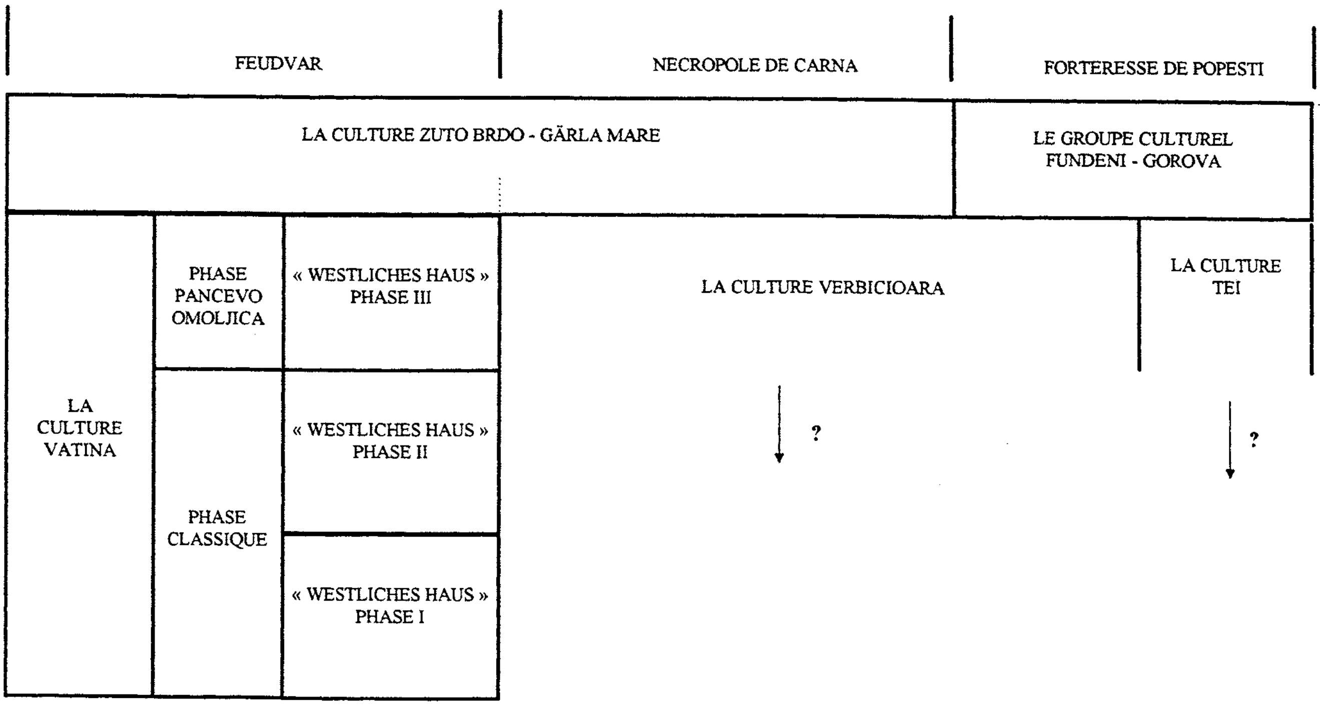
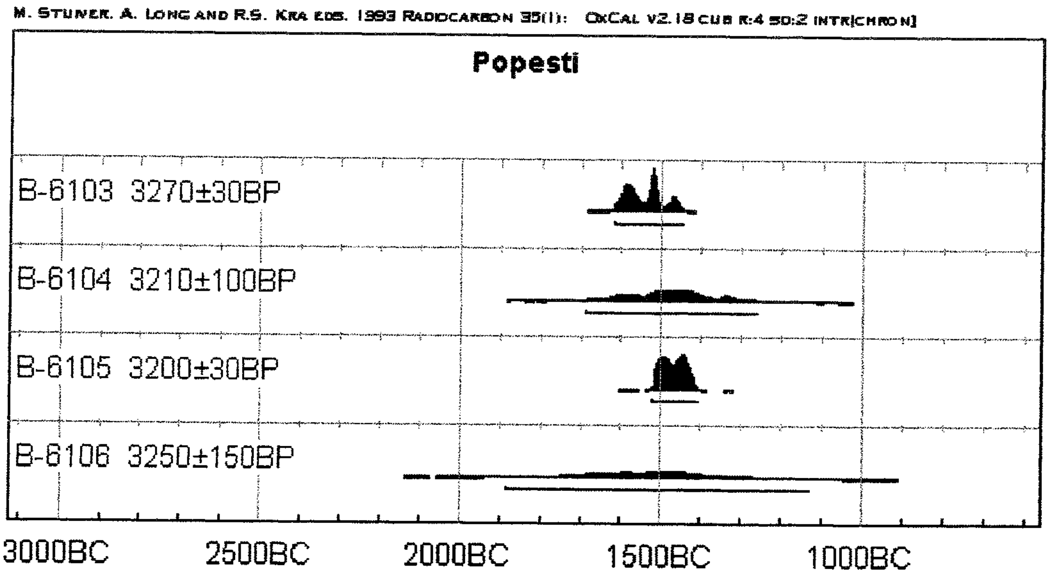


Fig. 2 : Rapport entre les chronologies de la «Westliches Haus» de Feudvar, de la nécropole de Cärna et de la forteresse de Popesti, établies à partir de la céramique.



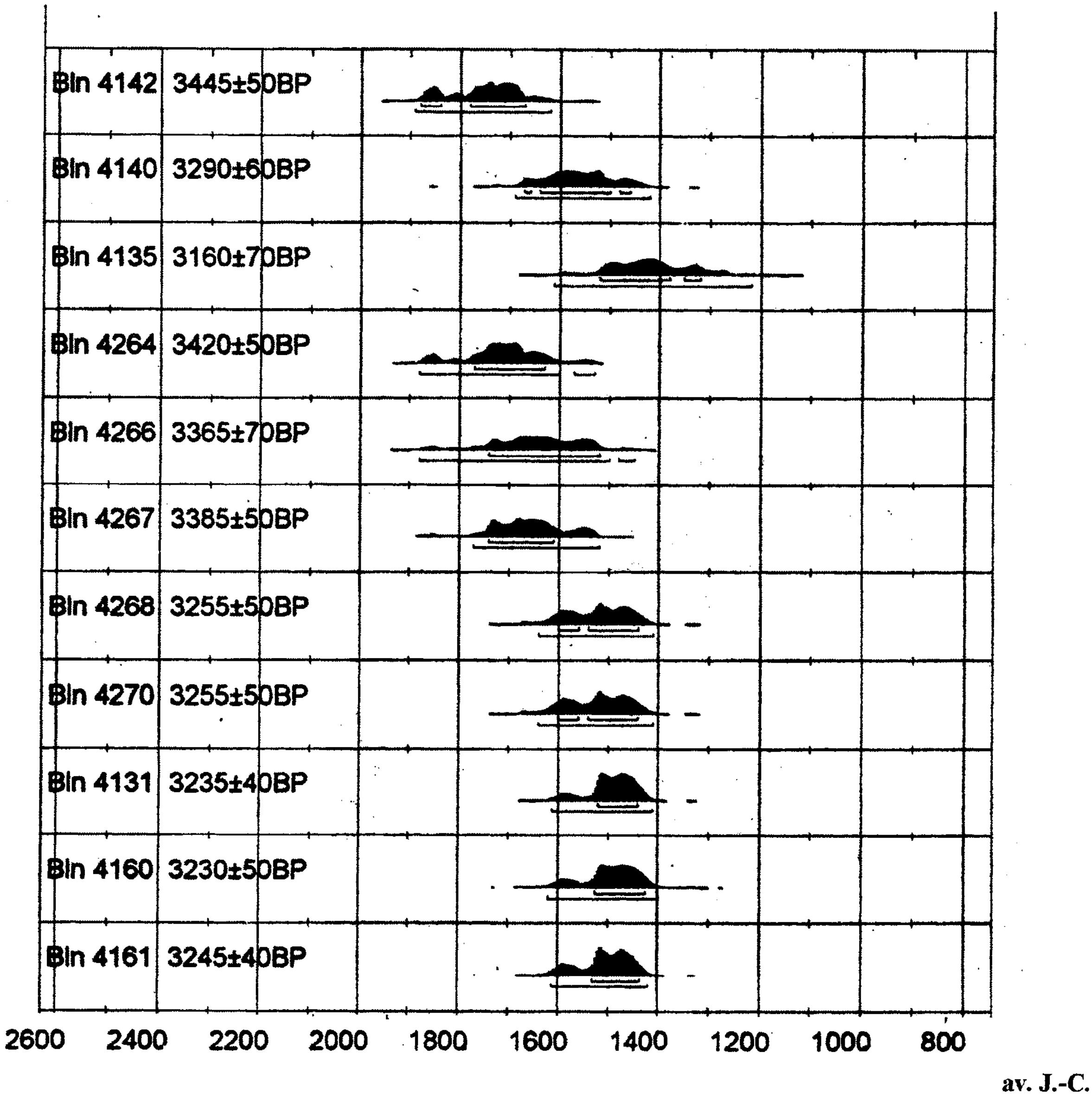


Fig. 3 : Diagrammes de probabilité de toutes les dates ^{14}C provenant des sites de Feudvar et de Popesti.

Conclusion sur l'ensemble des datations

Ainsi la sélection effectuée à partir de la nature du matériel daté ou de l'emplacement des prélèvements pour les 16 datations publiées pour les deux sites conduit à comparer leur chronologie à partir de seulement deux résultats : la moyenne des trois dates sur restes culinaires de Feudvar, d'une part, et la mesure d'une branche ayant servi à la construction de la première forteresse du Popesti, d'autre part (fig. 4).

Il reste à déterminer si ces deux évènements archéologiques peuvent être contemporains ou quel peut être leur écart maximal et, si celui-ci est réduit, quels en sont les conséquences archéologiques pour le Bronze final dans la région.

LA DATATION DES ENTITÉS CULTURELLES

En considérant à nouveau la synthèse chronostatigraphique de la figure 1 et, en particulier, la colonne correspondant au site Feudvar, il est bien évident que déduire des datations radiocarbone une contemporanénité ou un faible écart de temps entre la première phase de la culture Vatina et le groupe de Fundeni-Govora peut surprendre en raison de la superpositon de plusieurs phases culturelles à Feudvar. En tout cas cela va à l'encontre d'une chronologie longue qui avait été précédemment supposée.

Contradiction entre les données radiocarbone et la précédente hypothèse sur la chronologie du site de Feuvar et l'âge réel de la culture Vatina

Lors de la première publication site de Feudvar (Hänsel et Medovic, 1991), la phase post-classique de la culture de Vatina (phase «Pancevo Omoljica») avait été datée des environs de 1600 av. J.-C. en raison de la présence d'une épingle considérée comme typique du début de la période Reinecke Bronze B1. Le désacord avec la datation radiocarbone est évident. En effet, en considérant uniquement les échantillons prélevés dans la toiture et les dates les plus extrêmes des intervalles de dates en années réelles, en particulier de Bln-4264 et de Bln-4266, on peut à la rigueur supposer un temps très court pour la deuxième phase de la culture de « Wesliches Haus ». Dans ce cas on situe la destruction de la première maison autour de 1700 à 1650 av. J.-C.

Cependant on ne peut alors absolument pas expliquer les dates obtenues sur les échantillons du toit et encore moins sur la moyenne des échantillons culinaires qui excluent toute date antérieure à 1600 av. J.-C. La contradiction est donc flagrante dans l'interprétation et on ne peut qu'exclure une date aussi ancienne pour la phase post-classique de la culture de Vatina.

Exclusion de la contemporanéité des sites par les contraintes de l'étude des céramiques

On a précédemment souligné l'importance des données céramiques de la nécropole de Cârna (Dumitrescu, 1961), site non daté au radiocarbone mais situé en position intermédiaire entre Feudvar et Popesti. Ce site ne peut être antérieur au niveau à culture « Zuto Brdo-Gârla Mare » de Feudvar (Hänsel et Medovic, 1994), tout en étant sûrement contemporain de Popesti (Palincas, 1996). Mais le groupe de « Fundeni-Govora » présent à Popesti ne peut avoir débuté plus tôt en raison des témoins des cultures de « Verbicioara » et « Tei » que l'on retrouve sous-jacents respectivement à Cârna (Morintz, 1978 ; Chicideanu, 1986) et à Popesti.

Il est donc exclu que la culture de Vatina, même dans sa phase post-classique et *a fortiori* dans sa phase classique, c'est-à-dire celle dont les datations ont été analysées ci dessus, puisse être contemporaine du groupe de Fundeni-Govora.

Les évidences archéologiques conduisent donc à admettre obligatoirement un certain laps de temps entre les deux sites datés, laps de temps suffisant, peut-être de un à deux siècles, pour prendre en compte les deux phases de la culture Vatina mais très certainement pas aussi important que supposé précédemment.

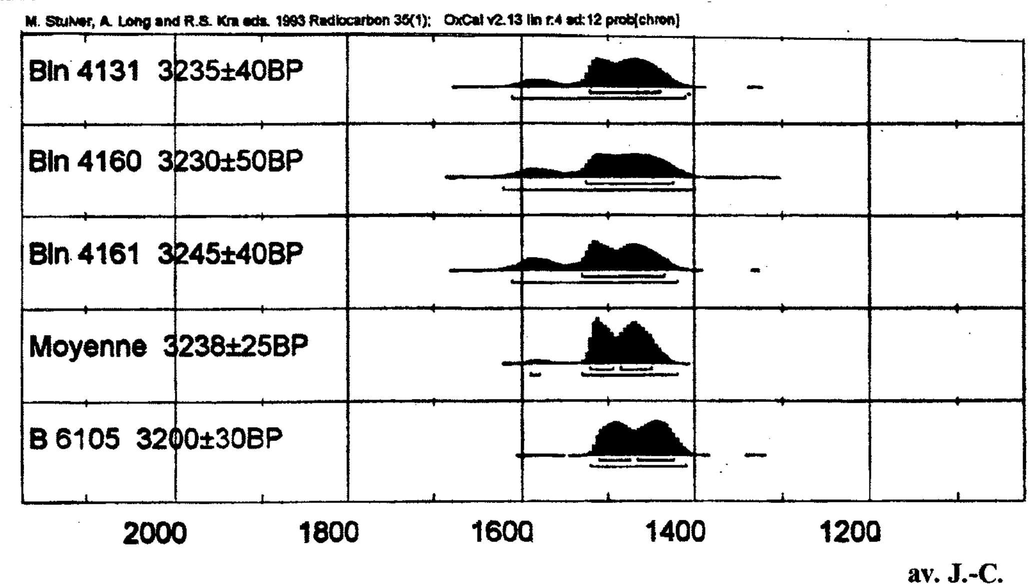


Fig. 4 : Diagramme de probabilités des trois dates ^{14}C sur restes culinaires du site de Feudvar avec leur moyenne et de la seule date ^{14}C sélectionnée pour le site de Popesti.

CONCLUSION

Au terme de l'analyse des datations radiocarbone des sites de Feudvar et Popesti, il est certain que la durée de la culture de Vatina du Bronze moyen dans le bas bassin du Danube n'a pas duré aussi longtemps que précédemment supposé. Cet examen permet de faire l'hypothèse d'une destruction de la première maison de Feudvar au tout début de l'intervalle indiqué pour la moyenne des trois dates du matériel culinaire de ce site (1530 à 1420) soit vers 1530 avant J.-C. La fin de la phase classique de cette culture est sûrement définie par la date obtenue à Popesti et serait alors au plus tard juste avant la fin de l'intervalle donné par la datation B-6105 (1520 à 1410), soit vers 1450 à 1410 avant J.-C.

Dans ces conditions la forteresse de Popesti n'a pu être bâtie que vers 1410 av. J.-C. et cela d'ailleurs cadre bien avec des analogies de céramique entre ce site et le site de Kastanas en Grèce du Nord, daté des environs de 1400 à 1300-1250 av. J.-C. à la base de la céramique Helladique tardive III B (Hochstetter, 1982 et 1984).

Ainsi c'est par la sélection rigoureuse de quelques datations, même réalisées dans des sites relativement éloignés, mais reliés par des évidences archéologiques, que la chronologie de certaines phases culturelles peut être précisée, sans pour autant qu'il ait eu besoin d'effectuer un grand nombre de datations.

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CALIBRATION DU TAUX D'ÉPIMÉRISATION DE L'ISOLEUCINE PAR LE ^{14}C : EXEMPLE DU MAROC

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Résumé : Le cadre lithostratigraphique et culturel de la partie supérieure du dernier cycle climatique du littoral atlantique du Maroc, entre Casablanca et Tanger, est précisé par des données croisées entre des datations par le ^{14}C conventionnelles ou par accélérateur et par les acides aminés. Les conditions thermiques le long des côtes marocaines septentrionales sont restées favorables à la différenciation d'une échelle aminochronologique régionale. La mesure des rapports D-alloisoleucine/L-isoleucine (AIle/Ile) de l'hydrolysat total des acides aminés mesurés par chromatographie liquide a été appliquée à plusieurs types de tests dont les taux d'épimérisation peuvent varier du simple au double selon le genre : gastéropodes et pélécypodes marins, *Patella, Monodonta, Mytilus,* et gastéropodes continentaux, *Helix* et *Rumina*. Les sites échantillonnés, grottes, abris sous roche, paléorivages, dunes littorales, nappes continentales, représentent des milieux de conditions thermiques et de fossilisation variées. Dans les conditions thermiques stables d'abris sous roche et de grottes, le taux d'épimérisation de *Helix* suit une courbe linéaire au moins jusque vers 25 000 BP, concordante avec les âges ^{14}C.

Abstract : The lithostratigraphic and archaeological framework of the units of the upper part of the last climatic cycle from sites along the northern Atlantic coast of Morocco, from Tangier to Casablanca, is established with the classical and AMS ^{14}C and amino acids dating methods. Due to the intermediate high thermal history of this part of Morocco, racemization ratios in molluscs are sufficiently high to establish a good regional aminochronological scale. Measurement of the D-alloisoleucine/L-isoleucine (AIle/Ile) ratios of the hydrolysate of total amino acids is applied to marine shells *Patella, Monodonta, Mytilus,* and continental gastropods *Helix* et *Rumina*. Sites sampled belong to supratidal and infratidal beach deposits, eolianites and cave deposits. Results for shells from all the sites indicate statistically significant differences and increasing values of the ratios conformable to the stratigraphic position and to the ^{14}C dates. Ratios for *Helix* from caves, as compared to ^{14}C dates, seem to indicate a linear increase of values until at least 25 ka.

Mots-clés : Datation radiocarbone, acides aminés, préhistoire, Holocène, Maroc.

Key-words : Radiocarbone dating, amino acids, archeology, Holocene, Morocco.

INTRODUCTION

Les paléorivages du Maroc réunissent les conditions favorables à l'enregistrement de stationnements marins depuis le Pliocène : soulèvement régional quasi-continu et conditions climatiques propices à la diagenèse rapide des dépôts littoraux. Dans ce contexte, les formations littorales du dernier cycle climatique de la côte atlantique septentrionale ont, dans le passé, servi à définir des étages du Quaternaire marocain : Ouljien (= dernier interglaciaire ou Eémien) sur la base de dépôts marins littoraux étagés entre 5 et 8 m NGM (Gigout, 1949), Soltanien (= Würm ou Weichsélien) d'après le remplissage continental de la grotte de Dar Es Soltan I (Choubert *et al.*, 1956), Mellahien (= Flandrien) d'après les dépôts de l'Oued Mellah (Biberson, 1958).

Les travaux franco-marocains de la Mission préhistorique et paléontologique française au Maroc (devenue Mission « littoral ») avec l'Institut National des Sciences de l'Archéologie et du Patrimoine du Royaume du Maroc, ont permis d'établir un cadre lithostratigraphique et culturel de ce dernier cycle climatique, précisé par des datations numériques (^{14}C, OSL, TL) (Daugas *et al.*, 1989 ; Ousmoï, 1989 ; Rhodes, 1990 ; Smith, 1990 ; Texier *et al.*, 1988 ; Texier et Raynal, 1989). Une attention particulière a été portée aux sites préhistoriques du

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littoral de Rabat-Temara-Skhirat, riches en restes humains atériens et ibéromaurusiens. À l'exception de la nécropole de Rouazi à Skhirat (Daugas *et al.*, 1984 ; Lacombe et Daugas, 1988 ; Lacombe *et al.*, 1990), ces gisements sont en grottes. Le remplissage continental de la cavité de Dar Es Soltan 1 (Ruhlman, 1951) avait anciennement servi à définir le Soltanien (Choubert *et al.*, 1956). La cavité voisine de Dar Es Soltan 2 (Debénath, 1972, 1976, 1978) offre un remplissage comparable qui ne concerne sans doute qu'une partie de l'intervalle de temps attribué classiquement au Soltanien. Une disposition stratigraphique analogue se rencontre dans les grottes d'El Harhoura I et II (Debénath, 1982 ; Debénath et Lacombe, 1986) et d'El Mnasra (Lacombe *et al.*, 1991). De nouvelles unités lithostratigraphiques de référence ont été définies (Lefèvre *et al.*, 1994 ; Texier *et al.*, 1994). Le Membre de Lahlalfa, défini dans la région de Casablanca, traduit une continentalisation du littoral liée à la régression glacio-eustatique mondiale qui a suivi le dernier interglaciaire Ouljien. Ce complexe continental représente le bilan des stades isotopiques 4 à 2 et équivaut à l'étage classique du Soltanien. La Formation de Reddad Ben Ali, de la région de Casablanca, est une séquence régressive témoignant d'une succession de milieux intertidaux, supratidaux puis dunaires. Elle enregistre un haut stationnement de la mer de +2 à +4 m que les données radiométriques permettent de placer dans l'Holocène récent, autour de 3700 BP. Dès 3500 BP, la régression est amorcée et vers 3300 BP, les faciès éoliens envahissent l'espace exondé. Un enregistrement analogue se rencontre à Skhirat : les coquilles associées aux faciès de haut de plage ont donné sur *Mytilus* des âges ^{14}C de l'ordre de 3500- 3700 BP (LY-6360, LY-6359 et LY-6358). Le littoral atlantique du Maroc septentrional, par rapport à d'autres régions de la côte atlantique de l'Afrique du nord-ouest, a donc enregistré de façon préférentielle le haut niveau marin de 3700-3500 BP.

MÉTHODOLOGIE

RADIOCARBONE

Des datations radiocarbone conventionnelles (GEOTOP et Lyon) et par accélérateur (Isotrace à Toronto) ont été spécialement produites sur certains échantillons soumis à l'analyse des acides aminés. L'échantillonnage méticuleux a permis de rejeter des échantillons concrétionnés, brûlés, altérés ou corrodés. Un âge ^{14}C du GEOTOP a été intercalibré avec un âge du laboratoire de datation de la Commission géologique à Ottawa. En raison du faible nombre de datations ^{14}C, qui rend difficile une analyse des facteurs géochimiques initiaux, et de la plus grande marge d'erreur de la méthode des acides aminés par rapport à celle du ^{14}C, les âges ^{14}C bruts ont été retenus pour établir le cadre chronologique de référence de la côte atlantique du Maroc. Nous n'avons pas tenu compte de la différence de l'effet de réservoir entre les coquilles marine et continentales, ni de la tendance des gastéropodes continentaux à un déficit en ^{14}C.

ACIDES AMINÉS

La méthode de datation par les acides aminés repose sur un processus naturel : les acides aminés d'un organisme vivant sont lévogyres (L) et se transforment progressivement, dès la mort de l'organisme, en isomères dextrogyres (D). Cette réaction réversible tend vers un rapport d'équilibre D/L, de l'ordre de 1. Parmi les acides aminés, l'isoleucine (Ile) comprend deux carbones chiraux et se transforme en D-alloisoleucine (Alle) selon une réaction racémique appelée épimérisation. Ces deux stéréoisomères peuvent être distingués par chromatographie en phase liquide. L'épimérisation tend vers un rapport d'équilibre Alle/Ile = 1,3.

La vitesse de racémisation augmente avec la température et, dans une moindre mesure, dépend d'autres facteurs. Elle varie selon les espèces. Il est donc possible de comparer les âges relatifs de fossiles d'une même région et, si l'histoire thermique de la région est connue, de calculer des âges absolus. Les coquilles et organismes carbonatés sont les plus favorables et les plus utilisés en aminochronologie.

Au Maroc, les conditions thermiques moyennement élevées (18-19°C pour l'actuel) auxquelles furent soumis les fossiles analysés sont à l'origine de taux de racémisation relativement rapides et favorables à la différenciation de plusieurs aminozones (Occhietti *et al.*, 1993 ; Occhietti et Raynal, 1996). Les coquilles datées, d'origine marine ou continentale, ont été prélevées à 20 cm ou plus de la surface exposée du dépôt. Les coquilles marines proviennent de thanatocénoses naturelles ou anthropiques. Les coquilles de gastéropodes continentaux (*Helix* et *Rumina*) ont été prélevées dans des remplissages de grottes et des cordons dunaires. Des échantillons des sites méditerranéens de la grotte de Kaf-Tat-El-Ghar (Province de Tetouan) et du cordon dunaire de Nador serviront d'éléments de comparaison.

RÉSULTATS, DISCUSSION

Sur la côte atlantique marocaine, le genre *Patella* est le mieux distribué dans l'espace et le temps ; il a un taux de racémisation moyen et montre une variabilité intraspécifique satisfaisante (Bowen et Sykes, 1985), quoique moins favorable que celle de *Glycymeris*, référence aminochronologique du bassin méditerranéen (Hearty *et al.*, 1986). Les taux de racémisation de *Patella* serviront donc de référence au cadre aminochronologique de la côte atlantique du Maroc. Le genre *Mytilus* est moins bien distribué. D'autres espèces moins fréquentes (*Monodonta, Ostrea* sp., *Cardium edule*) ont servi d'éléments de comparaison.

COQUILLES MARINES

D'après les données des sites du tableau 1 et de huit autres sites, les taux d'épimérisation des coquilles marines des genres *Patella* et *Mytilus* indiquent des différences statistiquement significatives et des valeurs croissantes cohérentes avec la position stratigraphique et les datations radiocarbone disponibles. Comme attendu (Miller et Mangerud, 1985), le taux d'épimérisation de *Mytilus* est plus rapide. Les rapports Alle/Ile des autres espèces s'ordonnent également selon la position stratigraphique. Les rapports Alle/Ile des coquilles de différents autres sites en plein air sont cohérents dans chaque site mais indiquent une variabilité du taux d'épimérisation de la même espèce entre certains sites. Ces variations sont attribuées à des conditions initiales de fossilisation différentes, en particulier la durée d'exposition au soleil avant enfouissement.

Stratigraphie	Culture	Site	Age 14C BP	Genre	AIle/Ile	NI
Holocène		Dar Bou Azza	3726 ±60 Ly-6368	*Mytilus*	0,098 ± 0,059	3
		El Kiffen	3530 ±120 UQ-1872	*Patella*	0,081 ± 0,019	10
		plage 0-2m	3330 ±120 UQ-1873	*Monodonta*	0,113 ± 0,02	6
	Néolithique final	Dar Es Soltan I	3330 ± 60 GSC-5852	*Patella*	0,107 ± 0,021	15
		couche 2		*Mytilus*	0,153 ± 0,043	3
		Skhirat	4950 ± 150* UQ-1557	*Patella*	0,145 ± 0,016	6
		base cordon		*Mytilus*	0,251 ± 0,030	6
Soltanien	Ibéromaurusien	Dar Es Soltan II grotte	16 500 ± 250 *UQ-1558	*Patella*	0,101 ?	1
	Atérien	Dar Es Soltan II	37 220 ± 290 *TO-2045	*Patella*	0,229 ± 0,022	6
		grotte		*Mytilus*	0,376 ± 0,017	3
	?	El Mnasra c.3 grotte		*Patella*	0,280 ± 0,051	3
	Atérien	El Mnasra grotte		*Patella*	0,300 ± 0,064	5
	Atérien	Dar Es Soltan I grotte		*Patella*	0,336 ± 0,097	3
	Atérien ? *Homo*	Dar Es Soltan II grotte		*Patella*	0,369 ± 0,020	2
Ouljien		Larache		*Patella*	0,533 ± 0,125	3
2-4 m		Dar Bouazza		*Patella*	0,547 ± 0,105	4

Tab. 1 : Taux d'épimérisation des acides aminés totaux des coquilles marines *Patella, Mytilus* et *Monodonta* (* prélèvement commun ^{14}C et acides aminés).
Tab. 1 : Epimerization ratios for total amino acids in Patella, Mytilus and Monodonta marine shells (Same sampling for ^{14}C and amino acids).*

GASTÉROPODES CONTINENTAUX

Les rapports AIle/Ile moyens obtenus sur le genre *Helix* (tab. 2), confrontés aux datations radiocarbone, montrent une vitesse d'épimérisation linéaire au moins jusque vers 25 ka (fig. 1). La variabilité intraspécifique, nulle pour Nador, augmente avec l'âge. La courbe des moyennes indique une homogénéité de la vitesse de racémisation entre des sites distants de plusieurs centaines de kilomètres mais d'histoire thermique analogue. Elle souligne que les coquilles accumulées sous grotte représentent un matériel favorable à l'aminochronologie, en raison d'une atténuation des variations thermiques. En dehors de la région étudiée, deux séries continentales du Soltanien (vallée du Souss et région de Nador, Occhietti *et al.*, 1994), ont montré clairement un taux d'épimérisation d'*Helix* et de *Rumina* croissant vers les unités plus anciennes, à l'exception des lits supérieurs situés à moins de 1 m de la surface apparemment affectés par des conditions thermiques plus chaudes. Dans ce cas, les conditions thermiques postérieures à l'enfouissement expliquent l'inversion de tendance.

Cette série de mesures du taux d'épimérisation du genre *Helix* ouvre la voie à une méthode de datation applicable à du matériel archéologique. Elle s'adresse tout particulièrement à des sites et dépôts du Soltanien ancien et moyen, non datables par le ^{14}C. Notons que le genre *Rumina*, moins fréquent qu'*Helix* en contexte archéologique, a donné des taux d'épimérisation sensiblement égaux à ceux d'*Helix*. Il sera donc possible d'utiliser les deux genres à fin de datation.

Stratigraphie	Culture	Site	Age 14C BP	AIle/Ile	NI
Holocène		Nador cordon dunaire	2950 ± 100 * UQ-1462	0,033 ± 0	3
	Cardial	Kaf Taht El Ghar grotte	6050 ± 120 Ly-3821 charbon	0,062 ± 0,008	7
Soltanien	migration dans Iberomaurusien	Dar Es Soltan II grotte		0,104 ± 0,015	9
	migration dans Atérien	Dar Es Soltan II grotte	16 090 ± 90 * TO-2046	0,234 ± 0,010	7
	Atérien	El Harhoura I grotte	25 580 ± 130 * TO-2047	0,312 ± 0,046	4

Tab. 2 : Taux d'épimérisation des acides aminés totaux du gastéropode continental *Helix* (* prélèvement commun ^{14}C et acides aminés).
Tab. 2 : Epimerization ratios for total amino acids in Helix shells (Same sampling for ^{14}C and amino acids).*

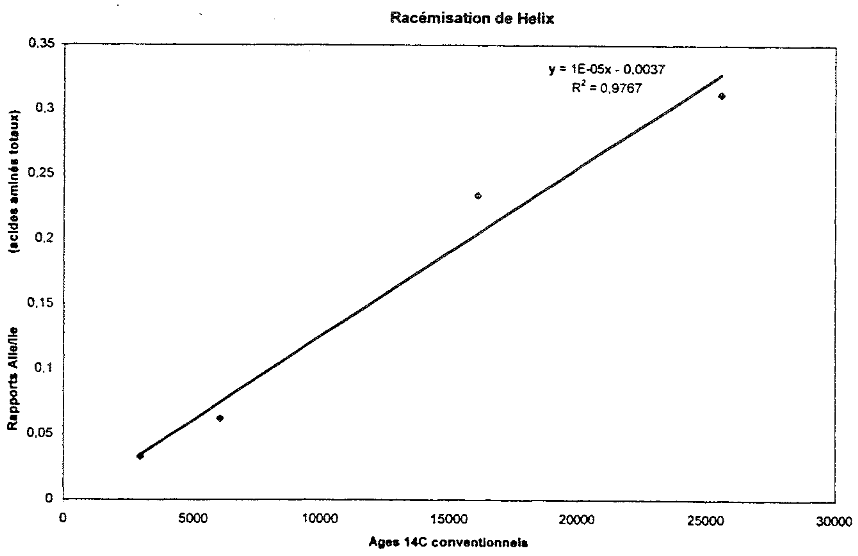

Fig. 1 : Courbe de régression des taux d'épimérisation des acides aminés totaux par rapport aux âges ^{14}C conventionnels du gastéropode continental *Helix*.
Fig. 1 : Regression curve of the epimerization ratios (total amino acids) vs conventional ^{14}C ages from the continental gastropod Helix.

DISCUSSION

Les résultats présentés montrent une plus forte variabilité des taux d'épimérisation des unités plus anciennes. La reproductibilité des résultats étant constamment vérifiée au laboratoire, les écarts-types élevés sont donc représentatifs. Par ailleurs, toutes les mesures valides obtenues ont été prises en compte, sans tri sélectif, sauf un cas évident de remaniement anthropique. Seules les mesures présentant des anomalies (pics parasites, anomalie de la concentration standard Norleucine) ont été rejetées. La variabilité des taux d'épimérisation reflète la variabilité naturelle intragénique et intraspécifique et d'éventuels remaniements. Dans le cas de gisements préhistoriques, les thanatocénoses échantillonnées peuvent contenir des spécimens remaniés par l'activité humaine. De tels cas sont relativement faciles à identifier dans les unités holocènes. Par ailleurs, la colonisation d'unités sous-jacentes par des gastéropodes continentaux sur plusieurs dizaines de centimètres pose un problème majeur de datation. Ainsi, l'unité dite «atérienne» de Dar Es Soltan II contient *Patella* datée de 37 220 ± 290 BP (TO-2045) et *Helix* daté de 16 090 ± 90 BP (TO-2046) : les gastéropodes auraient colonisé le niveau atérien 20 000 ans après sa mise en place. *Helix* est un bon matériel aminochronologique, en tenant compte des anomalies du radiocarbone propres aux gastéropodes continentaux, mais ne date pas nécessairement les unités qui le contiennent.

CONCLUSION

Les conditions d'épimérisation de *Patella* et d'*Helix* sont favorables à l'identification d'événements intervenus pendant le Soltanien, dont la partie inférieure reste encore très mal connue, et l'Holocène. L'épimérisation d'*Helix,* approximativement linéaire jusque vers 25 ka, ouvre en outre une possibilité de datation absolue peu coûteuse, aux réserves évoquées près. Compte-tenu de la faible quantité d'échantillon nécessaire, du coût peu élevé et de la rapidité d'analyse, la méthode de datation par les acides aminés se révèle très utile car elle permet de vérifier à peu de frais l'homogénéité d'un échantillon (source naturelle et anthropique) avant par exemple de procéder à une datation par accélérateur. L'interprétation des résultats aminochronologiques demande comme pour toute méthode de datation une bonne connaissance des conditions de terrain.

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DATATION DIRECTE DES PEINTURES PRÉHISTORIQUES PAR LA MÉTHODE DU CARBONE 14 EN SPECTROMÉTRIE DE MASSE PAR ACCÉLÉRATEUR

Hélène VALLADAS, Nadine TISNÉRAT*, Hélène CACHIER* et Maurice ARNOLD**

Résumé : Cet article présente les datations faites au Laboratoire des Sciences du Climat de l'Environnement sur des tracés ou peintures préhistoriques réalisées avec du charbon de bois. Après une brève description du protocole utilisé (prélèvement, traitement chimique...) nous discuterons des résultats obtenus.

Jusqu'à présent, près de 70 datations de peintures ont été réalisées pour plusieurs grottes ornées de France et d'Espagne. Elles ont révélé notamment que certaines grottes avaient été décorées au cours de plusieurs périodes distinctes et que l'art pariétal était apparu plus tôt qu'on ne le pensait, au début du Paléolithique supérieur. Ces premiers résultats montrent le grand intérêt d'établir une chronologie de l'art pariétal préhistorique pour en retracer l'évolution.

Abstract : Presented below are some radiocarbon dates obtained at the «Laboratoire des Sciences du Climat et de l'Environnement» for charcoal used in the execution of several prehistoric caves paintings. The presentation of the dates will be preceded by a short discussion of the experimental procedure used in our Laboratory (pigment sampling, chemical treatment, etc.).

Until now, 70 pigment specimens from cave paintings in France and Spain have been dated at our laboratory. The ages obtained have shown that the art of cave painting appeared early in the Upper Palaeolithic period, much earlier than previously believed and that in several caves the paintings were made during successive visits thousands of years apart. The high artisitic quality of the earliest paintings underlines the importance of absolute chronology in any attempted study of the evolution of prehistoric art.

Mots-clés : Datation par le carbone 14 en S.M.A., grottes ornées, peintures, charbon, Paléolithique supérieur.

Key-words : A.M.S. carbon 14 dating, prehistoric cave paintings, charcoal, Upper Palaeolithic.

INTRODUCTION

Depuis une quinzaine d'années, plusieurs approches ont été proposées pour établir la chronologie de l'art pariétal. Certaines se sont intéressées à la surface des parois décorées, par exemple à la formation de patine (Dorns, 1983) ou à l'érosion des tracés (Bednarik, 1992). Comme ces phénomènes sont très dépendants de l'environnement, les chronologies proposées restent imprécises. Une autre approche a été de dater directement les pigments des peintures par la méthode du ^{14}C, en spectrométrie de masse par accélérateur (SMA). Les premières applications ont porté sur des résidus de sang humain utilisé pour des figures pariétales de sites australiens et tasmaniens (Loy *et al.*, 1990). Des peintures rupestres australiennes à base de cire d'abeille ont aussi été datées (Nelson *et al.*, 1995). Ces applications restent peu nombreuses et la plupart des autres datations directes ont porté sur des peintures réalisées avec du charbon de bois (Russ *et al.*, 1990 ; Valladas *et al.*, 1992 ; Igler *et al.*, 1994 ; Evin, 1996).

Cet article présente les résultats obtenus, depuis 1990, avec le Tandétron du Campus de Gif-sur-Yvette sur des peintures préhistoriques du Sud de la France et d'Espagne. Après un aperçu du prélèvement des échantillons et des problèmes spécifiques liés à leur datation, nous décrirons leur protocole de préparation. Nous discuterons ensuite des résultats obtenus sur les différentes fractions organiques d'un même pigment. Pour terminer, nous rappellerons les principales datations faites, notamment, dans les grottes Cosquer et Chauvet.

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LES PRÉLÈVEMENTS

Les prélèvements ont été faits en collaboration avec les Préhistoriens en charge de l'étude des grottes ornées : F. Bernaldo de Quiros, V. Cabrera-Valdes, A. Moure et C. Gonzales, pour les grottes d'Altamira et d'El Castillo (Cantabrie) ; J. Clottes et J. Courtin, pour la grotte Cosquer (Provence) ; J. Clottes, pour la grotte Chauvet (Ardèche) ; S. Corchon, pour la grotte de Palomera (Burgos) ; J. Fortea-Perez, pour la grotte de Covaciella (Asturies) ; M. Lorblanchet, pour les grottes de Cougnac et du Pech-Merle (Lot).

Pour ne pas endommager les peintures de façon visible, les échantillons (10 à 100 mg) sont prélevés, quand c'est possible, dans des fissures de la paroi où le pigment est plus épais, à l'aide d'un scalpel. Ils contiennent, en plus du pigment carboné, de nombreux grains de calcite issus de la paroi rocheuse. Selon la quantité de matière disponible, le prélèvement est réalisé en un ou plusieurs points d'une même figure.

PROBLÈMES SPÉCIFIQUES LIÉS A LA DATATION DES PIGMENTS

La première question porte sur la relation entre l'âge du charbon de bois et celui de la peinture. Sa réalisation est-elle contemporaine de la mort de l'arbre qui a fourni le charbon ou l'artiste a-t-il récolté des charbons au sol provenant d'une occupation antérieure, pouvant être beaucoup plus anciens (Bednarik, 1994) Les données stratigraphiques apportent parfois des éléments de réponse. On peut aussi se demander s'il y a eu utilisation de charbon naturel fossile (Beck *et al.*, 1998 ; Dorns, 1998) ou si le pigment n'a pas été obtenu en mélangeant plusieurs fragments charbonnés d'origine variée. L'analyse de l'échantillon au Microscope électronique à balayage permet souvent de préciser la nature des pigments utilisés. Enfin, on peut envisager la possibilité que certaines peintures ont subi des retouches au cours d'occupations préhistoriques successives. Seule, la multiplication des datations en plusieurs points d'une même figure est susceptible d'informer sur l'existence d'une telle pratique.

Ces questions mises à part, la datation des peintures à base de charbons de bois rencontre les mêmes difficultés que les autres datations C-14. La principale cause d'erreur est donc la contamination de l'échantillon par du carbone étranger (Van Strydonck *et al.*, ce volume). Cependant, le cas des peintures est particulier puisqu'elles sont exposées à la surface et donc continuellement soumises aux agents extérieurs. Les risques de contamination dépendent des grottes et des conditions de leur découverte. Ils sont plus importants dans le cas des grottes découvertes anciennement, qui ont été beaucoup visitées. Celles qui ont toujours été protégées sont donc plus favorables à la datation.

Parmi les différentes sources de contaminations en matières organiques, on peut évoquer celles résultant des visites répétées de la grotte par l'homme : contacts des mains, dépôts de fibres vestimentaires ou de carbone des lampes à acétylène sur les peintures... Les animaux vivant dans la grotte et les micro-organismes variés (bactéries, champignons, algues...) qui peuvent se développer, notamment, quand la grotte est beaucoup visitée, sont également des agents contaminants potentiels. Il en est de même des carbonates et des acides humiques ou fulviques dissous dans les eaux souterraines.

Dans la plupart des cas cités ci-dessus, la matière organique de contamination est d'origine récente. Si elle n'était pas éliminée avant la datation, elle entraînerait un rajeunissement de l'échantillon. La première étape de la datation consiste donc à traiter l'échantillon chimiquement pour éliminer les contaminations en carbone étranger.

TRAITEMENT DES ÉCHANTILLONS

Les pigments charbonnés sont soumis au traitement acide- base- acide, utilisé pour tous les charbons de bois (Hedges *et al.*, 1989) mais il est moins rigoureux, en raison de la petite quantité d'échantillons disponible et de leur fragilité (Valladas *et al.*, 1992). Chaque pigment réagit différemment et le traitement, plus ou moins fort, est adapté à chacun d'eux.

Pour faciliter les manipulations, l'échantillon est déposé après sa première attaque par l'acide chlorhydrique (0,5 à 1 %) sur un filtre de quartz pré-nettoyé. Le traitement basique, d'abord léger, est intensifié progressivement selon que le pigment est attaqué ou non. Il commence avec une solution de pyrophosphate de sodium très diluée puis de plus en plus concentrée. Une solution ammoniacale est ensuite utilisée, dont on augmente aussi la concentration. Dans certains cas, on termine avec une solution de soude. En règle général, ce traitement basique est stoppé dès que la solution qui s'écoule du filtre supportant l'échantillon, est fortement colorée. Cela implique, en effet, que chaque grain en suspension a été décapé en surface mais aussi qu'une fraction déjà importante de l'échantillon de départ a été dissoute et qu'il y a donc risque de le perdre dans sa totalité si le traitement n'est pas interrompu à temps. La «fraction charbonnée» est alors traitée une deuxième fois avec de l'acide chlorhydrique.

La «fraction humique» entraînée par la solution basique est reprécipitée par de l'acide chlorhydrique et collectée sur un deuxième filtre de quartz. Elle représente une part souvent importante de l'échantillon de départ mais peut contenir des contaminations.

Les filtres supportant le charbon purifié ou les acides humiques subissent ensuite un traitement thermique sous courant d'oxygène pur, entre 280 et 320°C selon les cas, pendant une heure environ pour permettre l'élimination de dépôts organiques peu réfractaires et donc vraisemblablement récents. Ce traitement thermique permet aussi de s'affranchir de la plupart des contaminations apportées durant le protocole d'attaque chimique.

Après ce traitement de nettoyage, les échantillons sont préparés pour l'analyse au Tandétron : oxydation en gaz carbonique puis réduction en graphite, à partir duquel sont préparées les cibles destinées au Tandétron (Arnold *et al.*, 1987). La quantité de carbone obtenue pour la datation varie selon les échantillons, entre 0,5 et 1 mg, d'où une perte s'élevant souvent à plus de 90 % de l'échantillon de départ au cours des traitements chimiques et thermiques.

La fiabilité de ce protocole a été testée sur un échantillon de charbon de bois d'un niveau solutréen de l'Abri des Peyrugues (Lot) qui a été divisé en plusieurs lots. Deux d'entre eux, pesant chacun une centaine de milligrammes ont subi un traitement chimique rigoureux. Les autres lots, de quelques dizaines de milligrammes seulement, ont été soumis au même traitement que les pigments. Les âges obtenus sur chaque lot sont reportés dans le tableau 1 : on constate que le traitement appliqué aux peintures donne le même résultat que le traitement plus rigoureux. De plus, il se confirme que le traitement thermique contribue à l'élimination des contaminations. En effet, l'échantillon non traité thermiquement donne un âge sensiblement plus jeune.

Mesure sans filtre
Attaque chimique classique (HCl, NaOH)
20.410 ± 280 (GifA 91186)
20.290 ± 230 (GifA 92168)

Mesure sur filtre de quartz
Attaque chimique ménagée utilisée pour les pigments, suivie du traitement thermique sous courant d'oxygène
20.750 ± 240 (GifA 91417)
20.400 ± 220 (GifA 91410)
20.470 ± 290 (GifA 91427)

Attaque chimique ménagée sans traitement thermique
19.100 ± 220 (GifA 91142)

Tab. 1 : Ages, ans BP, (à un sigma) obtenus sur un échantillon de charbon de bois de l'abri des Peyrugues après différents traitements.

Par ailleurs, la contamination en carbone étranger des pigments durant le protocole de préparation a été estimée indépendamment à partir d'un graphite et d'un charbon de bois plus ancien que 100 kans. Cette contamination (0,50 ± 0.12 pMC) est prise en compte dans le calcul de l'âge des échantillons.

DATATION DES DIFFÉRENTES FRACTIONS ORGANIQUES DU MÊME PIGMENT

Pour avoir une idée du taux de contamination du pigment, on date sa «fraction humique» quand elle est en quantité suffisante (Batten *et al.*, 1986). On peut ainsi comparer l'âge du charbon purifié à celui de cette fraction qui contient, entre autre, les contaminations en carbone étranger (tab. 2). Trois cas se sont alors présentés. Les deux premiers, qui sont les plus fréquents, ont été rencontrés, notamment, avec des échantillons des grottes Cosquer et Chauvet.

Cas n°1 : l'âge du charbon purifié et de sa «fraction humique» sont concordants. On considère en général que ce bon accord atteste la fiabilité des résultats même s'il n'exclut pas la possibilité que les deux fractions soient contaminées. Cependant, ce risque semble peu probable dans le cas du mouchage de torche de la grotte Chauvet et des représentations de la main négative et du cheval de Cosquer. En effet, leur traitement chimique était satisfaisant et, de plus, des résultats concordants ont été obtenus sur une deuxième aliquote de ces prélèvements, traité ultérieurement.

Cas n°2 : la «fraction humique» donne un âge sensiblement plus jeune que le charbon associé. Cette différence attendue, variable selon les échantillons, atteint plusieurs milliers d'années pour le mégaceros et le bison 1 de la grotte Cosquer. Ces résultats suggèrent que ces pigments étaient contaminés en carbone récent. Dans le cas des deux bisons de Cosquer, une deuxième aliquote des mêmes prélèvements a été traitée volontairement de façon plus rigoureuse et datée indépendamment. Comme les résultats sont concordants, il n'y a pas de raison de douter de leur fiabilité.

Cas n°3, le plus inattendu : la «fraction humique» donne un âge plus grand que celui des charbons purifiés. Cette situation a été rencontrée sur deux des trois bisons datés du plafond peint d'Altamira. Lors des premières mesures, les âges des charbons variaient entre 13.500 et 14.500 BP alors que ceux des fractions humiques étaient regroupés autour de 14.500 BP. Pour les bisons XLIV et XXXVI, les charbons étaient de plusieurs centaines d'années postérieurs aux fractions humiques associées. De nouveaux échantillons des mêmes prélèvements ont alors été traités. Cette fois, la fraction humique n'a pu être datée. Pour le bison XLIV, le nouveau résultat sur charbon était compatible avec le premier. En revanche, pour le bison XXXVI, la nouvelle date, plus ancienne que la première, se situait autour de 14.700 BP, comme celle obtenue au préalable sur la fraction humique. Pour le bison XXXIII, les deux âges sur charbon et celui de la fraction humique se situaient autour de 14.500 BP.

Comment interpréter la dispersion des dates sur charbons et le fait qu'elles soient, parfois, inférieures à celles des «fractions humiques» ? On peut naturellement envisager que les peintures d'un même panneau ne sont pas synchrones mais, dans le cas d'Altamira, l'homogénéité du plafond peint suggère que sa décoration a été conçue à une même période. La présence dans les échantillons de contamination en carbone insoluble d'origine récente apparaît comme l'explication la plus plausible pour la dispersion observée. En effet, cette grotte a été beaucoup visitée depuis sa découverte, à la fin du siècle dernier. Selon cette hypothèse, ce sont les âges les plus anciens qui seraient les plus fiables. Le comportement des échantillons pendant leur traitement chimique apporte, lui aussi, des arguments en faveur de cette hypothèse. En raison de leur grande sensibilité au traitement basique, le protocole de purification a dû être interrompu pour des solutions diluées de pyrophosphate de sodium. Il est alors possible que les «fractions carbonées» insolubles aient conservé certains agents particulaires, contaminants récents stables et ayant résisté à cette attaque basique légère. Les «fractions humiques», provenant principalement de la dissolution du charbon à dater seraient moins contaminées.

Dans le cas particulier des pigments d'Altamira, on peut donc penser que ce sont les âges des «fractions humiques», en accord avec les âges les plus anciens (GifA 96060, GifA 91181, GifA 96071, tab. 2) obtenus sur les «fractions carbonées» des bisons XXXVI et XXXIII, qui fournissent les estimations chronologiques les plus pertinentes pour les peintures étudiées.

L'exemple des peintures de Cosquer, Chauvet et Altamira montre l'intérêt de comparer les âges des différentes fractions organiques et de multiplier les mesures sur un même échantillon de pigment pour apprécier la cohérence des datations. Il apparaît aussi qu'il est préférable de dater séparément plusieurs échantillons distincts plutôt qu'un échantillon moyen prélevé sur tout le tracé d'une figure.

RÉSULTATS

A titre d'exemple sont reportés, sur la figure 1, les résultats obtenus pour les grottes Cosquer (Bouches-du-Rhône) et Chauvet (Ardèche).

LA GROTTE COSQUER

Une vingtaine de datations qui ont porté sur trois mains négatives, cinq figurations animales et deux signes, ont été faites en collaboration avec J. Clottes et J. Courtin (Clottes *et al.*, 1992a, 1997). Ces datations ont confirmé

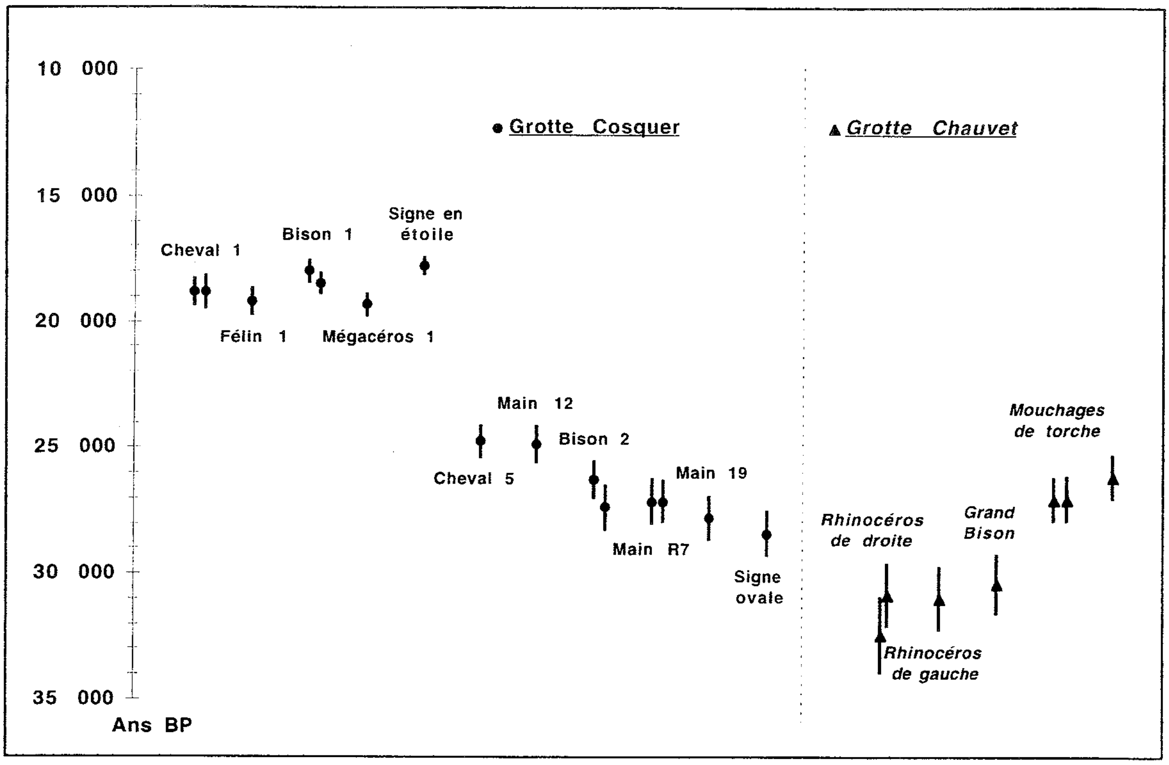

Fig. 1 : Répartition des âges obtenus pour les peintures et les charbons de bois trouvés au sol des grottes Cosquer (A) et Chauvet (B). L'incertitude sur l'âge est donnée à deux sigma (95 % de probabilité).
Fig. 1 : Age distribution of Cosquer (A) and Chauvet (B) cave paintings. Ages (BP) are given with a 95 % probability.

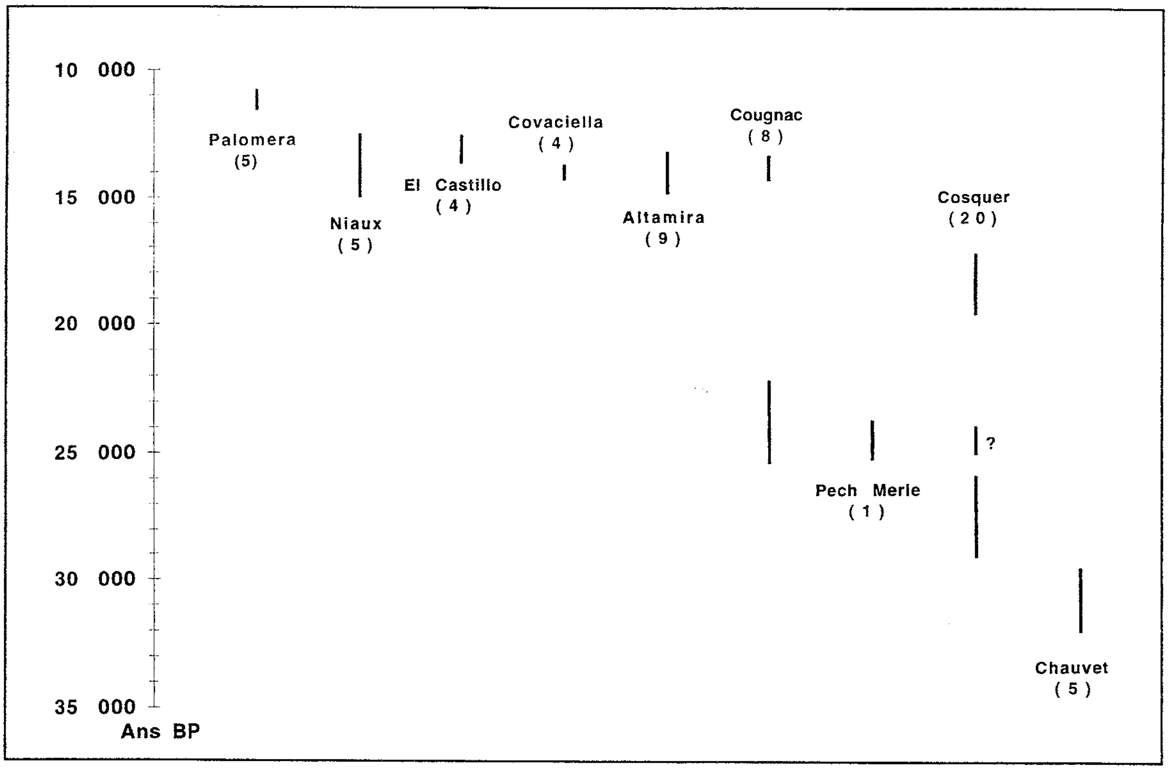

Fig. 2 : Plage chronologique proposée pour des grottes ornées de France et d'Espagne, à partir des datations directes des peintures. Le nombre de datations est indiqué à côté de chaque barre. Les données sur les datations d'Altamira, d'El Castillo et de Niaux sont publiés dans Valladas *et al.*, (1992) et Clottes *et al.*, (1992b) ; celles de Cougnac et de Pech-Merle, dans Valladas *et al.*, (1994) et Lorblanchet (1995) respectivement ; enfin celles de Palomera et de Covaciella, dans Corchon *et al.*, (1996) et Fortea Perez (1996), respectivement.
Fig. 2 : Age ranges proposed for some decorated French and Spanich caves on the basis of pigment radiocarbon dates. Above and below each bar is given the number of specimens dated. The dates of Altamira, El Castillo and Niaux were published by Valladas *et al.*, (1992) and Clottes *et al.*, (1992b) ; those of Cougnac and Pech-Merle by Valladas *et al.*, (1994) and Lorblanchet (1995), respectively; those of Palomera and Covaciella by Corchon *et al.*, (1996) and Fortea Perez (1996), respectively.

Grotte	Figure	Age ^{14}C ans BP (2sigma)	Référence de mesure
<u>Cas n°1</u>			
Chauvet	**Mouchage de torche 1**		
	Charbon 1	26.980 ± 820	GifA 95129
	Fraction humique 1	25.700 ± 1.700	GifA 95158
	Charbon 2	26.980 ± 840	GifA 95130
Cosquer	**Cheval 1**		
	Charbon 1	18.840 ± 480	GifA 92416
	Fraction humique 1	18.760 ± 440	GifA 92422
	Charbon 2	18.820 ± 620	GifA 92417
	Main R7		
	Charbon 1	27.110 ± 780	GifA 92409
	Fraction humique 1	26.180 ± 660	GifA 92424
	Charbon 2	27.110 ± 700	GifA 92491
<u>Cas n°2</u>			
Cosquer	**Bison 1**		
	Charbon 1	18.010 ± 380	GifA 92419
	Fraction humique 1	16.390 ± 520	GifA 92423
	Charbon 2	18.530 ± 360	GifA 92492
	Bison 2		
	Charbon 1	26.250 ± 700	GifA 96069
	Fraction humique 1	23.080 ± 1.280	GifA 95308
	Charbon 2	27.350 ± 860	GifA 95195
	Mégaceros 1		
	Charbon 1	19.340 ± 400	GifA 95135
	Fraction humique 1	13.460 ± 660	GifA 95365
<u>Cas n°3</u>			
Altamira*	**Bison XLIV**		
	Charbon 1	13.570 ± 380	GifA 91178
	Fraction humique 1	14.410 ± 400	GifA 91249
	Charbon 2	13.130 ± 240	GifA 96067
	Bison XXXVI		
	Charbon 1	13.940 ± 340	GifA 91179
	Fraction humique 1	14.710 ± 400	GifA 91254
	Charbon 2	14.800 ± 300	GifA 96060
	Bison XXXIII		
	Charbon 1	14.330 ± 380	GifA 91181
	Fraction humique 1	14.250 ± 360	GifA 91330
	Charbon 2	14.820 ± 260	GifA 96071

* Numérotation des bisons selon Breuil and Obermaier (1935).

Tab. 2 : Comparaison des âges obtenus sur les différentes fractions organiques d'un même échantillon de pigment.

les observations de ces deux préhistoriens, en montrant que la grotte avait été décorée au cours d'au moins deux grandes périodes. La première avec, notamment, les tracés de mains négatives (R7 et 19), d'un bison et du signe ovale, se situe entre 27 et 28 kans BP. Quant à la seconde, avec le signe en étoile et des représentations animales (bison, félin et cheval et mégaceros), elle se place il y a 19 kans environ. Les dates, obtenues sur des charbons trouvés à la surface du sol, correspondent à ces deux périodes mises en évidence à partir des peintures.

Notons que deux datations de 25 kans BP environ ont été obtenues pour la main négative (12) et le cheval (5), qui sont difficiles à interpréter actuellement. Il est possible que ces peintures datent de la première période de décoration mais que l'âge des pigments analysés soit légèrement sous-estimé du fait de leur contamination en carbone récent. On peut aussi envisager l'existence d'une troisième période de décoration de la grotte. De nouvelles analyses seraient nécessaires pour trancher entre ces deux hypothèses.

LA GROTTE CHAUVET

L'étude de cette grotte en est encore à ses débuts (Clottes *et al.,* 1995). Jusqu'à présent, seulement sept datations ont été réalisées sur trois peintures (deux rhinocéros affrontés et un bison) et deux mouchages de torche. Les résultats, statistiquement compatibles, montrent que ces peintures ont été réalisées à la même époque, il y a 31.000 ± 2.600 BP. Quant aux deux mouchages de torche, ils se placent entre 27.000 et 26.000 BP et sont donc postérieurs d'environ 4.000 ans à la réalisation des peintures. Il est intéressant de noter que l'un des deux mouchages était déposé sur une couche de calcite recouvrant un animal du panneau des rhinocéros affrontés. La date obtenue sur ce mouchage apporte donc des informations indirectes sur l'ancienneté des peintures.

Les trois autres datations, réalisées par les laboratoires de Lyon et d'Oxford, sur des charbons trouvés au sol montrent que la grotte a connu plusieurs incursions humaines entre 31.000 et 24.000 BP, séparées par quelques millénaires.

Les études ultérieures s'attacheront à montrer si cette grotte a été décorée au cours d'une même période ou de plusieurs étapes successives.

CONCLUSION

En résumé, la figure 2 rassemble les dates déjà publiées (dont les références sont données en légende). pour certaines peintures préhistoriques de France et d'Espagne. La plupart se placent pendant le Magdalénien alors que d'autres, plus anciennes remontent jusqu'au début du Paléolilthique supérieur. Même si ces résultats sont encore trop peu nombreux pour retracer l'évolution de l'art pariétal, ils contribuent déjà à modifier nos conceptions sur l'origine et l'évolution de cet art. Ainsi, les datations faites à Chauvet montrent que, dès l'Aurignacien, de grands artistes maîtrisaient parfaitement les techniques picturales ; ils suggèrent donc que l'art pariétal n'a pas évolué de façon linéaire du plus rudimentaire à l'élaboré (Clottes *et al.*, 1995). Enfin, grâce à la méthode du ^{14}C en SMA, il est maintenant possible de mieux connaître les différentes périodes de décoration des grottes.

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LES ISOTOPES DU CARBONE POUR LA CARACTÉRISATION ET LA DATATION DES CÉRAMIQUES ARCHÉOLOGIQUES
L'exemple de la céramique cannelée de Sintiou-Bara (Moyenne Vallée du Fleuve Sénégal)

Delphine SENASSON et ***, Jean-François SALIÈGE**, Alain PERSON*** et *, H. BOCOUM**** et Jean POLET* et ******

Résumé : Les sites majeurs de la moyenne vallée du fleuve Sénégal, comme Sintiou-Bara, Ogo, Tioubalel et Siwré, livrent une céramique particulière cannelée et engobée dans les niveaux supérieurs des séries stratigraphiques. Nous avons cherché à reconstituer les chaînes opératoires de fabrication et tenté de dater directement les tessons archéologiques. Nous présentons ici un exemple de l'apport des isotopes stables du carbone dans la caractérisation de la matière organique incluse dans les poteries, ainsi que deux résultats de datation par le radiocarbone effectuée sur ces mêmes céramiques.

Abstract : The main sites of the middle Senegal valley, such as Sintiou-Bara, Ogo, Tioubalel and Siwré, yielded a specific fluted and coated pottery in the upper levels of the stratigraphical series. Our aim has been to reconstruct the different stages of manufacturing process and to try to date the ceramic sherd itself. Here is an exemple of what the carbon stable isotope analysis can bring to the characterization of organic material of pottery. Finaly, two radiocarbon dates were determined for the same ceramics.

Mots-clés : Céramique, datation radiocarbone, Sintiou-Bara, moyenne vallée du fleuve Sénégal.

Key-words : Pottery, radiocarbon dating, Sintiou-Bara, middle senegal valley.

INTRODUCTION

L'étude du développement de la métallurgie du fer est l'une des préoccupations les plus actuelles de la recherche archéologique en Afrique de l'Ouest. Le cadre chronologique du contexte métallurgique de la moyenne vallée du fleuve Sénégal repose essentiellement sur la typologie de la céramique, élément particulièrement bien représenté dans la stratigraphie des sites. Une cinquantaine de dates radiocarbone sur charbons de bois y est associée (S.J. et K.R. McIntosh et Bocoum, 1992). L'utilisation des isotopes du carbone de la matière organique incluse dans les poteries peut fournir un ensemble de données paléotechniques à incorporer à l'étude de la chaîne opératoire céramologique et un référentiel temporel par la datation radiocarbone de l'objet céramique lui-même.

MATÉRIELS ET OBJECTIFS

LOCALISATION

Sintiou-Bara et la moyenne vallée du fleuve Sénégal

La moyenne vallée du fleuve Sénégal et sa plaine d'inondation regroupent la plus importante concentration de sites d'habitat correspondant au développement de la métallurgie du fer en Sénégambie. Plus de 400 sites ont été répertoriés au cours de prospections archéologiques (Martin et Becker, 1974) et certains, comme Sarré-Tioffi, Diallowalli, Tioubalel, Ogo, Siwré, Sintiou-Bara, ont déjà fait l'objet de nombreux travaux (Thilmans et Ravisé, 1980 ; Chavane, 1985 ; Bocoum, 1986 ; Thiam, 1984 ; S.J. et K.R. McIntosh et Bocoum, 1992 ; Garenne-Marot, 1993 ; Garenne-Marot et Polet, 1996).

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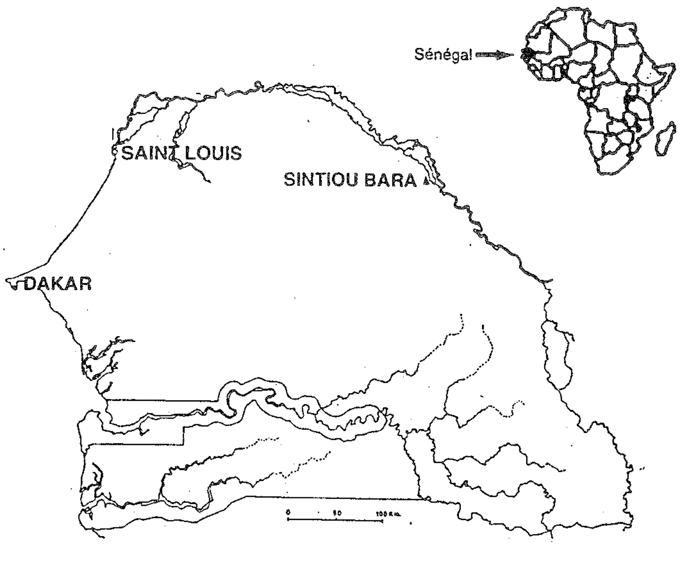

Fig. 1 : Sintiou-Bara et la Moyenne Vallée du Fleuve Sénégal.
Fig. 1 : Sintiou-Bara and the middle Senegal valley.

Sintiou-Bara (fig. 1), situé au nord d'Ourossogni (15° 42' N, 13° 23' W), dans la zone non inondable en période de crue (Jeeri) est, du point de vue de la superficie, le site le plus important de la moyenne vallée (67 ha). Il est constitué d'accumulations anthropiques sous forme de plages et de buttes circulaires ou elliptiques, dont le diamètre maximal est d'environ 50 m. Du point de vue chronologique, la période d'occupation de Sintiou-Bara s'étend sur plus d'un demi-millénaire : du Ve au XIe siècle après J.-C. (S.J. et K.R. McIntosh et Bocoum, 1992). La céramique cannelée et engobée est l'une des caractéristiques les plus remarquables des vestiges de la culture matérielle présente sur le site.

MATÉRIEL

La céramique "cannelée et engobée" de Sintiou-Bara

Les céramiques cannelées et engobées sont couramment considérées comme constituant un ensemble original et homogène. Celui-ci se manifeste dans les niveaux supérieurs des séries stratigraphiques (Thilmans et Ravisé, 1980), à travers des séries de coupelles, de bols, de vases à goulots, de vases à pieds et de grosses poteries globuleuses (fig. 2, 3, 4, 5). Trois éléments les caractérisent :

- cannelures multiples horizontales, au niveau du col et/ou du goulot et/ou du pied ;
- motifs cannelés incisés, sur la panse, parfois associés à un décor d'impressions couvrantes (tresses ou cordelettes) à mi-panse et/ou sur le fond ;
- surface extérieure (parfois intérieure) de couleur lie de vin, vermillon ou noire.

La forme des cannelures du profil varie selon les spécimens considérés : plus ou moins profondes, peu ou très écartées les unes des autres, séparées par des bourrelets de section triangulaire plus ou moins adoucie. D'après G. Thilmans et A. Ravisé (1980), ces cannelures multiples sont de véritables remodelages et non des cannelures incisées. Les motifs incisés sur les panses, sont variés et le plus souvent géométriques : chevrons, croix de Saint André, coeurs, cercles concentriques, mamelons, losanges, ovales... Généralement bien conservées, les surfaces sont lisses et brillantes.

Un style présent sur d'autres sites de la moyenne vallée du fleuve

Cette céramique cannelée se retrouve en proportions inégales dans d'autres sites : elle connaît un développement notable à Ogo, tandis qu'à Tioubalel et Siwré, elle apparaît de manière plus discrète. Dans la chronologie céramique proposée pour le premier millénaire et le premier quart du deuxième millénaire de notre ère, son apparition se situe entre le milieu du Xe et la fin du XIIe siècle (S.J. et K.R. MacIntosh et Bocoum, 1992).

OBJECTIFS

Reconstitution des chaînes opératoires de fabrication des poteries

Le premier objectif de notre étude est la reconstitution des chaînes opératoires. Cette production de céramiques fut étudiée jusqu'à présent dans ses aspects les plus " externes " : formes et décors. Or il est maintenant admis que les caractères descriptifs propres à un ensemble culturel doivent être recherchés non seulement dans les aspects morphologiques et ornementaux mais aussi technologiques. Ces données, une fois acquises, permettront de discuter de l'homogénéité du style des céramiques cannelées présentes dans les différents sites.

Datation des céramiques cannelées et engobées

Le second objectif concerne les rapports chronologiques à établir entre les niveaux des différentes séries stratigraphiques où elles se trouvent. Tioubalel et Siwré furent occupés du Ier au IXe siècle après J.-C., Sintiou-Bara, du Ve au XIe siècle après J.-C. (S.J. et K.R. MacIntosh et Bocoum, 1992). Nous chercherons à dater l'apparition de la céramique cannelée à Sintiou-Bara afin de déterminer si elle est contemporaine de celle de Tioubalel et Siwré.

MÉTHODOLOGIE

Le problème de l'identification des sources de carbone contemporaines de la fabrication des poteries

La datation par la méthode du carbone 14 de la matière organique incluse dans une céramique présente une difficulté majeure : l'identification des sources de carbone strictement contemporaines de la fabrication de la céramique (de Atley, 1980 ; Gabasio *et al.*, 1986 ; Saliège et Person, 1991 ; Hedges *et al.*, 1992 ; Delque-Kolic, 1995). Comment distinguer en effet, la matière organique liée naturellement à l'argile, qui peut n'avoir aucun lien direct avec l'âge de la poterie, de celle ajoutée par les potiers sous forme de dégraissants intentionnels ou de dépôts de surface ? La caractérisation de certaines étapes de la chaîne opératoire de fabrication par une méthode géochimique, fondée sur l'étude des teneurs en carbone organique total et des rapports isotopiques du carbone inclus dans les poteries, semble offrir de nouvelles perspectives pour les céramiques africaines du domaine tropical (Saliège et Person, 1991).

- En Afrique de l'Ouest, la végétation tropicale est caractérisée par deux grands groupes de plantes dont les cycles photosynthétiques se distinguent par un fractionnement isotopique du carbone bien marqué. Le premier groupe de plantes dit en "C3" fixe le carbone selon le cycle décrit par Calvin, et présente des valeurs de $\delta^{13}C$ comprises entre -22 et -28 ‰. Il comprend la totalité des arbres et la majeure partie des plantes terrestres et aquatiques. Le second groupe dit en "C4" fixe le carbone selon le cycle décrit par Hatch et Slack et présente des va-

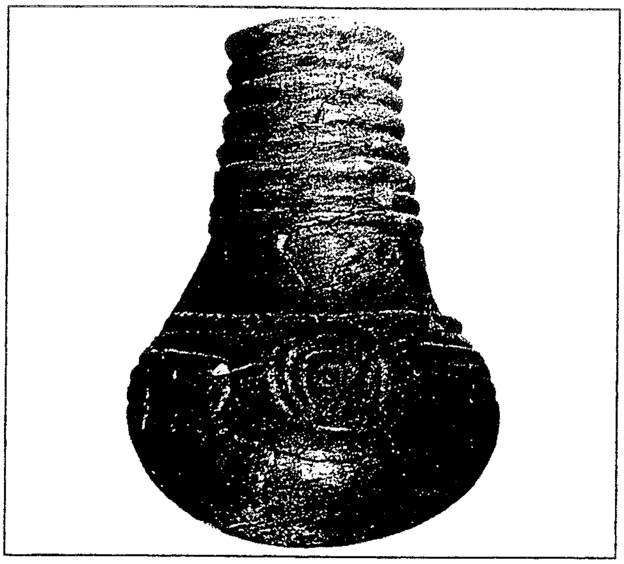

Fig. 2 : " Vase à goulot " de Sintiou-Bara.
Fig. 2 : " Pottery with neck " from Sintiou-Bara (Chavane, 1985).

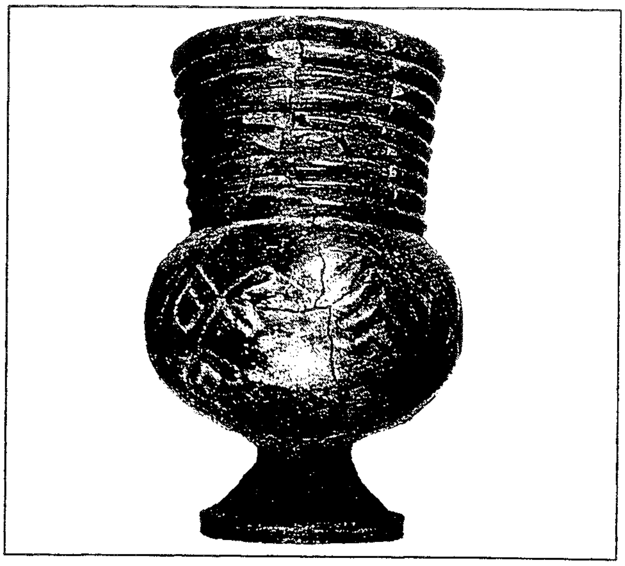

Fig. 3 : " Vase à pied " de Sintiou-Bara.
Fig. 3 : " Potterystand " from Sintiou-Bara (Chavane, 1985).

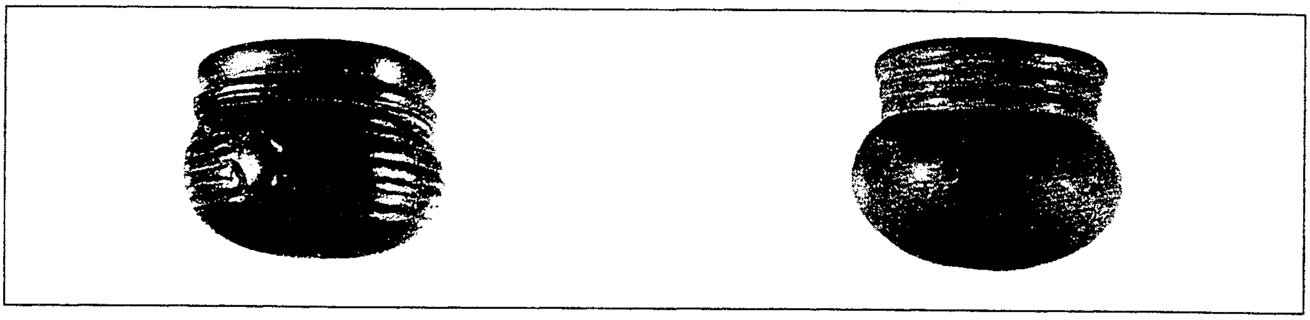

Fig. 4, 5 : " Bols " de Sintiou-Bara.
Fig.4, 5 : " Bowl " from Sintiou-Bara (Chavane, 1985).

leurs de $\delta^{13}C$ comprises entre -10 et -15 ‰. Il comprend la plupart des graminées (sorgho, mil...). L'intérêt majeur de ce second groupe, spécifique aux régions tropicales, est qu'en participant au cycle général du carbone, il sert de traceur de l'origine des différentes sources de matière organique. Par cette caractérisation géochimique de la matière organique des céramiques de Sintiou-Bara, nous pensons pouvoir identifier différentes sources de carbone contemporaines de leur fabrication.

- Les principales sources de carbone susceptibles d'être incluses dans les poteries concernent la matière organique liée naturellement à l'argile, la matière organique ajoutée intentionnellement à l'argile, la diffusion du carbone du combustible lors de la cuisson des pots (face interne et externe), les résidus alimentaires, les résidus charbonneux de foyers domestiques, les enduits organiques de surface, et les acides organiques et radicelles du sol. Une estimation statistique des teneurs en carbone organique et des valeurs de $\delta^{13}C$ associées de chaque source de carbone a été établie à partir de l'étude de céramiques maliennes et nigériennes (Saliège et Person, 1991).

La comparaison de ce référentiel avec les concentrations et les teneurs en $\delta^{13}C$ en carbone organique obtenues sur les poteries de Sintiou-Bara nous permettra de discuter de l'origine de la matière organique présente dans ces céramiques et en particulier de caractériser :

- la matière organique liée sédimentologiquement à l'argile,
- la matière organique intentionnellement ajoutée à l'argile comme dégraissant,
- certains traitements de surface comme l'application d'enduit organique.

Etude géochimique de la matière organique contenue dans les céramiques cannelées de Sintiou-Bara

À partir d'une observation microscopique en lame mince des tessons, trois grands groupes ont été définis : groupe A : céramiques cannelées noires à dégraissant organique (végétaux provenant de déjections animales ?), groupe B : céramiques cannelées lie de vin à dégraissant organique (fragments de végétaux), groupe C : céramiques cannelées lie de vin à dégraissant minéral (chamotte). Le carbone organique total (COT, %) et le $\delta^{13}C$ (‰) de la matière ont ensuite été mesurés sur les tessons, à partir de trois prélèvements effectués sur leurs faces externe et interne, et leur centre.

RÉSULTATS ET INTERPRÉTATIONS

Teneurs en carbone organique total (%) et $\delta^{13}C$ (‰)
Les résultats sont reportés dans le tableau 1.

Mode de préparation des pâtes

Groupe A : céramique cannelée noire à dégraissant organique (végétaux provenant de déjections animales ?)

Les valeurs COT du centre, représentatives de la pâte utilisée (argile + dégraissant) sont comprises entre 0,3 et 0,9 %. Comparées à celles du groupe C, plus faibles,

Grpe	Ech.	EXTERIEURE		CENTRE		INTERIEURE	
		C.O.T. (%)	$\delta^{13}C$ (‰)	C.O.T. (%)	$\delta^{13}C$ (‰)	C.O.T. (%)	$\delta^{13}C$ (‰)
A	SB.37	1,09	-21,67	0,43	-19,73	1,06	-21,45
	SB.90	1,95	-22,74	0,34	-19,90	0,50	-22,08
	SB.21	3,87	-19,70	0,87	-19,00	2,15	-18,66
	SB.43	2,31	-18,24	0,81	-20,65	1,10	-19,33
	SB.56	2,20	-20,90	0,89	-22,26	1,12	-20,86
B	SB.04	3,01	-17,40	1,10	-13,78	0,41	-18,63
C	SB.98	0,63	-23,83	0,10	-19,27	0,64	-26,30
	SB.25	0,68	-22,51	0,13	-18,70	0,59	-22,30

Tab. 1 : Concentrations en carbone organique total (% COT) et $\delta^{13}C$ (‰ PDB) mesurés sur les coupes des tessons du site de Sintiou-Bara.

elles démontrent la présence d'un matériau organique ajouté intentionnellement à l'argile. Les valeurs de $\delta^{13}C$ de ce dégraissant végétal au centre du tesson sont comprises entre -18 et -23 ‰, c'est-à-dire un mélange de plantes en C3 et en C4. On peut envisager que le potier se contentait de faucher sans discernement quelques végétaux de berges où les végétaux C3 et C4 cohabitent, mais on peut également émettre l'hypothèse de l'utilisation des déjections d'animaux domestiques (à l'alimentation variée). La littérature ethnographique récente (Thiam, 1984 ; Guèye, 1998) mentionne l'emploi d'excréments animaux (crottin de cheval, d'âne, bouse de vache...) séchés et réduits en poudre, dans la préparation des pâtes céramiques. Une recherche portant sur la caractérisation morphologique des lames minces de ces céramiques sénégalaises actuelles est en cours.

Groupe B : céramique cannelée lie de vin à dégraissant organique (fragments de végétaux)

La valeur COT du centre de 1,10 % comparée à celles du groupe C, démontre la présence d'un dégraissant organique intentionnellement ajouté à l'argile. La valeur de $\delta^{13}C$ de - 13,8 ‰ est caractéristique des plantes en C4. Elle est compatible avec un dégraissant de type végétal, comme la paille de fonio connue par la documentation ethnographique.

Groupe C : céramique cannelée lie de vin à dégraissant minéral (chamotte)

Les valeurs COT du centre sont toutes deux proches de 0,1%. Comparées à celles des groupes A et B, beaucoup plus fortes, elles montrent que cette quantité de COT résiduelle est celle de la matière organique liée naturellement à l'argile. L'hypothèse d'une faible teneur en matière organique liée à une cuisson longue à très haute température est infirmée par la couleur marron à noire conservée au coeur de la céramique. Ceci exclut en effet qu'elle ait subi un traitement thermique beaucoup plus élevé que les autres, susceptible d'avoir oxydé plus fortement le carbone organique originel. Ces valeurs confirment l'absence de matériaux organiques ajoutés volontairement à l'argile. Par ailleurs, la présence d'un dégraissant minéral (chamotte) est observée en lame mince. Les valeurs de $\delta^{13}C$ du centre, comprises entre -17 et -19 ‰, sont normales pour un sédiment argileux superficiel de bordure de mares ou de fleuve de région tropicale.

Traitements de surface

Groupe A : céramique cannelée noire à dégraissant organique (végétaux provenant de déjections animales ?)

Les valeurs COT des surfaces extérieures (comprises entre 1,1 et 3,9 %) et intérieures (comprises entre 1,1 et 2,1 %) sont plus fortes que celles du centre (comprises entre 0,3 et 0,9 %). Deux hypothèses sont envisageables. Si l'on considère que la cuisson a eu lieu en milieu oxydant, il est normal qu'un gradient croissant de la teneur en carbone se soit établi des surfaces interne et externe au coeur du tesson (diffusion de l'oxygène dans la pâte). Les fortes teneurs constatées, en contradiction avec cette hypothèse, ne peuvent s'expliquer que par l'application d'un enduit organique post-cuisson (la valeur de la surface interne de SB.90 en revanche plus faible peut être attribuée à une légère érosion ou à une répartition inégale de l'enduit). Si par contre la cuisson s'effectue en milieu réducteur, le gradient de la teneur en carbone sera peu prononcé et de surcroît la pyrolyse du combustible entraînera un enfumage des surfaces interne et externe. Les teneurs en $\delta^{13}C$ vont cependant nous aider à envisager la seconde hypothèse comme la plus probable. En effet si on envisage l'application sur les surfaces extérieure et intérieure de solutions gluantes obtenues à partir de branchettes et de feuilles d'arbre (*gumban*) réduites en morceaux, ou de solution à base d'écorces d'arbre (*senno*), pratique encore courante en Afrique de l'Ouest (Thiam, 1984), les valeurs de $\delta^{13}C$ doivent être comprises entre –22 et –28 ‰, car toutes ces solutions organiques sont issues de plantes en C3. En revanche si les potiers se sont servis comme combustible d'un mélange de paille (C4) et de branchage (C3), voire de déjections animales, il est normal que les dépôts carbonés accumulés en surface par enfumage aient des valeurs comprises entre -18 et -23 ‰, (identiques à celles qui sont obtenues au coeur du tesson). Le traçage isotopique nous permet ainsi de trancher en faveur d'une cuisson en milieu réducteur.

Groupe B : céramique cannelée lie de vin à dégraissant organique (fragments de végétaux)

La valeur COT de la surface extérieure de 3 %, plus forte que celle du centre, montre là aussi un traitement d'origine organique (comme pour le groupe précédent, la valeur plus faible de la surface interne peut être attribuée à une légère érosion ou à une répartition inégale de l'enduit). Les valeurs de $\delta^{13}C$ sont comprises entre - 17 et - 19 ‰. Les conditions de cuisson devaient être identiques à celles du groupe A.

Groupe C : céramique cannelée lie de vin à dégraissant minéral (chamotte)

Les surfaces externe et interne de couleur lie de vin (colorant d'origine minérale) présente des teneurs en COT comprises entre 0,6 et 0,7 %. Elles sont plus fortes que celles au coeur du tesson. Contrairement aux poteries des groupes A et B nous ne pouvons pas envisager l'hypothèse d'un enfumage tout simplement parce que celui-ci ne peut qu'entrainer une coloration noire. Par contre, les valeurs de $\delta^{13}C$, comprises entre - 22 et -26 ‰, sont caractéristiques des plantes en C3 et elles sont compatibles avec l'application d'une couche de finition, à base de solution d'écorces d'arbre, après la cuisson de la poterie.

Teneur en ^{14}C : relation avec l'âge de la poterie

L'addition de dégraissant organique dans l'argile, source de carbone incontestablement contemporaine de la fabrication des céramiques, rend envisageable la datation ^{14}C. Parmi les trois groupes de poteries considérés, seuls deux, ont été retenus : les céramiques cannelées noires à dégraissant organique (probablement déjections animales) (groupe A) et les céramiques cannelées lie de vin à dégraissant organique (fragments de tige de graminées) (groupe B). Les céramiques cannelées lie de vin à dégraissant minéral (groupe C) quant à elles, ne contiennent que de la matière organique liée géologiquement à l'argile. Bien que source de matières premières du potier, celle-ci n'a théoriquement aucun lien direct avec l'âge de la poterie. La seule composante strictement contemporaine de leur fabrication concerne les dépôts sur les surfaces extérieure et intérieure, négligeables dans le bilan quantitatif en carbone du tesson. Bien que la technique des S.M.A. nous affranchisse de la contrainte de quantité en carbone, compte tenu des délicats problèmes de pollution organique que peuvent poser ces dépôts, nous avons préféré travailler, dans cette première approche, sur le dégraissant végétal. A l'avenir nous pensons confronter les datations obtenues sur le dégraissant végétal à celles qui sont obtenues sur les dépôts de surface.

Les teneurs en ^{14}C ont été mesurées par scintillation liquide sur deux tessons cannelés : l'un lie de vin à dégraissant organique (SB.04), l'autre noir à dégraissant organique (SB.37) et sont reportées dans le tableau 2. Les tessons ont été pré-traités à l'acide chlorydrique dilué (8 %) pendant 12 h afin d'éliminer les carbonates, puis la combustion a été effectuée sous flux d'oxygène à une température comprise entre 450 et 550°C durant 1 h.

La transcription en âges conventionnels de ces teneurs en ^{14}C ne peut s'effectuer sans discuter au préalable de l'influence de la matière organique naturellement présente dans l'argile. Les sédiments superficiels argileux utilisables par les potières sont en effet riches en matière organique se renouvellant. Quelques mesures de la teneur en ^{14}C de la matière organique des bords du fleuve Niger ont fourni des âges compris entre 0 et 400 BP (Saliège et Person, 1991). Le tableau 3 permet d'appréhender cette influence.

Si l'on considère que l'influence de la matière organique liée à l'argile est négligeable (c'est-à-dire contemporaine de la poterie), les teneurs en ^{14}C peuvent être directement transcrites en âges conventionnels, soit : (Pa 1652) 85,05 $\pm$ 0,4 % NBS => 1300 $\pm$ 40 BP ; (Pa 1654) 85,20 $\pm$ 0,3 % NBS => 1285 $\pm$ 30 BP. Après correction dendrochronologique, ces deux poteries cannelées auraient été fabriquées entre 667-811 après J.-C. (Pa 1654, 2σ) et 657-854 après J.-C. (Pa 1652, 2σ). Si l'on tient compte de l'influence de la matière organique de l'argile, les âges rajeunissent en fonction du pourcentage de matière organique, de zéro à une centaine d'années.

CONCLUSION

La caractérisation isotopique de la matière organique contenue dans les céramiques cannelées de Sintiou-Bara a permis de mettre en évidence les deux groupes de poteries les plus favorables à l'utilisation de la méthode de datation par le radiocarbone. Les activités ^{14}C de deux poteries ont été mesurées et nous avons discuté de leur interprétation en termes d'âges. En l'état actuel des données, nous nous garderons cependant de proposer une insertion de cette approche chronologique des céramiques cannelées dans les contextes des différents sites de la moyenne vallée du fleuve Sénégal. Une telle discussion ne peut se faire sans avoir d'une part examiné les autres composantes de la chronologie céramique, établie à partir des sites de Tioubalel et Siwré, et, d'autre part, les caractéristiques des autres éléments de la culture matérielle associée (vestiges métallurgiques en particulier).

N° labo.	$\delta^{13}C$ moyen (‰) PDB	^{4}C % NBS.
Pa 1652 (lie de vin)	-12,7	85,05 $\pm$ 0,4
Pa 1654 (noire)	-19,50	85,20 $\pm$ 0,3

Tab. 2 : Teneurs en ^{14}C des deux tessons de Sintiou-Bara soumis à la datation.

Pa 1652	0	200 BP	400 BP
15 %	1285	1255	1225
20 %	1285	1245	1210
30 %	1285	1230	1170
Pa 1654	**0**	**200 BP**	**400 BP**
15 %	1300	1270	1240
20 %	1300	1260	1225
30 %	1300	1245	1185

Tab. 3 : Influence de la matière organique de l'argile sur l'âge des poteries. En abscisse, l'âge de la matière organique du sédiment ; en ordonnée, le pourcentage de la matière organique de l'argile par rapport à la matière organique totale.

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ON THE TAPHONOMY OF CHARCOAL SAMPLES FOR RADIOCARBON DATING

*Alex BAYLISS**

Abstract : Taphonomy, in this case defined as the relationship between the material dated and the context from which it was recovered, has always been fundamental to the utility and interpretation of radiocarbon measurements. The advent of routine mathematical modelling for the interpretation of radiocarbon dates together with relative chronological information provided by stratigraphy has made this relationship even more critical. The friable nature of charcoal makes this type of sample particularly problematic. A number of methods which can be used to assess the validity of our archaeological interpretations of the taphonomy of samples are discussed.

Résumé : La taphonomie - le rapport entre le matériel daté et la couche dont il provient - est toujours fondamentale pour l'utilité et l'interprétation des mesures radiocarbone. L'avènement des modèles mathématiques systématiques, qui interprètent des mesures radiocarbone en même temps que les chronologies relatives de la stratigraphie, a augmenté l'importance de ce rapport. La fragilité du charbon de bois pose un problème particulier. On discute quelques méthodes qu'on peut utiliser pour l'évaluation de la justesse de nos interprétations archéologiques sur la taphonomie des matériaux.

Key-words : Taphonomy, charcoal, mathematical modelling, high-precision, AMS.

Mots-clés : Taphonomie, charbon de bois, modèle mathématique, précision, accélérateur.

INTRODUCTION

Taphonomy is here defined as the process by which a sample came to be in the context from which it was recovered. It is therefore critical for understanding the chronological relationship between the actual calendar date of a radiocarbon sample and the date of the context. Obviously many other factors are also crucial for reliable dating (see van Strydonck *et al.*, this volume), but it is taphonomy on which I wish to concentrate here.

The understanding of this process has always been important for the selection of reliable samples for radiocarbon dating. However it has become even more pertinent in the last few years since sophisticated mathematical modelling of chronological problems has become available on a routine basis (Buck *et al.*, 1991, 1992, 1994 ; Bronk Ramsey, 1995). This allows the explicit and analytical interpretation of radiocarbon evidence together with the evidence for chronology provided by archaeology.

Recent experience from projects funded by English Heritage illustrates why the archaeological taphonomy of samples has increased in significance since the advent of this methodology. Between April 1994 and April 1997 English Heritage analysed 940 radiocarbon results from 67 projects. 71 % of these results were analysed using formal mathematical models. This increases to 94 % if only samples from excavations are considered (fig. 1). 80 % of measurements from these excavations have 'prior information' which can be included in the models. Although other sorts of 'priors' are encountered (eg tree-ring dates, coins, documentary evidence), by far the most common type is relative dating provided by stratigraphy. However, stratigraphy supplies a relative sequence of contexts. If such a sequence is to be included as 'prior information' in a Bayesian model (see Bronk Ramsey this volume), it is essential that the relative chronological sequence of the samples is the same as the relative sequence of the contexts. This requires a rigorous and explicit consideration of the taphonomic relationship between the context and the sample.

Rigour is obligatory. Every sample must be assumed to be residual unless there is convincing archaeological evidence to the contrary. This is because the integration of archaeological information into the interpretation of the radiocarbon evidence produces significantly more precise estimates of the dates of archaeological interest. For our projects the calendar dates are on average a third more precise (ie date ranges spanning 200 calendar years rather than 300 ; see Bayliss and Bronk Ramsey

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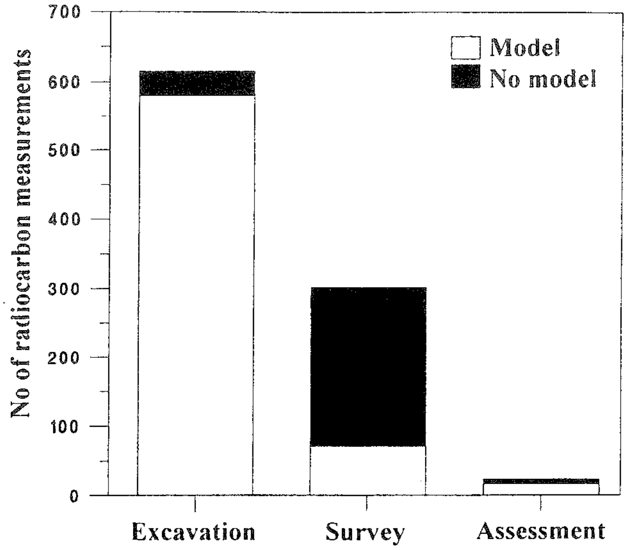

Fig. 1 : Proportions of dates funded by English Heritage (1994-7) which have been interpreted using formal mathematical models (n=940).

forthcoming), even though during this period we were introducing and refining the application of the methodology. This precision will be false and misleading if the taphonomic and stratigraphic relationships included in the models are incorrect. This is why it is so essential to be sceptical of the 'prior information' included in a model. On the other hand, the benefits of adopting this new methodology routinely are substantial, both in terms of more cost-effective use of radiocarbon dating, and also in terms of the range of archaeological problems which can be addressed using the technique.

1 - THE SCOPE OF THE PROBLEM

Charcoal samples are considered in this paper because our experience has shown that they are particularly problematic. This is because the fragile nature of the material means that it is rarely recovered as a large block from a single piece of wood. Even in this case the use of the carbonised wood in the structure is still a matter of archaeological interpretation (eg it could be reused), but in the more usual case of many fragments from a single context interpretation is even more complex. Here we have to decide not only how the fragments got into the context, but also whether they are of the same actual date.

Unfortunately the taphonomy of archaeological samples is never known. It can only be inferred by contextual interpretation (fig. 2). Consequently the archaeological criteria used to assess the taphonomy of samples are critical. However strict these criteria, or explicit the discussion of the sample taphonomy, it has

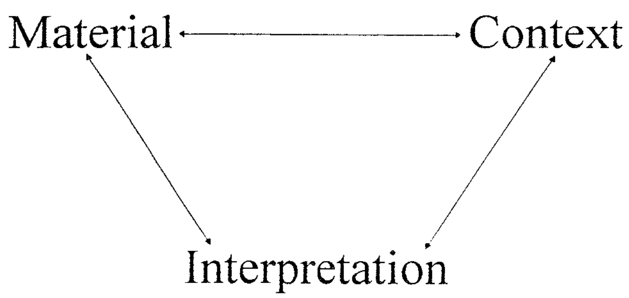

Fig. 2 : The relationships between data and interpretation.

to be recognised that the decisions on which sample selection is based are fundamentally interpretative and not known. This paper concentrates on what are usually regarded as 'good samples' and 'secure contexts', and examines some of the archaeological and other criteria which may be used to assess taphonomy and to check independently whether our assessments are correct.

One of the most convincing arguments for the contemporaneity of a sample and its context is articulation (Bayliss *et al.*, 1997 ; Bell *et al.*, 1996). Unfortunately this only applies to bone samples, although single pieces of timber charred *in situ* are analogous. The potential for reuse of structural timbers is however demonstrable from sites dated by dendrochronology (Hillam forthcoming), although the submission of multiple samples from the sapwood or outer rings of such timbers may allow this to be addressed. Such charred timbers are, however, rare. Indeed no example has been encountered from the projects funded by English Heritage over the last three years.

More common are samples where a functional relationship can be postulated between the sample and its context. The majority of charcoal samples funded by English Heritage fall into this group. It can include samples from the following categories of feature :

- hearths
- structural timber
- pyres/cremations
- kilns/furnaces
- burnt mounds

However, even in these cases, the chronological relationship between the sample dated and the context is not necessarily straightforward.

2 - A WORKED EXAMPLE

A recent example from excavations in 1991 on the Lower Terrace at Tintagel Castle, Cornwall (50.40.09N ; 04.45.28W) can be used to demonstrate some of the difficulties in the archaeological interpretation of functionality between samples and contexts and to suggest some of the ways by which our interpretation can be independently validated. The excavations form part of an ongoing programme of research on the site (Harry and Morris 1997 ; Morris *et al.*, 1990).

The basis of the radiocarbon programme is a sequence of hearths whose relative dates are known from stratigraphy. Well over 50 g of charcoal was recovered from each of these features. This enabled the submission of samples for high-precision radiocarbon measurements (Pearson, 1984). The pseudo-historical associations of the site with King Arthur (Thomas, 1993) and the occurrence of relatively well-dated imported ceramics (O'Mahoney, 1988) meant that high-precision was required if the dating programme was to produce archaeologically useful results.

The initial series of six high-precision measurements (table 1) along with the relative sequence provided by the stratigraphic relationships between the hearths, produced the model shown in figure 3. From this it is immediately apparent that the radiocarbon measurements are in significant disagreement with the stratigraphic sequence. This is because both the overall index of agreement (A=29.5 %) and the index of agreement for UB-3799 (A=6.8 %) are far too low. Further analysis shows that the probability that UB-3799 is really later than Hearths 123 and 126 is less than 1 in 100. This illustrates the use of diagnostic statistics to test whether the rela-

Laboratory Number	Context	Radiocarbon Age (BP)	$\delta^{13}C$ (‰)
UB-3795	123	1617±18	-26.4±0.2
UB-3796	123	1605±20	-26.3±0.2
UB-3797	126	1569±18	-26.6±0.2
UB-3798	126	1607±20	-25.4±0.2
UB-3883	171/173	1595±18	-25.8±0.2
UB-3799	113	1645±22	-26.0±0.2
OxA-6002	113	1490±50	-26.2
OxA-6003	113	1550±45	-25.0
OxA-6004	113	1430±45	-26.1
OxA-6005	113	1705±50	-25.5
OxA-6006	113	1565±45	-26.2

Tab. 1 : Radiocarbon results.

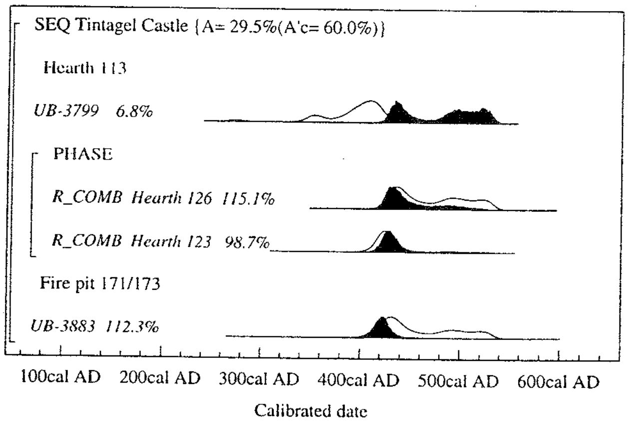

Fig. 3 : Probability distributions of dates from the sequence of hearths at Tintagel : each distribution represents the relative probability that an event occurs at some particular time. For each of the radiocarbon dates two distributions have been plotted, one in outline which is the result of simple radiocarbon calibration and a solid one which is based on the chronological model used ; the 'event' associated with, for example, the radiocarbon date UB-3883 is the growth of the wood which was carbonised and dated. The large square brackets down the left hand side, along with the OxCal keywords, define the overall model exactly.

tive order of contexts determined by archaeological stratigraphy is the same as the relative order of the samples which were submitted for dating. If the interpretation of taphonomy implicit in assuming that these two orders are the same is incorrect, then the mathematical modelling may itself high-light erroneous archaeological interpretations.

In this case, the anomaly identified by the model was further tested by the submission of five samples for AMS dating, each of which consisted of a single fragment of charcoal (table 1 ; Ashmore this volume). These five measurements are statistically significantly different from each other at 95 % confidence (T =18.2 ; T (5 %)=9.5 ; v=4 ; Ward and Wilson, 1978). This suggests that the bulk sample consisted of charcoal fragments of a number of different ages, and demonstrates how AMS measurements can be used to investigate the composition of bulk samples.

This analysis raises the question of why the charcoal from hearth 113 was so heterogeneous. Either the functional relationship between the context and the sample has been interpreted incorrectly, or the fuel procurement strategies of the occupants of Tintagel were unusual. In this case we decided that the context had been interpreted erroneously, and was in fact probably *ex situ* burnt material dumped from elsewhere. This conclusion was reached by scrutinising the photographic record and determining that, in contrast to the other dated hearths, there was no burnt surface beneath the carbonised material. This illustrates the importance of detailed recording and analysis to our assessment of samples.

Interpretation of the fuel/timber procurement strategies of a community is also vital for understanding the value of charcoal samples for radiocarbon dating. In this instance, the species represented are those which could have been available from local woodlands (Harry and Morris, 1997, 82 108). The proximity of the site to the coast might suggest that driftwood could have provided an alternative source of fuel, although the precipitous nature of the cliffs perhaps argues against this hypothesis (fig. 4). The fact that the oldest of the AMS results (OxA-6005) is from a piece of *Ulex/Cytisus* sp. charcoal, also makes the use of driftwood unlikely. This species is often collected for fuel as it burns particularly efficiently, although it rarely grows to a size larger than twigs.

3 - EVIDENCE FOR FUNCTIONALITY

The example of the sequence of early medieval hearths from Tintagel has introduced three means of testing whether a functional interpretation for the process of charcoal reaching a context may be valid. However there are a number of other strands of evidence which may also be cited.

3.1 - DIAGNOSTIC STATISTICS

The importance of measuring the agreement of a statistical model cannot be over-emphasised (Bronk Ramsey, 1995). This measures how consistent the 'prior information' is with the independent radiocarbon evidence. Where agreement is poor, it is necessary to re-examine the archaeological provenance of the samples and to check the laboratory notes on the processing of the radiocarbon samples. Usually it is archaeology which is at fault often the interpretation of the taphonomy of the samples is incorrect ; more rarely something has gone wrong with the recording of stratigraphy on site or with sample collection ; occasionally a radiocarbon measurement may be at fault. However, whatever the cause, poor agreement is a warning that the model cannot be accepted as it stands and demands further work. Conversely, good agreement does not necessarily mean that a model should be accepted without reservation. Statistically consistency is just one of the checks and balances in the modelling process. This process is fundamentally archaeological, and so the content of a model must also pass through all the stages of reasoning usual for archaeological interpretation in addition to any statistical criteria.

3.2 - MULTIPLE AMS MEASUREMENTS

Multiple AMS samples from single fragments of charcoal can also be a useful means of checking taphonomy. This approach is particularly valuable when no 'prior information' is available, and so statistical agreement cannot be used as an independent check on our interpretations. However, it can also be used in cases where we do not have a convincing interpretation for the taphonomy of a sample or the function of a context. At Northwold, Norfolk, for example, multiple AMS sampling was used to check the chronological homogeneity of the burnt mound deposit (Crowson and

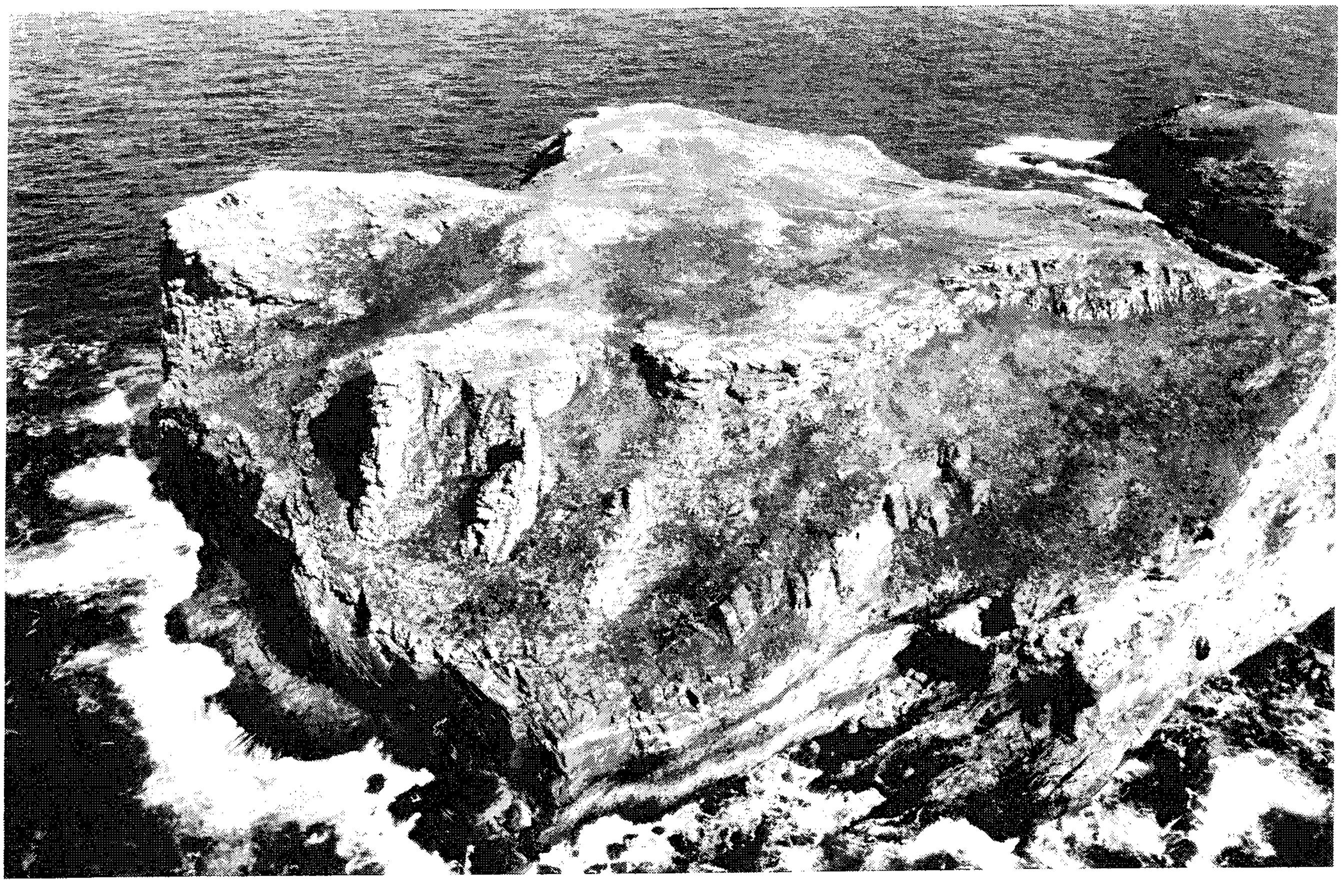

Fig. 4 : Aerial photograph showing the relief of Tintagel Castle.

Bayliss, this volume). The assumption is that the charcoal was fuel for whatever process was carried out at burnt mound sites, although interpretations of what exactly this process was differ widely.

3.3 - THE CHARCOAL ASSEMBLAGE

Finally, the Tintagel example shows the importance of understanding the charcoal assemblage which is present in a sample. The species and maturity of the material can throw light on the likely provenance of the sample, for example on the use of coppicing regimes for fuel production, or the utilisation of hedgerow or ancient woodland sources. The botanical expertise necessary to explore these issues is an invaluable and cost-effective element in a project team.

3.4 - EXPERIMENTAL ARCHAEOLOGY

Evidence for the taphonomy of a sample can also be provided by analogy from experimental archaeology. A good example of this is the excavation of a modern timber round-house at Pimperne, Dorset, where the posts of the inner ring were shown to have suffered severely from rot and the subsequent void was filled by material from the use of the roundhouse, such as soft-drink ring pulls and plastic toys (Reynolds, 1995). The interpretation of material from the post-holes of buildings relating to their use rather than construction is also supported by the species of the charcoal found from such archaeological contexts. Frequently these assemblages consists of typical 'fuel' species, such as *Prunus* sp. or Pomoideae, which simply do not produce timbers large enough to form major structural members.

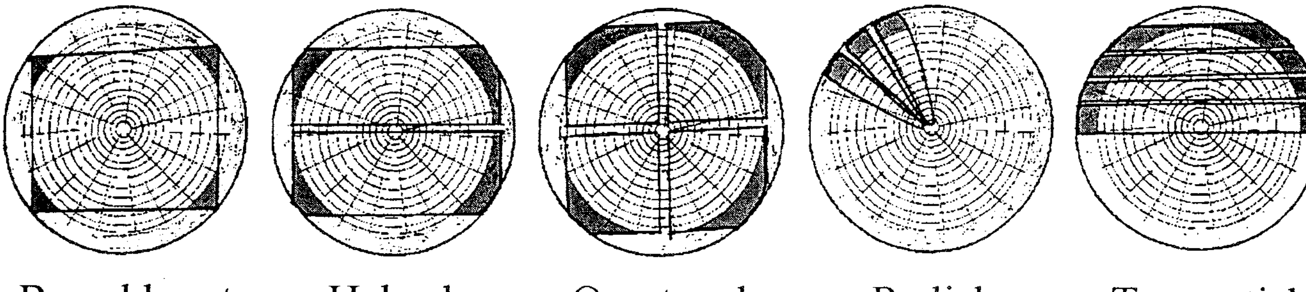

Fig. 5 : The main types of cross-sections found in standing buildings and waterlogged wooden structures in England (after Hillam forthcoming).

3.5 - WATERLOGGED AND STANDING STRUCTURES

This is not to say that structural timbers are not also sometimes recovered from such contexts, particularly where a building has been destroyed by fire, although instances are fairly rare. Where they do occur, however, we can use analagy from other archaeological sites where preservation is more complete. In particular, problems of the reuse and conversion of timbers can be addressed by referring to experience from waterlogged sites and surviving standing buildings. Where structural timbers do survive, the importance of identifying and submitting the outer rings of the timber, particularly the sapwood, cannot be over-estimated.

Figure 5 illustrates that the amount of sapwood on a structural timber may be severely limited by the method used to convert the tree into timber. However sapwood frequently does survive, and if this is identified and dated, a known age-at-death offset, calculated empirically from tree-ring samples can be applied. In England, for the main structural timber species, oak, this is 10-55 years (at 95 % confidence ; Hillam *et al.*, 1987). In other parts of the world sapwood estimates and the timber species used differ, but the principal is the same. Unfortunately if the sample is taken from the whole timber, rather than the sapwood only, this method cannot be applied.

Alternatively methods, such as using the average ring-widths of contemporary oaks to estimate the number of rings in a structural timber (Millet with James, 1983), have not proved useful, since the variability of such estimates add considerably to the errors on quoted dates, usually to the extent that these dates cease to be archaeologically informative. The validity of using such an estimate also depends very much on whether the method of conversion of the timber can be guaged. For English Heritage sites, it has usually been possible to bypass this problem by identifying sapwood. A small additional expenditure in charcoal analysis, produces considerable gains in the utility of the subsequent radiocarbon results.

Before leaving the particular case of charred structural timbers, the question of seasoning should also be addressed. This appears to have been extremely uncommon in England in the past (Rackham, 1990 ; Salzman, 1979), probably because the major building timber, oak, is more easily worked green. Tree-ring dates on medieval and later buildings which have known construction dates (usually provided by documentary evidence) suggests that there is rarely more than a gap of a few years between timber felling and use. Obviously this does not apply to reused timbers however, and, in the absence of diagnostic tool and joint markings which may be available on waterlogged material, multiple sampling from a number of carbonised timbers from a single building seems to be the only way to address this issue. This approach assumes that a sufficient number of samples should be able to isolate a few reused members. If the experimental evidence from Pimperne is accepted (see above), then dating other material from the posthole (eg bone) might also be a profitable strategy.

4 - SAMPLES WITHOUT FUNCTION

The strategies discussed so far in this paper relate to samples where there is some reason to believe that the charcoal recovered from a context is functionally related to the deposition of that context. Even in these cases, problems are frequently encountered and considerable care is needed if the dates produced are to be archaeologically useful and reliable.

Difficulties are considerably more severe when samples which do not have a functional relationship with their contexts are considered. These fall into two categories those where the charcoal has been deposited in a secondary context and was originally used elsewhere, and those where the derivation of the material is totally unknown.

Into the first category falls deposits such as middens and some primary pit fills. Except in rare circumstances, it is usually not possible to decide whether material in such contexts derives from the same archaeological event or comes from a number of different events. There *may* be evidence to suggest that a lens or context was all deposited at the same time, but there is rarely evidence to suggest that all the material is of the same date. In such cases, the only strategy available is to submit multiple samples from single items from the deposit on the principal that a context must date to the latest material recovered from it (Bayliss *et al.*, 1997 ; Ashmore this volume).

Material in the second category also needs this approach. Diffuse 'charcoal-rich' layers in ditches, 'occupation layers', 'trample', charred remains from postholes which do not appear to have formed parts of domestic buildings (eg fence lines, mortuary enclosures), all contain material which could have derived from any number of archaeological events and activities and which could be of differing actual dates. Micromorphology and other techniques used for the interpretation of soils may be particularly useful in deciding whether material from these categories of deposit is suitable for dating.

CONCLUSION

In England we are fortunate that it is rarely necessary to submit charcoal samples where a functional relationship cannot at least be postulated between context and dated material, since it is usually possible to find more reliable material to date. Even so, charcoal samples present particularly difficult archaeological problems. We can now employ a number of approaches to test our archaeological interpretation of charcoal deposits, although there is still much which we do not understand.

In particular, multiple sampling of archaeological contexts is an area which needs a great deal more investigation. How many samples do we need to date ? Can we bulid up experience which suggests how different categories of sites or contexts should be approached ? Most research so far has concentrated on estimating how many samples are needed where the relationship between the dated samples and the archaeological events or phases in question is undisputed (Bayliss and Orton, 1994 ; Buck and Christen, 1998). Estimating how many samples are needed when their derivation is itself unknown is a rather different problem, and demands some knowledge of the range of actual dates of the material contained in a context. We do not know this : we can only provide archaeological opinions based on our previous experience.

This paper attempts to suggest some ways in which archaeologists can attempt to test their interpretations of the taphonomy of charcoal samples. It remains true, however, that the taphonomy of a radiocarbon sample is never known, but can only be interpreted (fig. 2).

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DATING THE MESOLITHIC OF THE LOW COUNTRIES : SOME PRACTICAL CONSIDERATIONS

Philippe CROMBÉ, Henny GROENENDIJK** and Mark VAN STRYDONCK****

Abstract : The present article focuses on the dating problems that characterize Mesolithic open-air settlement research in the Low Countries, i.e. Belgium and The Netherlands. On the basis of recent dating projects in two relatively small study-areas, the «Veenkoloniën» in northern Netherlands and the «Waasland» region in northwestern Belgium, a protocol for selecting samples that guarantee the best dating results is proposed. For this purpose all standard available dating materials – scattered charcoal, charcoal from hearth-pits, charcoal from pit-like (natural) features and charred hazelnut shells - are discussed in terms of advantages and disadvantages.

Résumé : Le présent article aborde les problèmes de datation qui caractérisent la recherche des sites d'habitat de plein air d'âge mésolithique en Belgique et aux Pays-Bas. A partir des résultats de datations récemment effectuées dans deux microrégions, le «Veenkoloniën» dans le nord du Pays-Bas et le «Waasland» dans le nord ouest de la Belgique, un protocole de sélection d'échantillons est proposé. Ce protocole est basé sur une analyse approfondie des avantages et inconvénients des matériaux de datation disponibles en contexte sablonneux, notamment du charbon dispersé, du charbon provenant de foyers en fosse ou de structures en cuvette d'origine naturelle et de coquilles de noisettes brûlées.

Key-words : Mesolithic, open-air settlements, dating materials, sampling protocol.

Mots-clés : Mésolithique, site d'habitat de plein air, matériel de datation, protocole de sélection.

1 - INTRODUCTION

The actual Mesolithic ^{14}C-database of the Low Countries is characterized by a high frequency of dates that do not fit properly with the relative dating based on stratigraphical and archaeological (typological) evidence. The origin of this dating problem is caused by : 1° a bad or doubtful spatial association of the dated sample and the lithic industry, 2° dislocation caused by bioturbation processes, 3° multiple site occupation, 4° inbuilt age of the dating material.

Although many Mesolithic specialists of the Low Countries (Lanting & Mook, 1977 ; Newell, 1973 ; Waterbolk, 1985 ; Arts, 1989 ; Gob, 1984, 1991) have tackled the dating problem, only few (e.g. Waterbolk) have paid attention to the problem of sampling. Nearly all Mesolithic dating studies have focused on the interpretation and evaluation of the deviating dates and much less on the sample selection. As a result of this archaeologists take little attention in selecting samples that guarantee the best result in dating the human event of interest. A lot of interpretative problems can be avoided if the archaeologist is fully aware of the possibilities and limitations of each type of ^{14}C-sample.

This will be demonstrated using the results of recent dating projects from two geo-morphologically comparable regions within the Low Countries : the «Veenkoloniën» in Oost-Groningen and the «Waasland» in NW-Belgium (fig. 1). Recently in both areas a restricted number of Mesolithic open-air settlements was extensively ^{14}C-dated : the sites of «Nieuwe Pekela 3» (23 dates) and Leek «Mensumaweg» (3 dates) in the Netherlands and the sites of Melsele «Hof ten Damme» (15 dates) and Verrebroek «Dok» (10 dates) in Belgium. Although on all these sites the same dating materials are available - dispersed charcoal, charcoal from hearth-pits (Melsele excluded), charcoal from pit-like features and charred hazelnut shells - different dating strategies have been applied. The «Nieuw Pekela» site has been dated almost exclusively on charcoal samples originating from the bottom of hearth-pits. At Verrebroek carbonized hazelnut shells found within surface-hearths were preferably dated, while at Melsele random sampling of dislocated charcoal was chosen.

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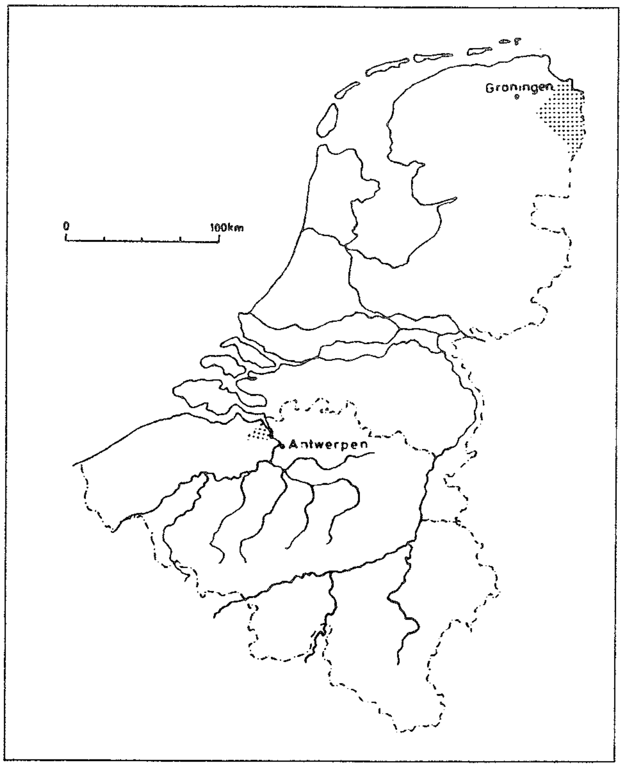


Fig. 1 : Geographical situation of both study-areas, the «Veenkoloniën» in Oost-Groningen (The Netherlands) and the «Waasland» polders in northwestern Belgium.

2 - DATING PROJECTS

2.1 - VERREBROEK « DOK »

2.1.1 - Site description and dating strategy

The site of Verrebroek (51°16'00"N, 4°12'42"E) is situated close to the Late Mesolithic site of Melsele. Both are lying in the northern polder area of Flanders, on the left bank of the river Scheldt. The site of Verrebroek is located farthest from the actual river on top of a large dune ridge ca. 2 m above actual sea level. It is sealed by a ca. 1 m thick layer of peat and medieval alluvial clay. Based on palynological evidence peat growth on the site started at the beginning of the Subboreal (ca. 4000-3500 BP).

The site of Verrebroek is undoubtfully one of the largest and best preserved Mesolithic sites actually known within Belgium. According to recent drillings (Crombé & Meganck, 1996) its size can be estimated at more than 3 hectares. The site is under excavation by the Ghent University since 1992 (Crombé, in press (b)). At present ca. 1.600 m^2 or 5 % of the total surface has been investigated.

The excavations so-far revealed numerous small (ca. 15-20 m^2) to medium sized (ca. 50-75 m^2) artifact concentrations yielding thousands of knapping debris. Generally two types of hearths are found. A first type consists of non-structural fireplaces, that can only be indirectly deduced from the distribution of burnt flint and charred organic material. The latter mainly consists of charred hazelnut shells and occasionally small burnt bone fragments. Associated charcoal is never observed. These so-called surface-hearths are nearly always lying in the centre or slightly eccentric within the artifact concentrations. The distribution and typology of the knapping debris and the tools indicate they played a central role in the activities that were performed within these units. An interpretation as «domestic hearths» seems most plausible.

A second type of hearths, the so-called hearth-pits, have a more variable position within the settlement. Most hearth-pits are located within the boundaries of the artifacts units, either in the centre or near the periphery. Only few pits are found isolated from the artifact units, thus spatially not associated to the lithic artifacts.

At present ten samples (table 1), charred nutshells and charcoal, are dated by AMS. Six out of the eight hazelnut samples are taken from surface-hearths within different artifact units. The two remaining samples originate from the filling of two hearth-pits (K16, K23), spatially associated to the artifact unit CVI and CX. The same pits have also been dated on a charcoal sample (table 1). These ^{14}C-analyses were carried out before the AMS facility became as high performed as it is today, which explains the rather important standard deviation. Because of a questioned relationship between the charred nutshell and charcoal samples, both sets of dates were treated separately.

2.1.2 - Dating results

Charred nutshells

Figure 2 represents the sumprobability of the dates obtained on the charred nutshells using a 100 yr moving average. Törnqvist and Bierkens (1994) argued that, if dates are to be used in histograms, any calibration curve reflecting medium-term ^{14}C variations is in many cases too detailed for calibrating ^{14}C-dates. For charcoal respectively wood samples a 100 and a 50 yr moving average was proposed. They also stated that when the interest is focused on the calendar age range rather than on the shape of the probability distribution, the result is usually not very sensitive to the degree of smoothing. In this study a 100 yr moving average was chosen, because of the rather large standard deviations.

The *floruit* (Ottaway, 1973 ; Aitchison *et al.*, 1990) covers a period ranging from 8184 to 7991 cal BC (Stuiver & Reimer, 1993), while the 95 % probability range covers a period from 8392 to 7696 cal BC (fig. 3). However, the possibility that all samples belong to one event, like a single season camp, must be verified. A T-test shows that it is statistically possible and that all samples can belong to the same event. If so the pooled mean of the data can be calculated (table 2).

The 2σ range of the pooled mean and the *floruit* cover almost the same period. This is a strong indication that the 8190 to 7980 range probably is the best estimator for the archaeological event(s). This is in perfect congruity with the relative dating, based on the tool typology and interregional comparisons. According to the general typological composition of the microlithic implements the site belongs to the Early Mesolithic dated to the Preboreal and/or first half of the Boreal (Crombé, in press (a)).

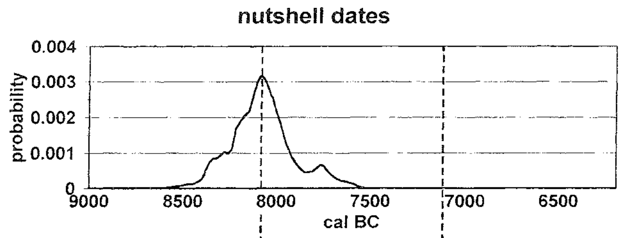
Charcoal

It is without any doubt that the youngest charcoal sample (fig. 3) is in no way relatable to the hazelnut dates. This date indicates a possible occupation or activity on the site during the early Atlantic period, though so-far no direct proof of this has been found. Probably the Late Mesolithic activity occurred beyond the excavated area.

The interpretation of the charcoal date from unit CVI depends upon the assumption whether this sample and

reference	BP date	material	unit	feature
UtC-3439	9150 ± 100	charred hazelnut	CVI	K16
UtC-3436	9130 ± 170	charred hazelnut	CII2	-
UtC-3451	9120 ± 120	charred hazelnut	CVII	K14
UtC-3915	9110 ± 65	charred hazelnut	CI	-
UtC-3445	9100 ± 130	charred hazelnut	CII1	-
UtC-2743	9000 ± 190	charred hazelnut	CV2	-
UtC-2744	8920 ± 130	charred hazelnut	CX	-
UtC-3444	8920 ± 100	charred hazelnut	CX	K23
UtC-3450	8700 ± 100	charcoal	CVI	K16
UtC-3443	7700 ± 100	charcoal	CX	K23

Table 1 : ^{14}C-dates from the site of Verrebroek.



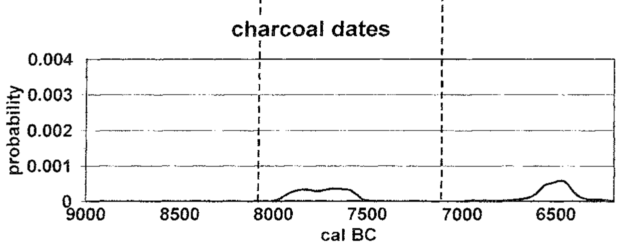


Fig. 2 : Dispersion diagram of the dates obtained on charred hazelnut shells from the site of Verrebroek «Dok».
Fig. 3 : Dispersion diagram of the dates obtained on charcoal from two hearth-pits at the site of Verrebroek «Dok».

the associated nutshell are considered contemporary or not. Compared to the associated nutshell the charcoal date differs too much to be contemporary, but compared to the 95 % probability range calculated from all the nutshell dates it is possible that the charcoal found in unit CVI belongs to the same group of dates as the nutshells.

2.1.3 - Discussion

Although in a very specific scenario it is possible that one of the charcoal dates can be associated to the nutshells it seems very unlikely that there is a relationship between the charcoal dates and the nutshell dates.

In our opinion the charcoal samples date the installation of the hearth-pits. The hazelnut shells from these features are probably residual fragments, originating from former surface-hearths that are lying right above or adjacent to the hearth-pits. They ended up in the hearth-pit probably at the time these features got filled up. This hypothetical scenario is partly corroborated by the perfect compatibility of the two hazelnut dates from within unit CX. One fragment is retrieved from the hearth-pit K23, the other one is found in the undisturbed soil outside this feature. Another indication of a certain diachrony between the artifact units and the spatially associated hearth-pits is to be found in the absence of a clear spatial coincidence between these features and the overheated artifacts. This has been clearly attested in units CI, CIX and CX.

2.2 - MELSELE «HOF TEN DAMME»

2.2.1 - Site description and dating strategy

The site (Van Roeyen, 1995) (51°15"01"N, 4°17"40"E) lies on the east side of a Pleistocene coversand mound underlying peaty and clayey sediments of the river Scheldt. Against the strongly eroded north side of the mound a complex deposit of peaty, sandy and clayey sediments was observed. The top of the deposits is weathered and a hiatus in the sedimentation, indicating that this surface was exposed for a considerable time. This complex as well as the higher-positioned coversands is covered with a peat layer and alluvial sediments. Archaeological material (van Berg *et al.,* 1991) from the Late Mesolithic and Neolithic was found in the homogenized topsoil of the mound. Bioturbation had caused vertical displacement of the artifacts and datable materials, except for the bark lining of a probable storage pit. Artifacts as well as charcoal were also found in large bowl-shaped pits, probably windblows. Some material was redeposited by erosion in the sediments against the north flank of the mound. Little material was found at the base of the peat layer or of the mound. The artifacts include lithic objects (14,000 fragments), ceramics (1,500 fragments), bone fragments (from wild and domesticated animals), charcoal and hazelnuts.

Because of the possible dislocation of the artifacts and the datable organic material (except the bark lining) the radiocarbon dating program was executed assuming that the samples were no longer in their original context (Van Strydonck *et al.,* 1995). A circular argument was avoided by initially separating the dating project and the study of the archaeological context. After this initial investigation we compared the two chronological models. Besides

BP date	cal BC date	cal BC date		rel. area under probability distr.
9065 ± 40	8066	1σ	8086-8035	1.00
		2σ	8190-8160	.03
			8136-7980	.97

Table 2 : Average of the charred nutshell dates from the site of Verrebroek.

archaeological related material, organic material from 3 geological profiles was dated.

2.2.2 - Dating results (table 3)

The dispersion diagram (fig. 4) shows single results around 8000, 6500 and 1500 cal BC. Two almost identical dates, but on a different kind of material at 4500 cal BC. Ten dates form a cluster, incorporating the entire 4th millennium cal BC. The two dates obtained on the bark from the pit form the beginning of this cluster. The youngest sample dates around 1500 cal BC (IRPA-938) was found in the same context (windblow α) as the oldest one (IRPA-933). Also UtC-1351 and IRPA-937 were found in the same context (windblow β). IRPA-1040 is part of the cluster although the sample comes from a stratigraphically much younger context. Charcoal migration was not only noticed on small or single lumps, also conglomerates (>10 g) were displaced.

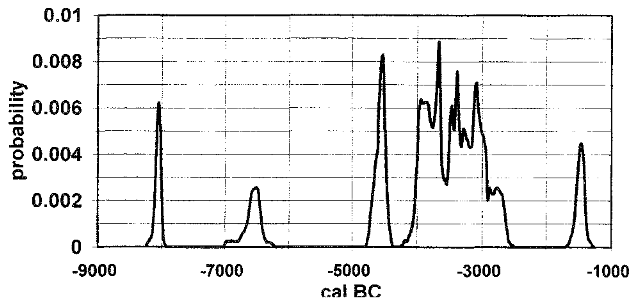


Fig. 4 : Dispersion diagram of the dates from Melsele «Hof ten Damme».

2.2.3 - Discussion

In spite of the mixing of the artifacts the dates around 6500 cal BC and 4500 cal BC could be related to stone artifacts found on the site. Lithic typology was inconclusive about a possible human occupation of the site around 8000 cal BC but a sporadic use of the site can not be ruled out, neither can it be fully proven. The nearby site at Verrebroek however gave dates covering the same period.

Peat dates proved that the site was inhabitable in the period between ca. 4500 and 3800 cal BC when the tidal activity of the river stops. One charcoal sample (UtC-1352) and the average of the bark dates (OxA-3092/3087) correspond with the end of this active sedimentation and the beginning of a period of stagnation in the Holocene floodplain expansion of the river Scheldt. The bark lining of the pit was the only sample that, without any doubt, was still *in situ*. A cluster, containing 10 ^{14}C dates, covers a period of at least 1000 yrs. The few Neolithic stone tools, part of the ceramic and probably most of the bones from domesticated fauna were presumably related to this phase. Although the dates reveal human activity for almost 800 ^{14}C yrs, within the excavated area no evidence was found for a permanent occupation of the site.

At the higher parts of the mound the peat started growing at about 2500 cal BC. This date corresponds to the youngest dates of the cluster, namely IRPA-1040 found in the peatbase and UtC-1445 found in a younger deposit. From that time on the landscape is characterized by a peatbog. The top of this peat layer is covered by a clastic alluvium. No trace of human activity could be demonstrated between 4000 BP and the Middle-Ages, neither archaeologically nor palynologically. This implicates that the youngest charcoal date can not be anthropogenic and must have been produced in a natural process.

2.3 - NIEUWE PEKELA 3 (NP3)

The Boreal Mesolithic site of «NP3» lies on a very pronounced, elongated but narrow dune amidst the extended coversand landscape known as the «Veenkoloniën». This ca. 200 km² area district was not intersected by water courses, which favoured peat growth from the Early Atlantic onwards. The pre-Atlantic relief shows an endless pattern of ridges and shallow depressions. Mesolithic occupation shows a preference to those sand dunes that lie adjacent to greater depressions coated with a thin layer of loam. This may have caused moist biotopes within a generally dry landscape at the time of the occupation.

On the site of «NP3» flint artifacts showed up over a length of 900 m. Within this spread it has been possible to distinguish some artifact concentrations. Also a huge

lab. ref.	description	Age BP
IRPA-938	charcoal from windblow a	3210 ± 60
UtC-1445	wood from gully	4180 ± 50
IRPA-1040	charcoal from peat base	4370 ± 65
IRPA-988	charcoal from transition peat/coversand	4460 ± 35
UtC-1430	charcoal from gully	4520 ± 100
IRPA-934	charcoal from coversand	4610 ± 60
UtC-1444	charcoal from coversand	4660 ± 60
IRPA-937	charcoal from windblow b	4850 ± 50
OxA-3092	bark from storage pit	4950 ± 80
UtC-1352	charcoal from coversand	5090 ± 80
OxA-3087	bark from storage pit	5130 ± 80
IRPA-945	wet wood from coversand	5690 ± 55
UtC-3191	carbonized hazelnut from coversand	5700 ± 60
UtC-1351	charcoal from windblow b	7730 ± 110
IRPA-933	charcoal from windblow a	9030 ± 70

Table 3 : ^{14}C-dates from the site of Melsele.

amount of hearth-pits were found. The Department of Archaeology of the State University of Groningen (GIA, the former BAI) collected more than 500 samples in several campaigns (Smit, 1995). The majority of the hearth-pits was easily recognized by means of the very dark charcoal filling at their bases. The state of good preservation enabled a thorough study of their form and contents. They prove to be shaft-like pits, dug out at about an arm's length, with only a small variety in width. The deep set fire tends to smoulder and has a very low fuel consumption. The hearth-pits may be found in clusters, leading to the assumption that they were fired in the open air and served special purposes, such as drying, smoking or cooking (Groenendijk, 1987).

The apparent abundance of the pit feature in the Netherlands enables us to argue on another scale than when hearth-pits would be encountered incidentally within artefact concentrations. Hearth-pits rather indicate a single use and quick refilling with coversand than a repeated clearance and eventually abandonment. This and the fact that peat growth sealed these pit features, resulted in data sets with very little contamination (table 4 ; fig. 5).

The abundance of lithic debris on «NP3» obscures a possible spatial association between activity areas with flint working and the location of hearth-pits. In a few cases hearth-pits lie clearly outside the lithic artifact units, so hearth-pits do not necessarily coincide with these. This is supported by the fact that only a small proportion of the hearth-pits show burnt flint artifacts in their contents. The hearth-pit feature can serve as an independent source of dating special activities on Mesolithic camp sites.

The low standard deviation is due to the fact that often big lumps of charcoal could be collected from the charcoal residu. The *floruit* covers a period ranging from 7281 to 7021 cal BC. The 95 % probability range covers a period from 7512 to 6670 cal BC. Only one sample, sample GrN-13751 (9110±45 BP), does not fall within the mentioned ranges ; its age is about 700 years older than the other dates. At present it is not clear how this must be explained. Consequently this «isolated» date has not been used for calculating the *floruit*.

2.4 - LEEK «MENSUMAWEG»

On the N.-flank of an ice-pushed ridge in the municipality of Leek, a Mesolithic site on a small coversand dune was

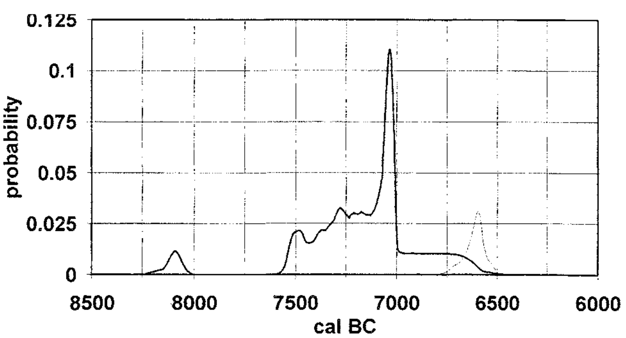


Fig. 5 : Dispersion diagram of the dates from «Nieuwe Pekela 3» (bold line) and Leek.

Gr-N	hearth-pit feature	BP date
13750	22884D	8230 ± 45 BP
13751	22884K	9110 ± 45 BP
15313	22884E	8090 ± 30 BP
18821	11	8090 ± 35 BP
18822	20189C	8260 ± 30 BP
18823	20189D	8115 ± 25 BP
18824	20189E	8185 ± 30 BP
18825	20189F	8300 ± 50 BP
18826	20189I	8110 ± 50 BP
18827	25189D	8135 ± 25 BP
18828	25189E	8110 ± 50 BP
18829	25189S	8145 ± 25 BP
18830	26N	7920 ± 50 BP
18831	26O	8230 ± 25 BP
18832	34	7955 ± 45 BP
18833	35	8115 ± 35 BP
18834	36	8260 ± 50 BP
18835	37	8320 ± 50 BP
18836	38	8240 ± 80 BP
18837	39	7870 ± 70 BP
18838	40	8020 ± 50 BP
18839	219	8490 ± 50 BP
18840	220	8415 ± 40 BP

Table 4 : ^{14}C-dated hearth-pits from the site «NP3» (charcoal only).

still partially covered with peat until 1996. A rescue excavation was carried out by the State Service for Archaeological Investigations (ROB, Amersfoort). The flint typology characterized the site as Boreal-Mesolithic. A concentration of charred *Corylus* shells, *Pinus* charcoal, burnt and unburnt flint artefacts indicated the presence of a surface-hearth with a reconstructed diameter of ca. 4 m. In the centre of the feature an extra intense concentration of charcoal and nutshells with a diameter of 35 cm was found.

At a deeper level, just outside the scatter of charred hazelnuts but within the spread of flint, a hearth-pit feature was uncovered, containing mainly *Pinus* charcoal. The podsolisation process had blurred the contours of the shaft itself as is usual in the sandy soils of the Netherlands. Nevertheless it seemed that the surface-hearth was a younger phenomenon. This "intersection" is a very rare observation and was chosen to cross-check the dating of both the hearths. Although the uncalibrated ^{14}C-dates seem to confirm the predicted stratigraphy (table 5), a possible contemporaneity between both features can not be ruled out statistically. A spatial and functional relationship between both hearth features or the activities in which they played a role is however not to be expected. On the other hand, the distribution of burnt flints and the presence of a surface-hearth in which hazelnuts were processed, seems to have a link.

3 - CONCLUSION

This study demonstrates that different ^{14}C-dating strategies can be used for Mesolithic open-air settlements situated on sandy soils. Choosing between

feature	sample	GrN	BP date
surface-hearth, centre	10 gr. nutshells	23671	7820 ± 40 BP
surface-hearth, periphery	26,6 gr. nutshells	23672	7820 ± 30 BP
hearth-pit	11,5 gr. charcoal	23673	7870 ± 40 BP

Table 5 : ^{14}C-dates of two hearth features from Leek.

one of these entirely depends on the objective(s) one is willing to achieve.

For the purpose of directly dating artifact units and elaborating refined and reliable typo-chronological frame-works, it is obvious that charred hazelnut shells are much more suited than charcoal, even if the latter is found spatially closely associated to the artifact concentrations and lithic industries. Contrary to charcoal, carbonized hazelnut shells have the advantage of being a short-lived material with a negligible inbuilt age. Furthermore they have a short residence time since they most likely have been consumed relatively rapidly after their growth season. Even if Mesolithic man did the roasting of hazelnuts in order to preserve them for storage, we may assume that the roasted nuts were eaten before the new harvest in late summer or early spring. So, in most cases there presumably will have passed only some months between the radiocarbon event and the human event to be dated. In order to reduce possible sample contamination, shells associated with surface-hearths should be preferred above scattered shells.

The Verrebroek and Melsele projects clearly indicate that it is probably better not to use charcoal samples for the construction or refinement of typo-chronologies, although this has been done for many years now, even till today. The typo-chronology of the Dutch Mesolithic for example (Newell, 1973 ; Lanting & Mook, 1977) is almost entirely based on charcoal samples originating from hearth-pits or features resembling hearth-pits. The main problem with these features is that they are most likely connected with specific, so-far indeterminate activities which generally occurred outside the occupation (=artifact) units, in the periphery of the domestic areas. Hence there is generally no direct and evident spatial connection between the dated hearth-pit and the lithic industry. Moreover, the dated features of Verrebroek prove that even if there is a clear spatial coincidence, still there can exist an important chronological hiatus between the occupation of the unit and the use of the hearth-pit. Similar observations have been reported at other Mesolithic open-air sites within the coversand region, e.g. at Brecht «Moordenaarsven» (Vermeersch *et al.*, 1992) and Havelte (Price *et al.*, 1974). This however does not mean that hearth-pits should not be dated any more. On the contrary, the dating project realized at «NP3» has clearly underlined the potential of charcoal samples from hearth-pits in reconstructing the internal organization and the duration of the occupation of open-air sites.

With regard to the reliability of these dates, as opposed to dates obtained on scattered or dislocated charcoal, there is strong evidence that they are highly secure. Due to their position at the bottom of shallow pits, there is much less chance that these samples are contaminated with migrated or percolated organic material. Furthermore it is highly probable that hearth-pits are generally not re-used. Another advantage is the presumably limited «old wood effect» of hearth-pit samples. Judging by the small size of most hearth-pits, it can be assumed that small branches will have been preferably used as fuel, thus assuring a close chronological connection between the ^{14}C event and the human event. This is so-far partly corroborated by anthracological analysis realized on hearth-pit samples from «NP3» (fig. 6). It appears that 32 % of the samples come from thin branches and 44 % from branches thicker than 5 cm. The category "trunkwood" however may well be overestimated, since this terminus happens to be applied also for wood with a diameter exceeding 5 cm. Branches are more often found in the charcoal, the old wood effect being only a minor contamination factor in Mesolithic hearth-pits.

It is beyond any doubt that the use of charcoal found outside hearth features (such as scattered charcoal fragments from the coversand) or within secondary contexts (such as natural windblow features), is most risky and has a number of real disadvantages, even if the sample is found within the limits of the artifact distribution. In fact when dealing with these samples one does not know exactly what is being dated. The real impact of the «old wood effect» is extremely difficult to access because in most cases it is not totally clear which part of a tree is dated by the sample (young branch or trunk ? outer or inner parts of tree ? number of tree rings ?). Another major problem is the impossibility of determining whether Mesolithic man, as result of various domestic activities produced the charcoal, or on the contrary natural processes such as forest-fires are responsible for the combustion. Furthermore there is a serious problem of association. The close spatial association between a scattered charcoal sample and the human event to be dated, usually an artifact unit, is not always a guarantee for a valid date, certainly not in a highly bioturbed sandy soil where the possible presence of migrated «older» or «younger» charcoal fragments must be taken into account.

Despite all the disadvantages, in specific cases, e.g. at Melsele, scattered and dislocated charcoal samples can be particularly helpful in detecting phenomena which did not produce or leave any archaeological material. However we do think that this type of samples must not be used if more reliable materials are present at the site.

4 - RECOMMENDATIONS

In view of future absolute dating of Mesolithic open-air settlements in sandy contexts, we would recommend the, preferably combined use of hazelnut shells and charcoal from hearth-pits. Referring to the results of the described dating projects in both study-areas, these materials actually guarantee the best dating results if dealing with typo-chronologies and intra-site analysis. On most Mesolithic sites in the Low Countries, and probably even beyond, at least one of these materials is available. Charred hazelnut shells are generally well represented on late Preboreal and Boreal sites ; during the early Atlantic the frequency apparently drops, though hazelnut

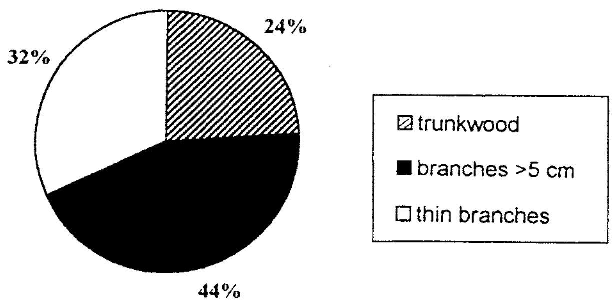


Fig. 6 : Classification of charcoal samples from hearth-pits at the site of «NP3» according to thickness (determination I.-L.M. Stuijts & R. de Man).

shells have already been reported on several Late Mesolithic settlements (e.g. Weelde «Paardsdrank», Remouchamps «Station Leduc», Melsele «Hof ten Damme...). Based on our experience we are convinced that hazelnut shells can be found on almost all sites on the condition that a fine-screening (2-3 mm width) of the soil is done. On the other hand in the Netherlands hearth-pits seem to be almost omni-present on Mesolithic settlements. The apparent scarcity of these features in Belgium is most likely related to the excavation method, which, contrary to the Netherlands, is less oriented towards large-scale investigations.

The use of scattered or dislocated charcoal samples should in our opinion be limited as these are evidently the least «verifiable» samples. Certainly when hazelnut and/or hearth-pit dates are not available, one should seriously consider not to submit samples of isolated charcoal for dating. In the case that these samples are after all used, we would recommend to date individual and identified fragments (species, brunch- or twigwood, etc.) by means of the AMS, in order to reduce possible contamination and the effects of the materials own inbuilt age. Furthermore it is recommended to put the data along with information obtained by other means (e.g. dated stratigraphical markers such as peat development, the deposition of sediment layers, etc.) in a model. These models will help to recognize natural processes from human activities.

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SINGLE ENTITY DATING

*Patrick ASHMORE**

Abstract : Archaeological sites include charcoal older than the period of formation of archaeological features more often than has generally been recognised. Radiocarbon dating of samples which combine more than one piece of charcoal to produce carbon for dating can thus cause serious dating errors, which will carry through into the interpretative process.

Résumé : Contrairement à ce qui est généralement admis, il est assez fréquent de trouver sur les sites des charbons de bois antérieurs à la période de formation archéologique. La datation radiocarbone d'échantillons incluant plus d'un fragment de charbon de bois pour produire le carbone à dater peut donc mener à de graves erreurs de datation qui se répercutent ensuite sur le processus d'interprétation.

Key-words : Radiocarbon dating, charcoal, dating errors.

Mots-clés : Datation radiocarbone, charbon de bois, erreurs de datation.

INTRODUCTION

The chronologies provided by radiocarbon, with all their faults, are crucial to the interpretation of evidence about past ways of life. During the last 20 years, Historic Scotland and its predecessors have accepted well over 1000 applications for dating of archaeological samples, and rejected between 200 and 300, in addition to paying for a large number of dates from palaeoenvironmental sites. During that time the accuracy of laboratories has usually come to match the precision claimed. Yet in that same period not all archaeologists and specialists in the palaeoenvironmental sciences have improved their sample selection.

Housley and colleagues have recently covered many of the problems associated with bone in their article on late-glacial human recolonisation of Northern Europe (Housley *et al.*, 1997, 26-35). I will not touch on the problems of peat or soil. I shall concentrate on the problems associated with charcoal samples, presenting several cases which will demonstrate that there is much more frequent survival of old charcoal on Scottish archaeological sites than has generally been supposed.

I hope to demonstrate that the single greatest improvement that Historic Scotland can make to its dating programme is to pay for radiocarbon dating only if the sample dated is a single entity. The definition of a single entity I shall use here is *anything which is demonstrably a single natural organic whole*. Thus a wattle hurdle is not a single entity. Twigs found on a hearth do not form a single entity even if they are of the same species. Of course, choosing to date a single entity is not enough in itself to guarantee a useful date. A whole tree is a single entity, yet a piece of the heartwood of an old oak tree is often not much use for dating the context in which it survives.

In what follows, all the samples were prepared for dating at Scottish Universities Research and Reactor Centre in East Kilbride. It measured bulk sample dates, and single entity dates were measured on the accelerator mass spectrometer at Arizona. Calculations of the proportions of old and young charcoal follow the methods of Taylor (1987).

CULHAWK

This first example shows that dates from bulk samples can be significantly misleading even on an apparently simple site.

Excavation at Culhawk near Kirriemuir in Angus, eastern Scotland, revealed remains of an Iron Age wooden roundhouse with a ring of postholes, pits and a surrounding ditch. I am grateful to Mr T. Rees of AOC Scotland Ltd (Rees, 1997, 1998) for the archaeological information which follows. The site showed no signs of multi-periodicity nor of major replacements of timber,

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and the excavator's supposition that it did not remain in use for much more than a generation seems reasonable enough from the physical remains which survived. Judging by the sizes of the post holes, the species used and the charcoal retrieved, the timbers were not particularly large.

Three bulk dates (GU- series) were obtained, two from postholes (059 and 061) and one from the ring-ditch (084). Three AMS dates (AA- series) were obtained from each of the same contexts (tab. 1).

CULHAWK CONTEXT 084

The four dates from the ditch do not form a coherent group. The bulk sample date probably represents a mixture of Neolithic and Iron Age charcoal. The two Neolithic AMS dates are not significantly different from each other. An attempt to group them produces a chi-squared value of 2.42 while the 95 % value is 3.84. Perhaps the true date of the Neolithic charcoal in the ditch was close to the pooled mean of 4160 ± 35 BP. If so, the bulk date could represent a mixture of about 85 % charcoal dating to 4160 ± 35 BP with 15 % charcoal dating to 1805 ± 45 BP, the measured date of the third AMS sample.

CULHAWK CONTEXT 59

The four dates from this posthole do not form a coherent group. An attempt to group them produces a chi-squared value of 13.70 as opposed to a 99.5 % value of 12.8 ; so there is a less than one in two hundred chance that there is no significant difference between them. However, the three AMS dates form a coherent group with a chi squared value of 1.71, as opposed to 95 % value of 5.99. The simplest explanation given the demonstrable presence of Neolithic charcoal on the site, and the excavator's argument that the house was not long lived, is that the bulk sample contained both Neolithic and Iron Age charcoal. The bulk date is similar to that which would be obtained if about 10 % of the charcoal were dated to 4160 ± 35 BP (the likely date of the older charcoal in context 084) and 90 % of it were close to the weighted mean date of the AMS dates, 2014 ± 26 BP.

CULHAWK CONTEXT 061

A similar explanation applies to the four dates from this posthole. A mixture of 92 % charcoal of the weighted mean of the AMS dates, 2047 ± 26 BP, and about 8 % charcoal dating to 4160 ± 35 BP would explain the observed bulk date.

THE THREE CONTEXTS AND THE DATE OF THE STRUCTURE AT CULHAWK

All of the bulk dates from contexts at Culhawk give misleading information. The older bulk date suggested presence of charcoal of about 3770 ± 80 BP, but this is a completely misleading result. The old charcoal on the site is late Neolithic - nearly 400 years earlier. The two bulk dates of 2200 ± 50 BP and 2210 ± 50 BP are particularly pernicious because they are so believable. They imply occupation at the site between 400 and 50 cal BC, whereas the main occupation at the site more probably occurred between 100 BC and 10 AD, judging by the pooled mean of the AMS dates from contexts 059 and 061, with later activity between 120 cal AD and 365 cal AD judging by the youngest date from context 084.

In addition to suggesting that the main period of occupation of the site was some 200 radiocarbon years later than the bulk dates suggested, the AMS dates hint at the possibility of at least some slight reuse of the site a century or more later.

Because the rigorous recording standards of the excavator and the charcoal specialist made it possible to discount many other possible sources of error, and the AMS dates demonstrate the presence of old charcoal at Culhawk, it is easy to produce a plausible reconstruction of the source material of the observed dates. Culhawk is an almost perfect example of the dangers of dating bulk samples of charcoal even in circumstances where there is no indication of the likelihood of old charcoal.

EILEAN OLABHAT

The next case illustrates how the activities of our ancestors can confound reasonable expectations. I am grateful to Dr I Armit of Historic Scotland for the information which follows (Armit, 1996 ; Armit *et al.*, forthcoming). The case concerns a metalworking site of the early historic period in North Uist in the Western Isles of Scotland (tab. 2).

Dating of charcoal from bulk samples produced dates ranging from 1400 ± 90 to 2820 ± 70 BP. The dates get increasingly incredible for the metalworking as they get older. A possible explanation for the observed pattern of dates at the metalworking site is that at about 1400 ± 90 BP people dried out and re-used wood either from a nearby archaeologically excavated waterlogged Neolithic site, or from some other unexcavated site nearby. For instance the date of 2820 ± 70 BP could represent a 50:50 mix of charcoal of around 1400 BP and charcoal around 4500 BP which would be a credible date for the Neolithic activity.

If the hypothesis advanced above is correct and if the bulk samples contained between 15 % and 50 % of Neolithic charcoal, dating of seven single entity samples - individual pieces of roundwood - would probably have produced a majority of early historic dates and a minority of Neolithic dates. Interpretation would have been considerably easier. As it is, doubt must remain about the true contents of the bulk samples because once it be accepted that waterlogged wood may have been dried out and used for fuel, it must be accepted in such a high rainfall environment that the waterlogged wood may have come from any of several sources.

Dates subsequently obtained from food residues on pots from the metalworking phase (Armit *et al.*, forthcoming) confirm a broadly 6th century date for activity during that phase of the site.

STAOSNAIG PIT 24

Even on early sites, still earlier charcoal may survive. I am grateful to Dr S. Mithen of Reading University for the archaeological information which follows (Mithen, 1998). As part of the Southern Hebrides Mesolithic Project, he excavated a pit (Pit 24) at Staosnaig on Islay, an island in western Scotland. The pit contained hazelnut shells and micro-debitage from flint knapping. Nine dates were obtained from single pieces of charred material (tab. 3).

A grain date and two late dates for hazelnut are excluded from this table, because the point I wish to illustrate is solely that the earliest date, AA-21624 at 7935 ± 55 is significantly different from the other five pre-7500 BP

Lab Code	Description	Date BP	d13C
GU-7285	Pieces of carbonised *Betula sp.*, *Corylus avellana*, *Salix sp.*, *Alnus glutinosa* from context 084 in the ditch	3770 ± 80	-26.1
AA-26979	A single piece of carbonised *Alnus glutinosa* from context 084 in the ditch	4215 ± 50	-26.9
AA-26978	A single piece of carbonised *Corylus avellana* from context 084 in the ditch	4105 ± 50	-26.8
AA-26977	A single piece of carbonised *Betula sp.* from context 084 in the ditch	1805 ± 45	-26.1
GU-7283	Pieces of carbonised *Betula sp.*, *Corylus avellana*, *Ulmus sp. Alnus glutinosa* from context 059 in a pit	2210 ± 50	-26.0
AA-26973	*Ulmus sp.* from context 059 in a pit	2000 ± 45	-24.2
AA-26972	*Corylus avellana* from context 059 in a pit	1980 ± 45	-26.5
AA-26971	*Betula sp.* from context 059 in a pit	2060 ± 45	-26.1
GU-7284	Pieces of carbonised *Betula sp.*, *Corylus avellana*, *Calluna* from context 061 in a pit	2200 ± 50	-25.9
AA-26976	A single piece of carbonised *Calluna* from context 061 in a pit	2055 ± 45	-26.6
AA-26975	A single piece of carbonised *Corylus avellana* from context 061 in a pit	1995 ± 45	-25.2
AA-26974	A single piece of carbonised *Betula sp.* from context 061 in a pit	2090 ± 45	-28.2

Tab. 1 : Dates from Culhawk, Angus Scotland.

Lab Code	Context	Date BP	d13C
GU-3233	charcoal with debris from metalworking	1400 ± 90	-26.8
GU-2327	charcoal occupation associated with metalworking debris.	1800 ± 50	-25.6
GU-3231	as GU-3233	1860 ± 60	-27.8
GU-2326	as GU-2327	2010 ± 50	-25.0
GU-3232	as GU-3233	2160 ± 80	-25.9
GU-3234	as GU-3233	2490 ± 170	-26.4
GU-3230	as GU-3233	2820 ± 70	-28.0

Tab. 2 : Dates from Eilean Olabhat.

Lab Code	Description	Date BP	d13C
AA21619	Hazelnut shell from sample ST9402 from Spit 1 of the pit	7760 ± 55	-24.8
AA21624	Hazelnut shell from sample ST9407 from Spit 2 of the pit	7935 ± 55	-25.1
AA21623	Hazelnut shell from sample ST9406 from Spit 2 of the pit	7665 ± 55	-27.6
AA21621	Hazelnut shell from sample ST9404 from Spit 2 of the pit	7780 ± 55	-25.6
AA21622	Hazelnut shell from sample ST9405 from Spit 3 of the pit	7660 ± 55	-25.7
Q-3278 Bulk date	Hazelnut shell fragments lying immediately adjacent to each other, from Spit 4 of the pit	7720 ± 110	

Tab. 3 : Some dates from Pit 24, Staosnaig, Islay, Scotland.

dates (T=16.7 ; 5 % = 11.1). One at least of the charred hazelnut shells in the pit was therefore old at the time it was deposited in this pit. Thus the single entity approach has shown that it is highly likely that the material in the pit was diachronic, and therefore even very early contexts may have still earlier charcoal in them. Of the three dates omitted from the table, AA-21618 (3455 ± 60 BP) for grain from the top of the context may be a later intrusion. The significance of two other dates AA-21620 (7040 ± 55 BP) and AA-26227 (7420 ± 65 BP) from a single sample of material from the lowest spit in the context is still under discussion (Mithen S. *pers. comm.*).

CALANAIS, WESTERN ISLES

On some sites the need for single entity dating has always been obvious. The 1980 and 1981 excavations at Calanais in the Western Isles of Scotland (Ashmore, 1996, 1998a) showed that structures had been built on the site before the central monolith and ring of stones was set up and the small chambered cairn placed inside it, and that the site continued in use thereafter. Some material, possibly including charred organic material, had been imported. Some had been shifted from one position to another on the site. Some layers had been truncated and turbated by ploughing, and others turbated by biological activity. Chemical weathering had changed the nature of other layers. The likelihood of mixtures of charcoal of different periods in the layers was high.

Four dates from Calanais relate broadly to construction of the stone circle and chambered cairn there (tab. 4). Six were in contexts relating to destruction of the cairn and probably to the emptying out of its chamber (tab. 5). Each date was obtained from a single piece of charcoal, to avoid the possibility of mixing charcoal of different periods.

It is clear from the stratigraphic sequence at Calanais that the stone ring is earlier than the cairn, and from details of the layers that it and the cairn are fairly similar in date. however, the dates obtained from layers relating to erection of the ring of stones and a slightly earlier fire are statistically indistinguishable from those which date the construction of the chambered cairn which was built inside the ring. That means either :

1. that charcoal from a single source (perhaps the early fire) has got into the layers which survive from the period of building of the main ring of stones, and also into those which go with building of the chambered cairn, or,
2. that the pieces of charcoal are close in date to the date of the layers in which they were found, and the ring and chambered cairn were built at similar dates.

There is no obvious way of choosing between these alternatives until they are considered in conjunction with dates from the dilapidation layers. It seems likely that the cairn was emptied out and its contents scattered in and around the ring at some time in the Bronze Age. Five dates were obtained from individual bits of charcoal in the layers produced by this despoliation and one date from an immediately underlying layer.

The three early dates in these destruction layers were indistinguishable as a group from those in layers related to the setting up of the stone ring and building of the cairn. Since there is no evidence that they derive from disturbance of material from underlying layers, it seems likely that they represent material taken from the chamber of the cairn.

Technically, the three later dates provide neither a safe *terminus post quem* (because they are in a soil whose final form was later than dilapidation) nor a safe *terminus ante quem* (because they may be from residual material) for destruction of the cairn. It is purely economy of hypothesis that suggests that the ploughing accompanied dilapidation - and while economy of hypothesis is intellectually satisfying to those brought up in Western thought models, it is probably no more useful in retrieving ancient truths than calculating an average date from samples of significantly different dates.

The Neolithic dates from the early layers form a statistically coherent group dated to 2870 to 2630 cal BC and those from the destruction layers also form a statistically coherent group dated to 2860 to 2590 cal BC. Taken together they form a statistically coherent group, and thus it seems likely that the date of construction of the chambered cairn and stone circle fall within a fairly tight time span within the period from about 2900 to about 2600 cal BC.

The point that is most vital here is that if the charcoal from the destruction layer had been dated as a bulk sample, a date of round about 3820 +/ 60 BP would have been obtained, which would have corresponded to no particular real event. Such a date would probably have led to discussions about a possible early date for the beakers in this layer, and about various dates for construction of the ring and chambered cairn, all devoid of meaning because based on a spurious 'date'.

SEQUENCING TOOLS AND THE CASE OF BARNHOUSE

Application of tools to exploit the information from sequences of layers or other contexts, like those presented by Bronk Ramsey in Oxcal (1995), or Bayesian methods like those discussed by Buck and colleagues (Buck *et al.*, 1991), can only be used with extreme caution. The date of a sample is not necessarily the same as that of the context in which it was found. Proving the relative dates of the contexts does not prove the relative dates of the samples. Apparent inversions in sample dates may be due to the sample in the later context being truly earlier than the one in the earlier context, rather than being due to the statistical errors of radiocarbon measurements. An example of the potential pitfalls is provided by a sequence from the important Neolithic settlement at Barnhouse in Orkney. I am grateful to Colin Richards of Glasgow University for the archaeological information which follows (Richards, 1993) (fig. 1).

Barnhouse is a settlement in the heart of Orkney. The evidence from it is of a high calibre and its relationships to the stone circle at Stenness nearby, to the great tomb at Maes Howe, and to the settlement at Skara Brae are of the highest interest. Several local sequences of layers were discovered and dates were obtained from organic material in them. The dates for Barnhouse lie in a flat part of the calibration curve (Ashmore, 1998). If the samples could be shown to be contemporary with those layers, Bayesian methods or the Gibbs Sampler methods used by Oxcal could refine dating (Bronk Ramsey, 1995).

The birch samples from later contexts in House 8 seem 'old' in comparison to the House 2 grain dates (fig. 1), and in analysing the consequences of the relationship of the dates, Oxcal pushes the House 2 dates earlier. The Oxcal analysis thus suggests that the primary occupation of house 2 would date to before 3100 cal BC (fig. 2) If this could be accepted it would be an important result, and it is very tempting to believe it. Unfortunately it cannot be accepted.

Lab Code	description	date BP	d13C
AA-24959	A single piece of carbonised *Betula* (birch) from Feature B871 2368/81 a localised fire, or of a small dump of ashes and charcoal cultivated into a soil	4140 ± 45	-26.3
AA-24969	A single piece of carbonised *Salix sp.* (willow) from Feature H767 230/81, the primary pit of Ring Stone 42. It could be residual from a context like B871, the fire incorporated in the soil	4095 ± 45	-25.4
AA-24964	A single piece of carbonised *Betula* (birch) from Feature 398 592/81, the layer of green clay under the cairn. It could be residual	4185 ± 45	-26.1
AA-24966	A single piece of carbonised *Betula* (birch) from Feature H732 116/81 which gives a *terminus post quem* for inner cairn construction. It could be residual	4210 ± 50	-26.1

Tab. 4 : Dates from contexts related to setting up of the ring of stones and construction of the chambered cairn at Calanais, Western Isles, Scotland.

Lab Code	description	date BP	d13C
AA-24968	A single piece of carbonised *Salix sp.* (willow) from Layer H738 203/81, a greasy brown layer immediately under the highly ard-marked layer H707	3575 ± 45	-25.8
AA-24956	a single carbonised twig of *Pomoideae* sp. from an ardmark in Feature B123 54/80, green-yellow clay with ardmarks	3580 ± 45	-26.6
AA-24962	A single piece of carbonised *Betula* (birch) from Layer D344 95/81, a layer of dark brown clayey soil with charcoal. Ardmarks were visible in it lower parts	3555 ± 50	-27.2
AA-24960	A single piece of carbonised *Corylus avellana* (hazel) from Layer D315 687/81, a heavily ard-marked layer with charcoal in both soil and ardmarks	4205 ± 50	-25.4
AA-24961	A single piece of carbonised *Betula* (birch) from Layer D315 685/81, a heavily ard-marked layer with charcoal in both soil and ardmarks	4055 ± 50	-30.6
AA-24963	A single piece of carbonised *Betula* (birch) from Layer D369 678/81, the lower level of D315	4115 ± 45	-25.2

Tab. 5 : Dates from the despoliation layers at Calanais, Western Isles.

The grain dates of the samples from House 2 are well related to the dates of the contexts in which they were found. However, the birch samples in the later contexts may appear as old as they do because of an inherent age of several decades in the birch. For instance, rather than being freshly collected when used they may have come from the inner thatch of a house roof. In circumstances such as these, the tools provided by Bayesian Analysis and Oxcal cannot help refine the sequence. Suitable circumstances are likely to prove rare, particularly where bulk samples are used to provide dates.

CONCLUSIONS

It may be that charcoal is usually broken down fairly quickly in biologically active soil. But at least on archaeological sites, survival of old charcoal seems to be more common than previously supposed and it may be that charcoal is preferentially preserved at those spots where archaeological sites survive. Unless the dates of the individual pieces of charcoal composing a bulk sample are known, a bulk date will often be impossible to interpret. It could be explained away by a wide variety of combinations of different amounts of charcoal of different dates.

The implications of the examples discussed above and those from several other sites in Scotland (amongst others, Balnuaran of Clava (Bradley, 1997, 1998a), Chapelfield (Atkinson, 1998a), Lon Mor (Bonsall, 1997), Loudoun Hill (Atkinson, 1998b) and Newton of Petty (Bradley, 1998b)), are quite clear. While two or three dates from single entities from one context will be more costly then a single bulk date, they will often have a considerable interpretative value, while a single date which averages unduly old and young dates will have no value. All dates for bulk charcoal samples must be re-

OxA-3498 (4590 ± 75 BP) OxA-3499 (4570 ± 75 BP) both from charred barley from the primary occupation of house 2, which was built on a fresh site ;

which are earlier than

OxA-3500 (4420 ± 70) for final occupation of house 2, several layers of ash and clay above the sources of OxA-3498 and OxA-3499 ;

which is earlier than

OxA-3763 (4360 ± 60 BP) and OxA3764 (4400± 65 BP) and OxA3765 (4475±70 BP) all from birch charcoal from the floor of structure 8 of a later phase than house 2.

Fig. 1 : A Sequence of dates from House 2 and House 8 at Barnhouse, Orkney, Scotland.

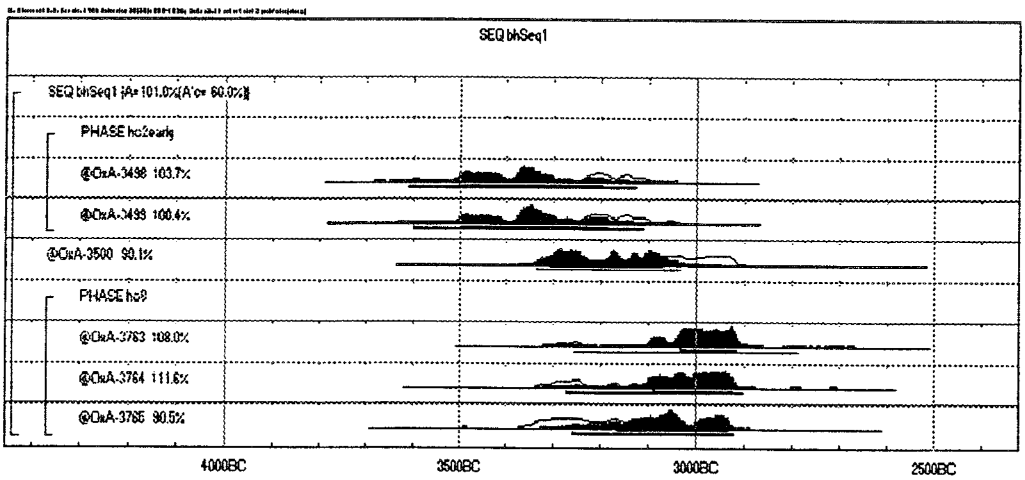

Fig. 2 : A Sequence of dates from House 2 and House 8 at Barnhouse, Orkney, Scotland optimised using Oxcal.

evaluated, and it seems likely that scholars will wish to use them with even more caution than previously seemed sensible. Similar considerations apply to other materials. In future, all radiocarbon dates from archaeological sites should be obtained from single entities.

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Note : the following standard abbreviations have been used. *D&ES* is *Discovery and Excavation in Scotland*. *PPS* is the *Proceedings of the Prehistoric Society*. *Proc. Soc. Antiq. Scot* is the *Proceedings of the Society of Antiquaries of Scotland*.

CALIBRATION ET STATISTIQUES

Actes du colloque « C14 Archéologie », 1998, p. 73-77.

RADIOCARBON CALIBRATION : TOWARDS THE COMPLETE DATING RANGE

*Johannes VAN DER PLICHT**

Abstract : Radiocarbon calibration based on dendrochronology and U-series dated corals yield a calibration curve (INTCAL98) well into the Late Glacial. In addition, an annually laminated sediment from Japan provides atmospheric calibration information for almost the complete radiocarbon dating range (back to about 45,000 years ago).

Résumé : La dendrochronologie et la datation de coraux par la méthode uranium/thorium mènent à une courbe de calibration du ^{14}C (INTCAL98) permettant de remonter à la fin du dernier Glaciaire. De plus, des sédiments annuellement laminés provenant du Japon, fournissent des informations dans presque tout l'intervalle de datation du ^{14}C (jusqu'à il y a 45 000 ans).

Key-words : Laminated sediment, radiocarbon, calibration, AMS dating, late glacial, upper palaeolithic.

Mots-clés : Sédiments laminés, ^{14}C, calibration, datation par AMS, fin du dernier Glaciaire, Paléolithique supérieur.

INTRODUCTION

The isotope ^{14}C (radiocarbon) is continuously produced in the earth's atmosphere by cosmic radiation. Radiocarbon is radioactive and decays with a half life of 5730 years. A stationary state of production, distribution between the main carbon reservoirs (atmosphere, ocean and biosphere) results in a more or less constant ^{14}C concentration in atmospheric CO_2 (Mook and Waterbolk, 1985 ; Mook and Streurman, 1983).

However, it is known for some time that the ^{14}C concentration of atmospheric CO_2 has not always been the same in the past. In tree rings, natural variations of the atmospheric $^{14}CO_2$ abundance were discovered on a time scale of one decade to a few centuries (de Vries, 1958). Later it was discovered that these variations can be attributed to variations in solar activity (Stuiver, 1965), which in turn influence the production of ^{14}C in the atmosphere. Also changes of the geomagnetic field strength influences the production of ^{14}C in the atmosphere (Bucha, 1970). This is understood because both solar activity and geomagnetic field strength determine the amount of cosmic radiation impinging on the earth. In addition the atmospheric $^{14}CO_2$ concentration also depends on exchange between the atmosphere and ocean. Finally, the half life is measured as 5730 ± 40 years (Godwin, 1962) but the value used for ^{14}C age calculations is kept as the original value of 5568 years (Libby, 1955).

Both the varying ^{14}C concentration and the half life discrepancy cause the ^{14}C time scale (BP) to be different from the historical time scale (BC/AD). Thus, although the radiocarbon content can be measured accurately, the radiocarbon years are generally related to historical ages in a complicated way. Therefore the ^{14}C method has to be calibrated : the relation between BP and cal BC/AD has to be established. This can be done by measuring ^{14}C ages of samples which are also dated by other, independent means.

This other method, independent from ^{14}C, should preferably be absolute in order to establish a true correlation between ^{14}C time and the absolute, historical time scale. The ideal samples for calibration are tree rings, because they can be dated absolutely by means of dendrochronology. Other dating methods used in conjunction with ^{14}C are, for instance, U-series dating and (to a lesser extent) TL (thermoluminescence). These methods are not absolute in the same way as dendrochronology, because they are physical/chemical dating methods and therefore have measurement errors. Laminated sediments (varves) can be counted, in analogy with tree rings ; organic material from the sediments can be dated by ^{14}C. These chronologies are floating and thus not absolute ; they have to be matched to the tree-ring record.

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INTCAL98

The tree-ring calibration curve, based on wood dated by both dendrochronology and ^{14}C, now covers practically the whole Holocene (well into the Preboreal). Absolute data (from German oak) extend back to ca. 8300 cal BC ; a floating German Pine Chronology, matched to the absolute record, is presently going back to ca. 9900 cal BC (Kromer and Spurk, 1998). The curve consists of thousands of ^{14}C measurements on mainly American, German and Irish wood. It is not likely that the dendrochronology can be pushed much farther back in time since the climate becomes too cold. So, in order to calibrate the radiocarbon time scale beyond the dendro-dated tree-ring limit, other dating methods have to be applied. One of these method is combined ^{14}C/U-series dating.

The best calibration records are obtained for Pacific corals by mass spectrometry for both dating methods : AMS (Accelerator Mass Spectrometry) for ^{14}C, and TIMS (Thermal Ionization Mass Spectrometry) for the U-series isotopes. For U-series dating is, the sample needs to be a closed system, i.e. no U or Th isotopes should exchange with the environment since fossilization. For corals, this is a valid assumption in general.

Furthermore, corals obviously yield a marine calibration curve, which can not be compared directly to terrestrial calibration data because of the so-called reservoir effect ; the surface ocean has an apparent age, taken as 400 years, constant for the time span covered. For Holocene corals, this can be tested with the dendrochronologically obtained calibration curve. Because of both the good precision of TIMS and the reliability of corals for the U-series dating technique, this method can be considered absolute for practical purposes.

The coral calibration datapoints cover mainly the Late Glacial Period, with additional (low-time resolution) data to the Last Glacial Maximum (LGM) and 2 isolated data points at c. 30,000 and 40,000 cal BP (Bard *et al.*, 1998 ; Burr *et al.*, 1998).

The latest calibration data will be published in a new calibration volume of Radiocarbon, in conjunction with the 1997 Groningen Radiocarbon Conference Proceedings (Stuiver and van der Plicht, 1998). A new calibration curve will be constructed and released as INTCAL 98. This new curve is constructed from the following datasets :

a. tree rings absolutely dated by dendrochronology, from mainly American, German and Irish wood. Radiocarbon measurements were performed by the laboratories of Belfast, Groningen, Heidelberg, Pretoria, Seattle and Tucson ; these included intercalibration programs, and some revisions to the previous calibration curve (INTCAL93) have been made (Kromer *et al.*, 1996).

b. tree rings from the Preboreal German Pine, measured by Heidelberg and Seattle ; this chronology is floating and matched to the absolute chronology. It has recently been revised (Kromer and Spurk, 1998), and is believed to be correct within an error of 100 years.

c. a marine-derived curve for corals, dated by both ^{14}C and U-series isotopes (Bard *et al.*, 1998 ; Burr *et al.*, 1998). This dataset can be considered absolute for practical purposes.

INTCAL98 was «recommended» at the 1997 Groningen Radiocarbon Conference. Other records are not included, such as i) TL dating (Bell, 1991) because of the large error bars ; ii) speleothem dating by both ^{14}C and U/Th (Vogel and Kronfeld, 1997) because of the uncertainties in both methods (unknown initial ^{14}C age and possible detrital Th contamination) ; iii) varved sediments, because they are floating and not necessarily continuous. An exception is made for a high-resolution marine varved sediment, because it considerably strengthens the coral/tree-ring linkage (Hughen *et al.*, 1998).

CALIBRATION WITH VARVED RECORDS

Despite that they are not part of INTCAL98, varves do yield important calibration information, in particular the recently established chronology from Lake Suigetsu in Japan. European varved sediments extend back to around 11.500 cal BC (Wohlfarth *et al.*, 1996 ; Björck *et al.*, 1996).

The laminations from Lake Suigetsu, annual as far as we know, are preserved for the past 100.000 years ! The sediments from a 75 m long continuous core are characterized by dark-coloured clay with white layers due to spring season diatom blooms. Thus far, more than 250 terrestrial macrofossil samples (leaves, insects, wings, branches) from the annual sediments were measured by the Groningen AMS facility (Kitagawa and van der Plicht, 1998a).

Until now, the varve numbers have been counted in the 10.42-30.45 m deep section. This Lake Suigetsu floating varve chronology consists of 29,100 varves. The features in our data overlapping the tree ring calibration agree very well, even for «wiggles» in the ^{14}C calibration curves. Using this match we defined the absolute time scale, which then covers the absolute age range from 8830 to 37,930 cal BP. The combined ^{14}C and varve chronologies from Lake Suigetsu are used to calibrate the ^{14}C time scale beyond the range of the absolute tree-ring calibration. Figure 1 shows an atmospheric ^{14}C calibration for almost the complete ^{14}C dating range (< 45 ka).

The Lake Suigetsu data are also shown in fig. 2, here as $\Delta^{14}C$ versus time. $\Delta^{14}C$ is the atmospheric $^{14}CO_2$ content, in per mil deviation from the standard (Stuiver and Polach, 1977). The siderial years are expressed in cal BP, i.e. true years before 1950 AD (see footnote).

For the Late Glacial period, the Japanese varve data agree very well with the marine calibrations obtained by combined U/Th and ^{14}C dating of corals (Bard *et al.*, 1998 ; Burr *et al.*, 1998). Our data also agree with the varved sediments from Lake Gosciaz (Goslar *et al.*, 1995), and with recently published marine varves from the Cariaco Basin (Hughen *et al.*, 1998). The detailed $\Delta^{14}C$ record during the deglaciation shows millennium-scale fluctuations, superimposed on a long term increasing trend, resulting from a decreasing geomagnetic intensity and consistent with ^{10}Be records (Bard, 1997). For a more detailed discussion we refer to Kitagawa and van der Plicht (1998b).

Two example calibrations for two well-known volcanic ash layers during the Late Glacial : Vedde Ash and Laacher See are shown in fig. 3. The Vedde Ash has been dated at 10,330 ± 60 BP (Bard *et al.*, 1998). Calibration with a smoothed curve through the Lake Suigetsu data yields a calibrated date of about 10,000 cal BC. This agrees very well with 12,000 cal BP, obtained by calibration with U-series dates of corals (Bard *et al.*, 1998). This is not surprising since the U-series and Suigetsu calibration curves agree very well (Kitagawa and van der Plicht, 1998b). We note here that for the coral derived calibration curve, a 400-year reservoir correction is

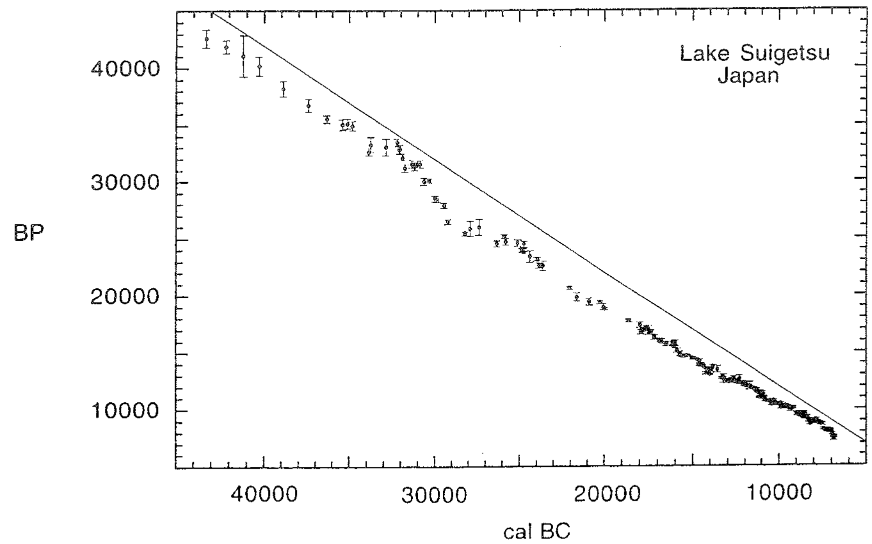

Fig. 1 : Amospheric radiocarbon calibration for the complete ^{14}C dating range (< 45 ka cal BP) reconstructed from annually laminated sediments from Lake Suigetsu (Japan). The straight line (the «Libby line») corresponds to BP = 1950 - cal AD.

assumed ; the correspondence between varves (terrestrial) and corals (marine) confirm that this reservoir correction is correct within error for this time frame.

The Laacher See Tephra (known as LST) is an important end-Allerød time marker for Central and Northern Europe. The ^{14}C age is now established as 11,060 ± 40 BP (Kromer *et al.*, 1998). The latest calendar date based on German varved sediments is 12,880 cal BP (Zolitschka, 1998). The result calibrated with the Lake Suigetsu curve is 10,900 cal BC in excellent agreement with the German record.

For the Pleniglacial beyond the LGM (Last Glacial Maximum) the Lake Suigetsu chronology for calibration purposes can only be applied with great care. The calendar ages older than about 20,000 should be considered as minimum ages. Therefore, the use in archaeology is still limited, also for chronostratigraphical investigations. In general, our data indicate that for the last 45,000 years, the calibration curve as derived for Lake Suigetsu stays below the Libby line which means radiocarbon ages (BP) remain younger than siderial ages (cal BP).

The long-term trend in $\Delta^{14}C$ agrees well with reconstruction of cosmogenic isotope production rate deduced by the ^{10}Be deposition and geomagnetic field intensity reconstruction (Bard, 1997). For this time span, we observe two pronounced peaks in $\Delta^{14}C$ at 23,000 and 31,000 cal BP. These apparent $\Delta^{14}C$ increases correspond to an increase in the concentration of another cosmogenic isotope, ^{10}Be, observed in ice cores and marine sediments, and are caused by geomagnetic effects.

The peak at 31,000 cal BP is about 300 per mil in $\Delta^{14}C$ after removing the long-term trend. For ^{10}Be, a factor of 2 is observed in Antarctic ice cores at 35,000 cal BP (Raisbeck *et al.*, 1987). This ^{10}Be increases a factor of 2 in ice cores during a period of ca. 2,000 years. This factor of 2 increase corresponds to a ^{14}C increase by a factor 1.3 or 300 per mil which is exactly what we observe in our data.

The time gap between the ^{14}C and ^{10}Be enhancements can be explained by errors in both varve and ice core chronologies. The dashed line in fig. 2 corresponds to an accumulated error of 2,000 years at 40,000 cal BP in the Japanese varve chronology. Recently, new ice core data from the Arctic determined the ^{10}Be spike at 41,000 cal BP (Yiou *et al.*, 1997) ; an increase in again another cosmogenic isotope, ^{36}Cl, is observed in the Arctic ice cores at

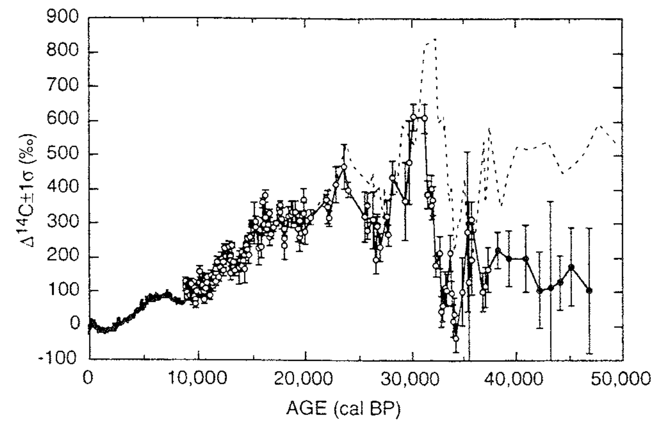

Fig. 2 : Atmospheric $\Delta^{14}C$ changes beyond the Last Glacial Maximum. The absolute (calendar ages older than 20,000 BP should be considered as minimum ages. The dashed line shows an instance with accumulated error of 2000 years at 40,000 cal BP in the varve chronology. The two peaks at 23,000 and 31,000 BP are superimposed on the long term $\Delta^{14}C$ change, probably caused by geomagnetic field change. O, varve counted ; ● (> 38.000 cal BP), not counted ; < 10,000 BP : dendrodata.

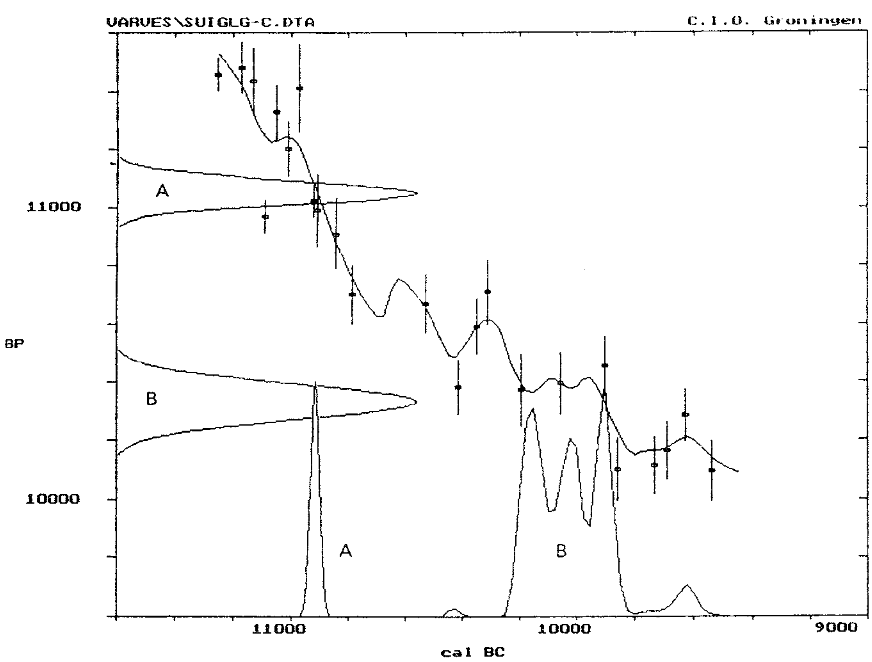

Fig. 3 : Calibration curve for the Younger Dryas period, based on the Lake Suigetsu varved chronology. Two volcanic layers, Laacher See Tephra (A) and Vedde Ash (B), are calibrated as an illustration.

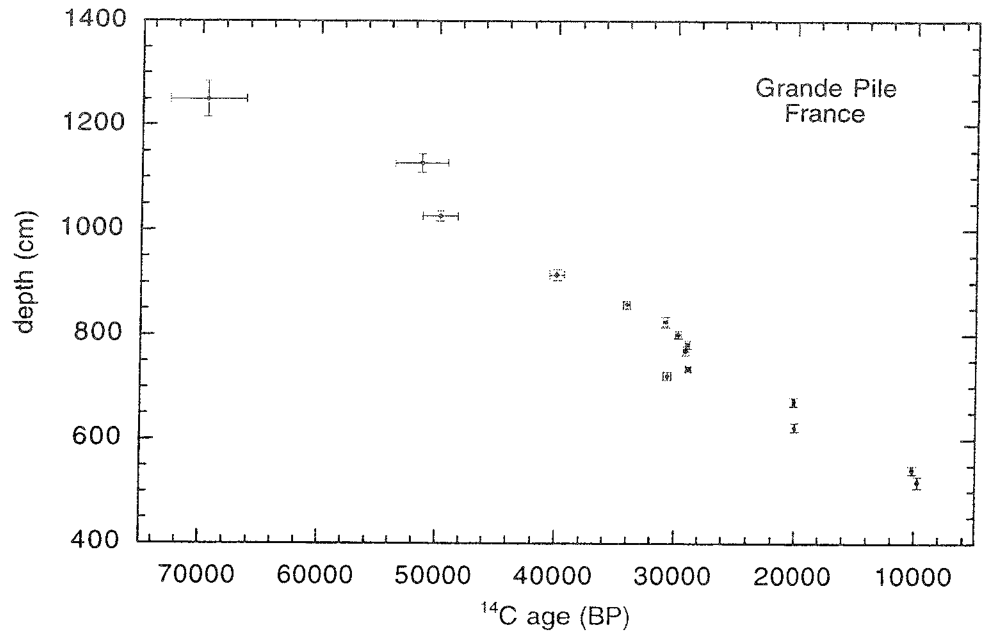

Fig. 4 : Grande Pile, France : ^{14}C-time (BP) versus depth. Note a possible anomaly around 30,000 BP.

38,000 cal BP (Baumgartner *et al.*, 1998). Clearly some fine-tuning has to take place for the various chronologies around this time. Especially beyond 31,000 cal yr BP, much work is still needed to obtain a better understanding of the atmospheric Δ^{14}C signal. Here, our calibration deviates from recent combined U/Th and ^{14}C dating of speleothems (Vogel and Kronfeld, 1997). These data suggest that ^{14}C dates at this time are 5,000 years too young. This discrepancy can be caused either by speleothem dating problems or missing varves in the older section of Lake Suigetsu.

At about 30,000 BP (^{14}C), we do observe an anomaly in the continuous pollen stratigraphy of Grande Pile, the key Pleistocene site in northeastern France. Many conventional ^{14}C datings were performed in Groningen in the 1980"s (Woillard and Mook, 1982). The dates as a function of sediment depth are shown in fig. 4. The sediment is continuously deposited during the past 140,000 years. The ^{14}C date of ⊕ 30,000 BP corresponds to the Denekamp interstadial, which is believed to correspond to interstadial (IS)-no. 8 in the Greenland ice cores (⊕ 35,000 cal BP).

The new varved chronology from Lake Suigetsu is a unique record yielding much possible information on ^{14}C calibration and its applications. More data will be measured to improve the time resolution, enabling a better study of geophysical phenomena reflected in atmospheric ^{14}C and calibration information for prehistory. For the oldest part of the dataset, much work is still needed to synchronize the varved record with the ice-core chronologies.

Footnote

BP : ^{14}C ages are reported in BP (Before Present), where Present is defined as 1950 (the «standard year»). BP ages are calculated from ^{14}C activities or concentrations as measured by proportional counters, liquid scintillators or Accelerator Mass Spectrometry ; by definition, BP includes a correction for isotopic fractionation by means of a measurement of the stable carbon isotope ^{13}C, expressed in $^{13}\delta$.
BC, AD : historical times (siderial years).
cal BC, cal AD : ^{14}C ages, calibrated into historical ages.
cal BP : for ^{14}C : calibrated before 1950, i.e. cal BP = 1950 - cal AD.
Also : siderial years before 1950, used for chronologies of ice cores, deep sea cores and laminated sediments.
$^{14}\Delta$: Δ^{14}C denotes the atmospheric $^{14}CO_2$ content, expressed as the per mil deviation of the ^{14}C content defined by the international oxalic acid standard ("1950") after decay and fractionation correction (Stuiver and Polach, 1977).

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RADIOCARBON AGE CALIBRATION FOR JAPANESE WOOD SAMPLES : WIGGLE-MATCHING ANALYSIS FOR A TEST SPECIMEN

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Abstract : A program of ^{14}C age calibration for samples of Japanese wood is planned using dendrochronologically dated tree-rings of cypresses, cedars and pines. We focused on ages between 350 BC and AD 500, corresponding to the periods known as Yayoi and Kofun in the history of Japan. As a preliminary experiment, we dated by AMS a sample specimen ranging from 200 to 90 BC, and compared the results with the calibration curves of Stuiver and Pearson (1986, 1993). Wiggle matching shows that the 1986 calibration curve gives a better result than the 1993 calibration curve.

Résumé : Un programme de calibration en âge ^{14}C est planifié pour des échantillons de bois japonais en utilisant des anneaux dendrochronologiquement datés de cyprès, cèdres et pins. Nous nous sommes concentrés sur des âges compris entre 350 BC et 500 AD correspondant à la période nommée Yayoi and Kofun dans l'histoire japonaise. Comme expérience préliminaire, nous avons daté des échantillons allant de 200 BC à 81 BC par spectrométrie de masse accélérée, et comparé les résultats aux courbes de calibration de Stuiver et Pearson (1986, 1993). Le wiggle-matching montre que l'ajustement à la courbe de calibration 1986 donne un meilleur résultat que la courbe 1993 de calibration.

Key-words : ^{14}C dating, ^{14}C calibration, AMS, wiggle-matching.

Mots-clés : Datation ^{14}C, calibration ^{14}C, spectrométrie de masse accélérée, wiggle-matching.

1 - INTRODUCTION

The period of 350 BC-AD 500 has been of great interest for many Japanese archaeologists, since during this period rapid changes took place in cultures and societies such as the initiation of wet rice agriculture, the use of iron and bronze, and the interaction between Eastern Asia and the Japanese archipelago. This period includes the prehistoric era called the ÅgYayoi PeriodÅh (ca.350 BC-AD 200) and the protohistoric era known as the ÅgKofun PeriodÅh (ca. AD 200-500), which is characterized by large mound tombs and the establishment of the first state in Japan. ^{14}C dates have played a minor role in the archaeological studies of these periods ; thus far, stylistic and typological examinations of pottery have been used to obtain detailed age information. Radiocarbon dates were extensively studied and compared with the relative pottery chronology in the late 1960's by Watanabe (1966) and Serizawa (1967). But since then no detailed ^{14}C survey has been reported mainly because of the rather large uncertainties in the ^{14}C ages.

In recent years, dendrochronology has been applied increasingly for research on the Yayoi and Kofun Periods since it provides exact ages, or at least the cutting dates for the trees (assuming they kept the outer rings). Dendrochronology for Japanese trees has been developed by one of the authors (T. Mitsutani) using trees such as Hinoki Cypress, Sugi Cedar, and Koyamaki Pine. The dendrochronological dates, which were recently obtained for the Hinoki pillars of an ancient structure excavated at the Ikegamisone Site, Osaka Pref., Japan, yields discussions among archaeologists on the absolute scales of the conventional pottery chronology, because the dendrochronological dates were found to be about 100 years older than the dates based on the typological and stylistic methods (Mitsutani, 1997).

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It is highly desirable to reexamine the ages of the Yayoi and Kofun Periods in Japanese history using absolute dating methods such as dendrochronology and ^{14}C. The use of dendrochronology, however, is limited because a large number of treerings has to be examined, ca. 200 years in the case of Japanese trees. On the other hand, recent developments in AMS ^{14}C measurements as well as precise calibration data available for the atmospheric ^{14}C record of the past enables us to determine the ages with more confidence than before. Precise dates can be obtained by means of the so-called wiggle-matching technique. This combination of ^{14}C and dendrochronology can lead to a rather exact age determination. Therefore, precise ^{14}C dating is also in increasing demand by archaeologists in Japan.

Conversion of ^{14}C dates to calendar years for Japanese samples are based on ^{14}C calibration curves obtained from North American and European trees, not from Japanese or Asian trees. Pioneering work in calibration of ^{14}C ages for a Japanese wood was performed by Kigoshi and Hasegawa (1966). The ^{14}C values back to ca.300 BC were determined using a Japanese Cedar (Sugi) from Yakushima island. Oda *et al.*, (1997) measured ^{14}C dates by AMS for 27 tree rings (single-year ring) of a Japanese Cypress (Hinoki) from the Kiso district dating between 1100 AD and 1900 AD, and compared the results with the calibration curve of Stuiver and Pearson (1993). They suggested that on a year-by-year basis there might exist possible deviations from the 1993 calibration curve of Stuiver and Pearson.

Although the use of universal calibration curves for Japanese samples of wood should be suitable for practical use, it is necessary to establish its basis of correctness. The aim of our research program is to improve the situation by establishing precise ^{14}C calibration using dendrochronologically dated cedars and cypresses, in particular for the Yayoi and Kofun time-frames. In this paper we present a preliminary study : the ^{14}C determination by AMS of fourteen decadal tree-rings from a test specimen, and the comparison of the calibrated ages with dendrochronology by wiggle-matching.

2 - MATERIAL AND METHODS

2.1 - DENDROCHRONOLOGY

The tree ring sample used in this study is a specimen from a Japanese Cedar (Sugi) tree, a bogwood excavated at Hakone located in the Fuji-Hakone National Park, Japan. A specimen of 6x5x70 cm with about 450 rings was selected for dating by both dendrochronology and ^{14}C.

The ring patterns spanned 453 years. Dendrochronological determination of ages has been performed by comparison of the standardized ring patterns with the master chronology for Sugi Cedar developed by the Nara National Cultural Properties Research Institute (1990). A master standard chronology for a Sugi Cedar has been established for tree ring ages back to 1313 BC. The specimen included ring dates of 245 BC to AD 207.

2.2 - SAMPLE TREATMENT

The surface few millimeters of the sample specimen was planed off to eliminate possible contamination with modern carbon. The portion of 200 BC to 81 BC was cut into decadal pieces of about 40 mm width x 5 mm thickness. Although the ring width varied layer by layer, we assumed each decadal piece represents the mean ^{14}C concentration in that time period. Each sample was degassed in distilled water under reduced pressure, and heated gently so that the sample is softened at the bottom of the beaker. The sample was then pulverized to very fine fiber tips of about 0.1x1 mm size using a mill. These tips were treated by acid-alkali-acid (AAA) using 1.2N HCl and 1.2N NaOH. In each step the sample reacted 5 times with acid or alkali for 1 hour.

These pretreated samples were further processed with $NaClO_2$+HCl to bleach out lignin with Cl_2, and finally with 17.5 % NaOH to remove most of β- and γ-cellulose. This α-cellulose fraction was neutralized with diluted HCl, washed with distilled water, filtrated and dried.

2.3 - AMS MEASUREMENT

A few tens mg of cellulose was weighed and sealed in a Vycor tube with CuO (organic carbon analysis grade : Wako Chemical Co.). The sample tube was heated to 850°C for two hours and oxidized to CO_2. The CO_2 was transferred to the high-vacuum CO_2 purification system at Nagoya University. The purified CO_2 was sealed off from the system.

The CO_2 samples were sent to the University of Groningen, the Netherlands in breakseals. Graphite targets were prepared in Groningen, and the ^{14}C dates were measured with the Groningen Tandetron AMS system (Wijma and van der Plicht, 1997).

3 - RESULTS AND DISCUSSION

The results of the ^{14}C measurements are shown in the Table. The errors include the statistics of ^{14}C counts, and uncertainties in the $^{13}C/^{12}C$ and $^{14}C/^{12}C$ ratios of the standard samples. The data do not include the blank corrections for the purification and target preparation, since we have not yet performed blank runs corresponding to these measurements. The extent of modern carbon contamination has been 0.05-0.1 % for the blank tests performed in the past few years at Nagoya University. These blanks also include the background in the graphite target preparation at Nagoya. Modern carbon contamination gives younger ages, but the correction is shown to be negligible.

The ^{14}C dates are compared with the dendrochronological dates (fig. 1 and 2) and the calibration curves of Stuiver and Pearson (1986, 1993). Listed in the last column of the Table are the wiggle-matched dates determined by the Groningen Radiocarbon Calibration Program (van der Plicht, 1993). The 1986-fit gives almost exactly the dendrochronological dates (they differ only by 1 year), and the 1993-fit gives dates which are younger by 15 years. The same age given by the 1986-fit and the dendrochronological dates in itself should not be regarded as statistically important.

To discuss the uncertainty associated in the above fittings we estimate errors using a method similar to the OxCal (Bronk Ramsey, 1995), since the Groningen Calibration Program does not include error estimation for wiggle-matching (van der Plicht, 1993). Probability distribution for a wiggle-matched age is calculated by combining individual distributions of tree-rings with known age-gaps (Bronk Ramsey, 1995). The obtained distributions indicate an approximate error (1σ

Sample name	Tree-ring age (BC)	Cellulose (mg)	^{14}C age (BP)	ID	Calibrated age (BC) 1986 (1993) fitting#
HK085B	90-81	3.87	2055Å}65	GrA-8084	84 (71)
HK095B*	100-91	6.74	2050Å}45	GrA-9321	94 (81)
			2085Å}45	GrA-9318	
HK105B*	110-101	6.64	2080Å}45	GrA-9316	104 (91)
			2120Å}45	GrA-9317	
HK115B	120-111	5.47	2035Å}45	GrA-9327	114 (101)
HK125B	130-121	5.99	2085Å}45	GrA-9322	124 (111)
HK135B	140-131	4.44	2150Å}65	GrA-8081	134 (121)
HK145B**	150-141	6.36	2130Å}65	GrA-8082	144 (131)
HK145B**	150-141	6.72	2080Å}40	GrA-9419	144 (131)
HK155B	160-151	6.83	2130Å}45	GrA-9328	154 (141)
HK165B*	170-161	5.69	2090Å}45	GrA-9323	164 (151)
			2180Å}45	GrA-9330	
HK175B	180-171	5.72	2150Å}75	GrA-8085	174 (161)
HK185B	190-181	6.49	2160Å}45	GrA-9326	184 (171)
HK195B	200-191	6.15	2125Å}45	GrA-9332	194 (181)

* CO_2 sample was splitted into two.**Two cellulose samples were prepared.
#Wiggle-matched ages based on the calibration curves of Stuiver and Pearson (1986, 1993).

Tab. : ^{14}C ages of 10 years tree-ring samples for a test specimen.

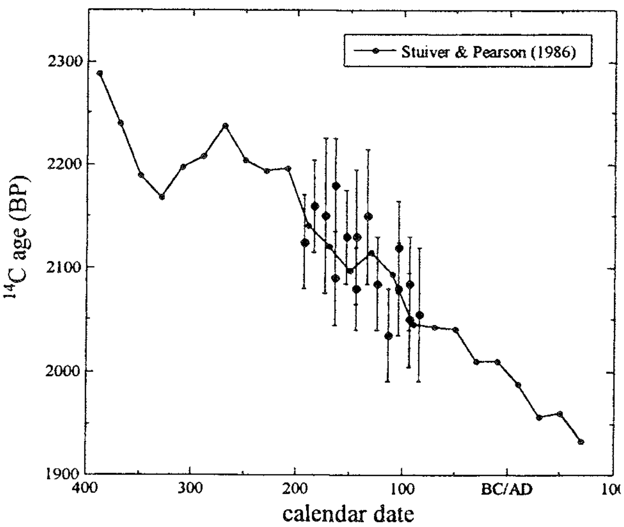

Fig. 1 : The measured ^{14}C dates compared with the tree-ring ages and the calibration curve of Stuiver and Pearson (1986).

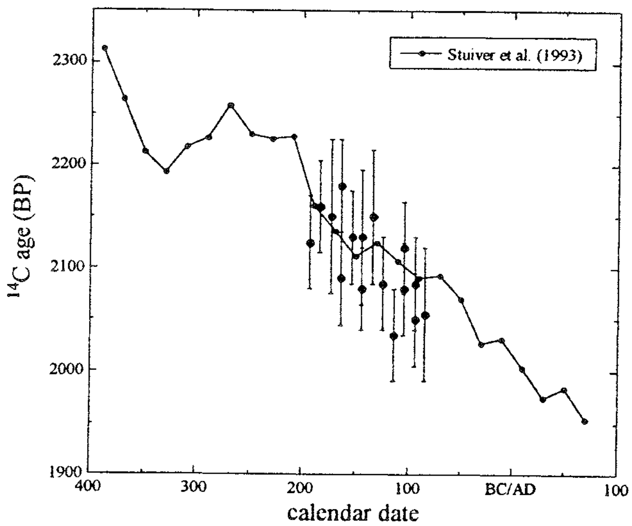

Fig. 2 : The measured ^{14}C dates compared with the tree-ring ages and the calibration curve of Stuiver and Pearson (1993).

equivalent) to be Å}16 years for the 1986 fit and Å}19 years for the 1993 fit. The probability distributions are somewhat asymmetrical and sensitive to how the data are weighted. However within the uncertainty the 1986-fit gives a better agreement than the 1993-fit. This can also be seen when comparing fig. 1 and 2. This observation is the same as made before by the Groningen group, using high-precision conventional ^{14}C measurements of large wood samples (van der Plicht and McCormac, 1995 ; van der Plicht, Jansma and Kars, 1995).

From the present study it is clear that the differences in ^{14}C between Japan and Europe or America, at least from 200 BC to 90 BC, are very small. This is not a surprising conclusion when we consider the fact that there is little local disturbance of ^{14}C in the atmosphere, since the air mass, as a whole, moves eastwards and reaches Japan without possible influence by the ocean. Another point which is clear from this study is the effectiveness of the wiggle-matching technique in ^{14}C dating.

4 - FUTURE PERSPECTIVES

Wiggle-matched dates using the available ^{14}C calibration curves are found to be consistent with the dendrochronological dates of Japanese tree rings from a test specimen. This shows a confidence in the dendrochronology for this specimen and provides a basis for future calibration work using Japanese tree-rings (Hinoki Cypresses and Sugi Cedars) for the planned periods of 400 BC-AD 500. The trees to be calibrated include Koyamaki Pines, for which ages from AD 22 to AD 741 are obtained. Wood from such trees has been used extensively as structural materials in ancient times in Japan.

In the near future ^{14}C calibration work will be continued by AMS ^{14}C dating using both the Groningen and Nagoya facilities. The sample preparation will be performed at the National Museum of Japanese History and also partly at Nagoya University. Also planned is the use of high precision gas proportional counting in Groningen for large size samples, when sufficient material is available.

CONCLUSION

As a preliminary experiment for the ^{14}C calibration program for Japanese samples of wood, we have measured ^{14}C dates by AMS using a test specimen. Comparisons between the dendrochronological dates and the generally accepted calibration curves (Stuiver and Pearson, 1986, 1993) show that the differences in ^{14}C between Japan and Europe or America, at least for 200-90 BC, are negligible. Wiggle-matching shows that the 1986 calibration curve gives a better fit than the 1993 curve.

Note : After submission of this paper, the newest issue of radiocarbon calibration (INTCAL 98) was published in late 1998 (M. Stuiver and J. van der Plicht eds. 1998 INTCAL 98 : Calibration Issue. Radiocarbon 40: 1041-1083). Deviation from the INTCAL 98 values (this work - INTCAL98) is calculated to be –3.9Å}13.3 ^{14}C yr for the calibrated year interval of 200 BC-90 BC. This again confirms that the differences in ^{14}C between Japan and Europe or America are negligible.

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THE ROLE OF STATISTICAL METHODS IN THE INTERPRETATION OF RADIOCARBON DATES

*Christopher BRONK RAMSEY**

Abstract : In order to study the past in a coherent way, we need to be able to find both the relative and absolute date of events. Like many other dating methods, Radiocarbon is frequently only an indirect method that requires the use of additional information to relate the measurements to the events and processes that are really of interest.
This paper discusses the strategies that can be employed when using statistical methods to draw inferences from both the dating evidence and other available information. It also covers how a connection can be made between the event-based radiocarbon evidence and archaeological hypotheses.

Résumé : Afin d'étudier le passé de manière cohérente, il est nécessaire d'obtenir la datation relative ainsi que la datation absolue des événements. Comme beaucoup d'autres méthodes, la datation par le radiocarbone ne constitue souvent qu'une méthode indirecte qui requiert l'utilisation d'autres informations, afin de faire le lien entre les mesures et ce qui nous intéresse vraiment, à savoir les événements qui ont eu lieu et les procédés utilisés.
Cet article traite des stratégies à employer lorsqu'on utilise des méthodes statistiques pour tirer des conclusions à partir des données basées sur la datation et d'autres informations. On aborde également le problème de la connexion entre, d'une part, l'information fournie par le radiocarbone - qui est basée sur des événements - et d'autre part les hypothèses archéologiques.

Key-words : Radiocarbon dating, statistics, bayesian, strategy, OxCal.

Mots-clés : Datation par le radiocarbone, statistiques, Bayesian, stratégie, OxCal.

INTRODUCTION

The role of radiocarbon in archaeology is gradually changing. In most regions, the main chronological framework has been established and the focus is now on the use of chronological measurements such as radiocarbon to help in the understanding and explanation of change. Individual calibrated radiocarbon dates, which relate to single events, are often insufficient to allow the archaeologist to interpret the relationships between events and the underlying processes. In these cases, both the design of the dating program and the analysis of the results need to be much more integrated into the archaeological investigation.

One of the main barriers to using individual dates directly in interpretation is the fact that scientific dating methods very rarely directly date the cultural phenomena that are of prime interest. Indirect dating usually has to be employed even in cases as simple as, for example, the construction of a single ring-ditch. Another layer of abstraction must be added if further deductions are to be made about the social context such as the period over which a particular class of ring-ditches was built.

Another factor that makes the use of simple logical deduction difficult, is the fact that the chronological information has significant uncertainties associated with it. Calibrated radiocarbon dates are a particular problem because of the multiple peaks in the likelihood distributions that are difficult to relate intuitively. The presence of this "fuzzy" data means that statistical methods form a particularly useful element in the interpretation of dating evidence of this kind.

THE DISCIPLINE FRAMEWORK

In order to see how statistics can be used for this particular purpose it is worth looking at the sort of information it is being used to analyse and the information it is expected to yield. The evidence can be divided into two broad categories : absolute chronological measurements (arising from scientific dating or historical evidence) and chronological relationships between events. The latter are drawn from a combination of hard physical evidence (such as stratigraphy) and archaeological interpretation (of both taphonomy and cultural phenomena). Even the simplest uses of

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radiocarbon evidence do therefore rely on information from a broad range of sources. Furthermore, these are all interrelated with, for example, the archaeological interpretation affecting the pre-treatment method used in radiocarbon dating and the radiocarbon dates affecting the archaeological understanding.

The simplistic positivist model of how the evidence is put together would entail the scientist generating hard dating evidence, the statistician analysing this and the archaeologist interpreting the results (see fig. 1). This is clearly only applicable in those cases where the scientific dating is straight forward and the statistical analysis entails little more than the combination of measurements on a single event. The very existence of a conference on Radiocarbon and Archaeology indicates that a more co-operative model is required for the dating itself and the same is certainly true for the statistical analysis. There is a close relationship between theory and the data (fig. 2).

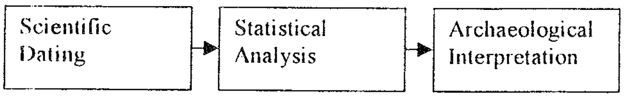

Fig. 1 : Simple positivist model of how statistical analysis relates to scientific dating for archaeology.

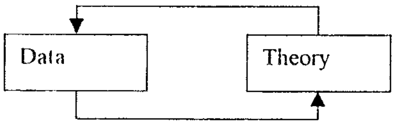

Fig. 2 : Actual relationship pertaining throughout most scientific disciplines including archaeology.

Although this carries with it the possibility that our interpretative theories might lack any objective foundation, in practice this can be avoided by trying not to get too much out of limited data sets. Circularity must also be avoided and it is important to have a good understanding of the distinction between the data supporting a theory and data merely being consistent with one (see below). The other problem with an integrated approach of this nature is that expertise in too many different disciplines might be needed. For this reason the points of contact between the different fields need to be as simple and non-technical as possible (fig. 3).

Many different possible analytical methods and tools could be used in order to perform this kind of analysis. The program OxCal (Bronk Ramsey, 1995 and 1998) has however been specifically designed in order to provide an accessible interface for Archaeologists and Earth Scientists, as does the BCal facility (Buck *et al.*, [this volume]). These allow non-statisticians to specify scientific dating data and chronological relationships in a well-defined way. By limiting the user to a small set of possible relationships, it is possible to ensure that the underlying statistical analysis can be performed automatically. It also turns out that by using only this limited set of individual relationships very complex models can still be built.

The specification of relationships and analytical functions in OxCal is performed through a text based "Chronological Query Language" (Bronk Ramsey, 1998). In the latest version (Bronk Ramsey, OxCal program), now undergoing testing, the elements of the model can be put together visually. This allows archaeologists to investigate interpretations of their data themselves, which is important given that this form of analysis should be integrated into the interpretative process. As with any other method, some initial help and advice is necessary in order to prevent misapplication of the technique (see Ashmore, [this volume]). Even after this, help and advice from specialists will still undoubtedly be needed in cases that are more complex but only after much of the preliminary groundwork has been done.

ANALYSIS REQUIREMENTS

Scientific dating gives us absolute chronological information about individual events. The context of these events and their relationships to each other are the subject

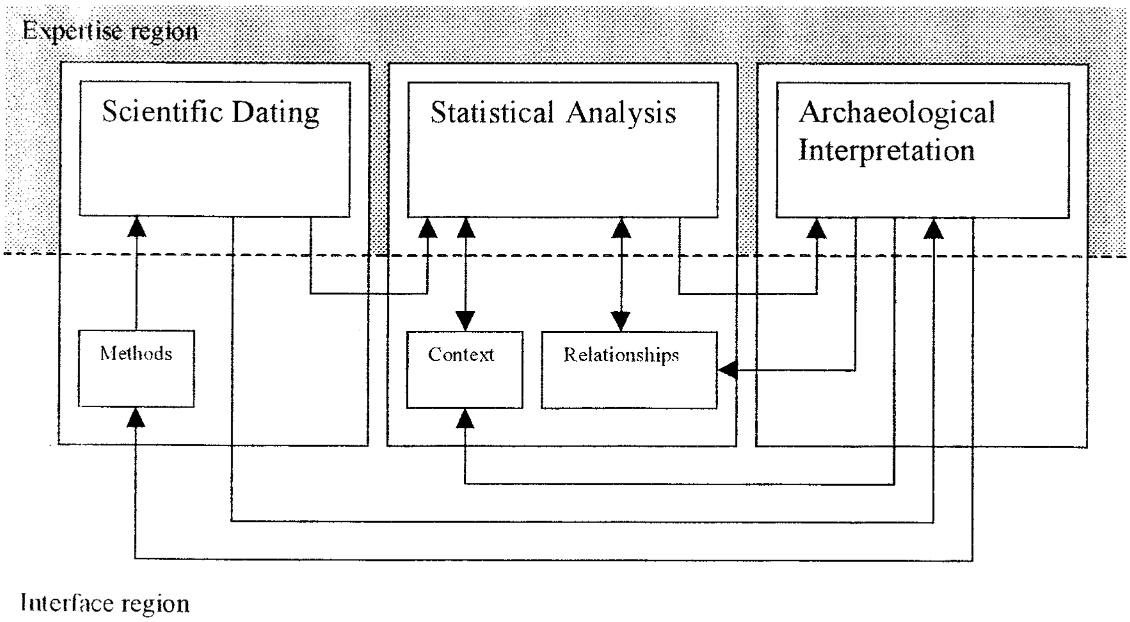

Fig. 3 : Schematic relationship between the different disciplines involved in radiocarbon dating and archaeological interpretation, showing how some areas of each dicipline are accessible to all others whereas details are understood only by experts. Note that in planning projects an understanding of these relationships is important and the experts in dating and statistics should almost always be involved at this stage.

of archaeological investigation. On the broadest level, there are two classes of relationship that need to be able to be analysed :

- Definite relationships - for example derived from site taphonomy and stratigraphy.
- Speculative relationships - for example derived from cultural hypotheses.

In practice, there is a blurring between these two classes. For example, although site taphonomy and sample context can be very carefully analysed they are always at some level based on speculative hypotheses. However, it is still good practice to try to split the relationships into these two groups as far as possible since the two should be treated differently.

Three statistical elements are useful for looking at the combination of absolute dating methods and relationships.

- Direct inferences and calculations.
- Hypothesis corroboration tests.
- Internal consistency tests.

It is worth looking at these in more detail. In order to illustrate the ideas discussed, this paper will draw on examples from the Stonehenge dating project (see Bronk Ramsey and Allen, 1995 and Bayliss *et al.*, 1997) and the British Bronze Age Metalwork dating project (Needham *et al.*, 1998 and Hedges *et al.*, [this volume]). The ways in which OxCal (which was used for both of these projects) attempts to provide the necessary tools will also be discussed.

DIRECT INFERENCE AND CALCULATIONS

This is the most obvious form of analysis and the one that is usually concentrated on. For example, if we have two dates relating to the same event then direct combination before calibration can be used to find our best estimate of the true age. Other calculations such as the span of the dated objects from each phase are mathematically more complicated and rely on the relationships between events derived either from definite relationships or speculative hypotheses.

In OxCal various functions are provided for finding intervals, first/last elements of groups, spans of dates and orders of events. These are useful both in themselves and for seeing if hypotheses can be supported by the hard evidence (see next subsection). The statistical methods that underpin this program (Bayesian analysis and Gibbs sampling, see for example Buck *et al.*, 1991 and Buck, Cavanagh and Litton, 1996) allow the inclusion of complex relationships. In the Stonehenge project, for example, the relationships between some 20 dates were used to date the construction of the main ring ditch (giving a range of 80 years).

In principle, many different calculations are possible and in specific cases some of these, such as wiggle matching of tree rings or estimates of deposition rates, can be very useful in an archaeological context.

HYPOTHESIS CORROBORATION TESTS

If we are dealing with largely speculative hypotheses, we need some way of seeing whether these can be supported by the scientific dating evidence. Indeed, in many cases this is more interesting than the actual dates of the events concerned. For example, in the case of the Bronze Age Metalwork whether or not the phases of use are sequential or overlapping is central to our understanding of the cultural changes involved. Such a hypothesis can be tested by seeing if the scientific results correspond to what you would expect if the hypothesis were correct. If the phases were sequential, we would expect one to end before the next started. Using the analytical methods we can infer the start and end of each phase and see if this is the case. Because the data is "fuzzy", the results of this analysis come as probabilities rather than as definite answers. If we had found that there was a 95 % probability that one phase stopped before the next started then we could have said that this analysis had shown (at 95 % confidence) that the phases were sequential. In this particular case, the dating resolution was not good enough and the probabilities were nearer 50 % indicating that the hypothesis might or might not be correct.

In this form of analysis the scientific dating information and definite relationships are used in order to see if speculative hypotheses can be directly supported.

INTERNAL CONSISTENCY TESTS

We should not be too disappointed that the direct corroboration is often not possible. It turns out that most scientific disciplines proceed to some extent on hypotheses that are consistent with the data rather than derived from them. This much weaker requirement for coherence or consistency can also be the target of statistical analysis. In our Bronze Age example, we do indeed find that the dating evidence is consistent with the notion of sequential phases. Given this hypothesis we can then make further deductions about the time of transition between phases and their duration.

OxCal's individual agreement indices (Bronk Ramsey, 1995) provide a way of checking the context of individual samples when stratigraphic information has been included in the model. This allows checks to be made on the internal consistency of the data and chronological relationships. The same indices can also be used, along with the overall agreement index, to check for the coherence of a speculative model. This was, for example, the method used to check that the sequential phase model was possible for the Bronze Age assemblages.

In general, this form of analysis can be used to double-check "definite" relationships and to see if speculative hypotheses are tenable or conversely whether the data can be used to reject them.

AN ANALYTICAL FRAMEWORK

Any generalised framework for analysis of this sort is clearly going to be simplified but some important elements can be identified. Figure 4 shows a schematic of the stages involved.

Once the scientific dating and archaeological information has been gathered, the first stage is to see if these two are in good agreement. If they are not then the context and relationship between the samples needs to be re-evaluated (if the dating itself is reliable). Once any problems of this sort have been dealt with, further analysis of the information can be performed to determine lengths of phases, likely dates for specific events etc. The Stonehenge dating project provides a good example of this kind of analysis. The information from the site stratigraphy has been included after careful consideration of the taphonomy of all samples. In that case, no speculative hypotheses were investigated and the analysis stopped at this point.

Ideas that are more speculative should be looked at after all of the "firm" evidence has been included. In some ca-

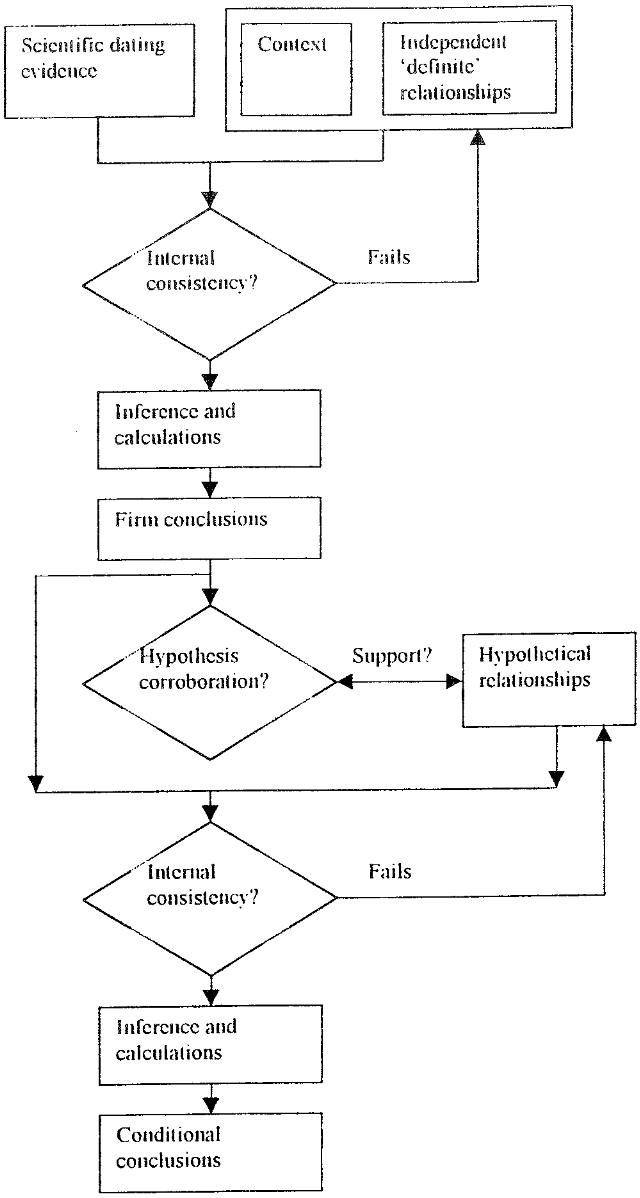

Fig. 4 : Proposed analytical framework for using scientific dating techniques to study archaeological hypotheses. This is not intended to cover all possibilities (for example failures in coherence tests might result in a re-evaluation of the scientific dating) but it covers the stages most likely to be employed.

ses (as with the British Bronze Assemblage project) there are no "firm" relationships between individual samples and only the second stage of analysis is performed. Ideally, hypothetical relationships should first be looked at to see if they could be directly supported by the hard evidence available. This is one of the most difficult parts of the analysis to perform, as it is not easy to generalise the procedures needed. The same consistency testing methods that are used for checking the agreement between the dating and stratigraphic relationships can also be used to check whether hypothetical relationships are ruled out by the data. Assuming they are not, further analysis allows conclusions to be drawn that are conditional on the truth of the speculative hypotheses made. In the Bronze Age project, for example, we first looked to see if the dating evidence could be used to demonstrate definite sequential phases. The evidence was not tight enough to be able to do this but the data were consistent with that hypothesis. By assuming its validity, we were then able to deduce the times for the transition between phases. These conclusions are, however, clearly conditional on the sequential phase model being correct. Hypotheses that are merely consistent with the data are still speculative unless other evidence can be used to support them. This should always be made explicit : internal consistency should never be confused with direct evidence.

Depending on the complexity of the problem being investigated, the overall analytical framework might be more or less elaborate. As indicated above, often only "firm" or "speculative" relationships are present rather than both. In many cases, however, several loops of analysis and data collection might be performed. It is also often useful to perform analysis on simulated dates before dating is undertaken to see if the archaeological questions of interest are likely to be answered and which samples are the most useful ones to date. This is particularly valuable in the case of radiocarbon dating where the precision of dates after calibration is very dependent on the time period in question.

CONCLUSION

Statistical methods which are useful for the archaeological interpretation of radiocarbon dates are becoming increasingly available (Bronk Ramsey, OxCal program, Bronk Ramsey, 1995 and Buck *et al.*, [this volume]). There are undoubtedly dangers in the misuse of these methods but the potential gains are worthwhile (Bayliss, 1998). Although often used simply to draw inferences they can also be used to test hypotheses, either by seeing if the data directly corroborate them, or if they are merely internally consistent. In doing so, they can be used to bridge the gap between the event-based radiocarbon data and the archaeological interpretation of the underlying processes of change.

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POSSIBILITIES OF CALENDRIC CONVERSION OF RADIOCARBON DATA FOR THE GLACIAL PERIODS

Olaf JÖRIS and Bernhard WENINGER**

Abstract : Based on dendrochronology, the calibration curve for Radiocarbon dates reaches back some 11,700 yr, allowing a precise calendric conversion of ^{14}C-ages on samples from the Holocene. In the present paper we review the possibilities of extending the ^{14}C-calibration curve into the Glacial periods, back to the limits of the Radiocarbon method at ca. 45 BP. The method is to compare, verify, and, where possible, combine published stable ($\delta^{18}O$) and radioactive (^{14}C, U/Th) isotope data from a variety of climate archives, namely Japanese varve sediments, North Atlantic marine records and Pacific corals, with the time-scales of the Greenlandic ice-cores.

Résumé : La courbe de calibration obtenue par dendrochronologie atteint quelque 11.700 années. Elle permet ainsi d'établir une conversion précise en années calendaires de l'âge radiocarbone d'échantillons pour la période Holocène. Nous étudions ici les possibilités d'étendre la courbe de calibration radiocarbone aux périodes glaciaires, jusqu'à la limite de la méthode radiocarbone soit 45000 BP. La méthode vise à comparer, vérifier, et si possible combiner des données publiées d'isotopes stables et radioactifs provenant de plusieurs archives climatologiques, varves sédimentaires japonaises, enregistrements marins de l'Atlantique nord et coraux du Pacific, avec l'échelle de temps des carottes glaciaires du Groënland.

Key-words : Radiocarbon dates, calibration, late glacial period.

Mots-clés : Dates radiocarbone, calibration, tardi-glaciaire.

INTRODUCTION

The initial assumption of Libby (1952), that the atmospheric $^{14}C/^{12}C$ ratio has remained constant through time, is well-known as having first-order validity only. Significant variations of the atmospheric ^{14}C-level were first recognised by Suess (1955), and since then much evidence has accumulated showing that these variations are largely the result of changes in the Earth's geomagnetic field, which modulates the primary flux of cosmic rays reaching the atmosphere, to produce radioactive ^{14}C via the $^{14}N(n,p)^{14}C$ reaction. Recent studies indicate that the geomagnetic field accounts for some 80 % of the slow (millenium scale) natural ^{14}C-variations during the last 50 ka (Laj *et al.*, 1996 ; Völker *et al.*, 1998). As shown in fig. 1, the geomagnetic $\Delta^{14}C$-data of Laj *et al.* (1996) agree well with the calibration data to be described below. We note there is accumulating evidence for additional, fast (century or decadel scale) fluctuations of atmospheric $\Delta^{14}C$ which also seem related to the geomagnetic field (Völker *et al.*, 1998). Further variations of the atmospheric $^{14}C/^{12}C$-ratio are to be expected for changes in ocean circulation and in sea surface temperatures (SST) (Siegenthaler *et al.*, 1980). Other geophysical causes, for example solar modulation of the (annual) cosmic ray flux reaching the earth, also seem responsible for changes in the atmospheric ^{14}C-production. The geomagnetic and solar $\Delta^{14}C$ variations are presently best documented in the tree-ring derived Holocene calibration curve, which is now extended back continuously some 11.7 ka (Spurk *et al.*, 1998). Disregarding minor uncertainties in the range of a few decades on both the BP and dendro time-scale (Kromer *et al.*, 1996), the German and Irish oak-based $\Delta^{14}C$-records can be elongated by a late Younger Dryas to Pre-Boreal pine section, thus entering the Glacial periods (Spurk *et al.*, 1998). An up-dated decadel data set for the entire Holocene section of the ^{14}C-calibration curve is in preparation.

The backbone of the ^{14}C-calibration curve is thus given by dendrochronology. Unfortunately, only few trees are preserved from the Glacial periods, and the available Late Glacial dendro/^{14}C data sets (Barbetti *et al.*, 1992 ; Kaiser, 1993 ; Kromer *et al.*, 1998) cover segments of only a few hundred years at the most and presently remain floating. However, if we accept different (non-tree) timescales, and combine these where necessary, there exists a large variety of supplementary climate archives,

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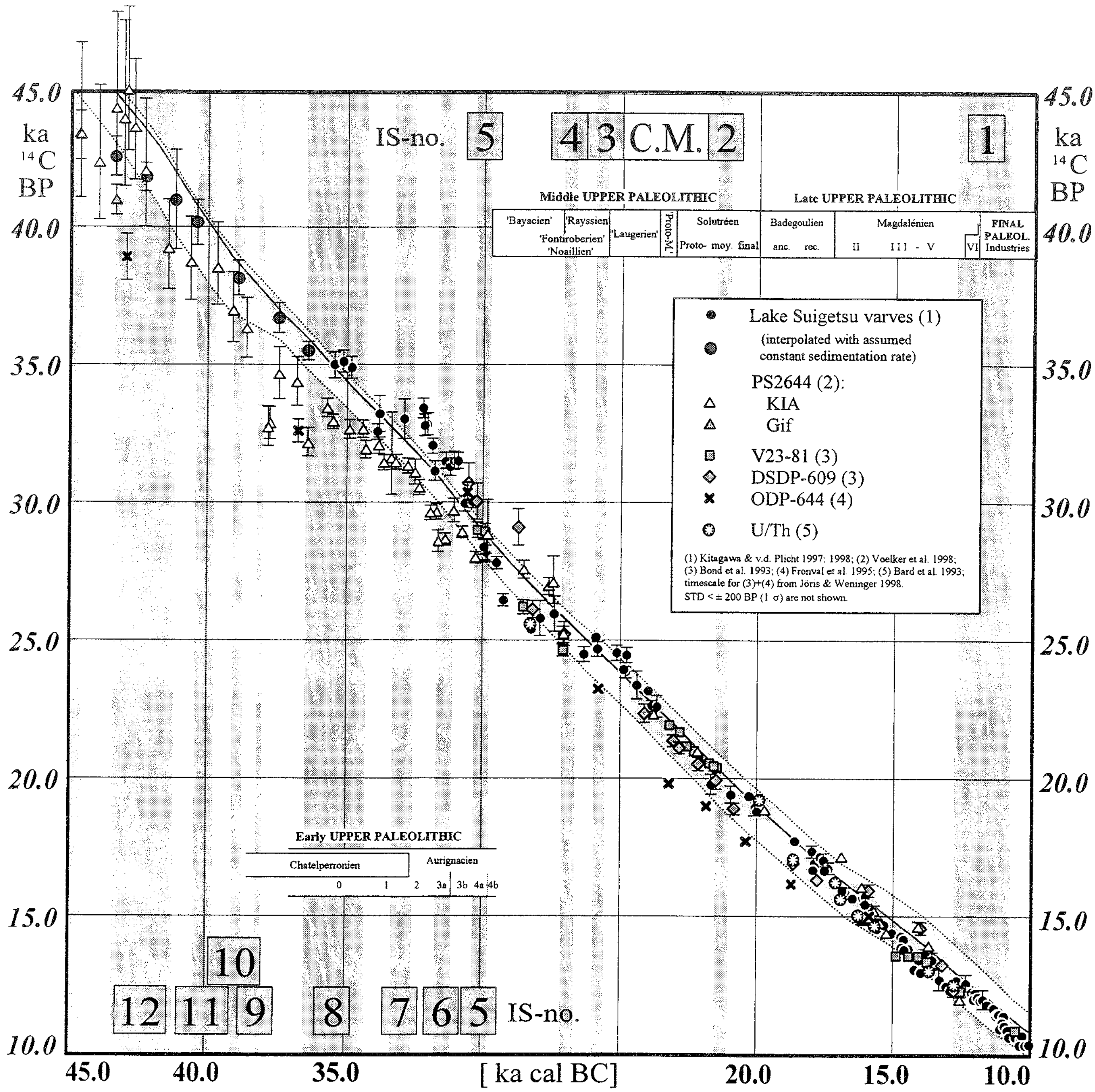

Fig. 1 : Time-window 10-45 ka calBC, showing paired ^{14}C and calendric ages for different data sets. Sequence of interstadials (IS : vertical gray shading) following Johnsen *et al.*, 1992. C.M. = cold maximum. GISP-2 timescale according to Meese *et al.*, 1994 and Sowers *et al.*, 1993. Upper Palaeolithic chronology for S.W. France after : Bosselin (1996) ; Djindjian (1993, 1996), and Weißmüller (1997, modified). Shaded band shows geomagnetic calibration curve (Laj *et al.*, 1996). Data points (± 1 σ error bars) are from : Lake Suigetsu varves, marine sediments (North Atlantic cores : PS2644, V23-81, DSDP-609, ODP-644 ; all ^{14}C-ages on planktic foraminifera), and corals (U/Th-^{14}C-data). All marine ^{14}C-ages include a reservoir correction of 400 BP. Additional Late Glacial calibration data of Bard *et al.* (1996), Burr *et al.* (1998), Edwards *et al.* (1993), and Hughen *et al.* (1996, 1998) are not included in the graph.

supplying data which can be used to extend the ^{14}C-calibration curve into the Glacial periods. Indeed, with recent advances in dating techniques, it seems to us that it is already now possible to construct a ^{14}C-calibration curve covering some large portion of the Upper Palaeolithic. In this paper, we briefly review the data available for this purpose.

GLACIAL ^{14}C CALIBRATION DATA DERIVED FROM U/TH-AGES

To begin, we note that the presently available ^{14}C-calibration data, compiled by Stuiver and Reimer (1993), already allow calibration of Palaeolithic ^{14}C-ages, with certain limitations, using coupled ^{14}C and Uranium series data on corals (Bard *et al.*, 1993 ; Edwards *et al.*, 1993). If the recent U/Th-data published by Bard *et al.* (1996) and Burr *et al.* (1998) is included, the extended calibration curve already now reaches back to the end of the Last Glacial Maximum at 19.950 calBC(U/Th), with a single oldest data point at 28.275 calBC(U/Th) (fig. 1). Of course, the Glacial U/Th-^{14}C-calibration data is still preliminary, and further checks on the reliability of the U/Th-ages do seem advisable, all the more because of the long undated time-spans in between neighbouring data points.

GLACIAL ^{14}C CALIBRATION DATA DERIVED VIA ICE-CORE SYNCHRONISATION

The U/Th dating method is now increasingly being applied using the highly precise TIMS-(Thermal Ionization Mass Spectrometry) technique, as pioneered by Edwards (1988) to derive absolute ages on coral samples. It is now widely acknowledged as the first-choice dating method on which to base Glacial ^{14}C-calibration. Nevertheless, there do exist other dating techniques, which can be used not only for purposes of comparison, but also to fill the prevailing gaps. Due to their overall length and dating precision (based on annual counts), both the Arctic and Antarctic ice-core timescales seem promising for the envisaged extension of the calibration curve. In the Early and Middle Würm (i.e. beyond the limits of the ^{14}C-method), the chronological frame of the polar ice-cores is based on synchronisms with deep-sea sediment records (SPECMAP, Sowers *et al.*, 1993, to which absolute time-scales have been applied by direct (radiometric) dating techniques, by age-depth interpolation, and by application of astronomical theory (Kukla *et al.*, 1981 ; Martinson *et al.*, 1987). For ages younger than 55.6 ka, annual ice-layer counts are available both for the Greenland GRIP and GISP2 cores, giving two independent absolute time-scales. A remaining problem is that the GRIP and GISP2 time-scales are known to deviate to a certain extent (Sowers *et al.*, 1993 ; Bender *et al.*, 1997).

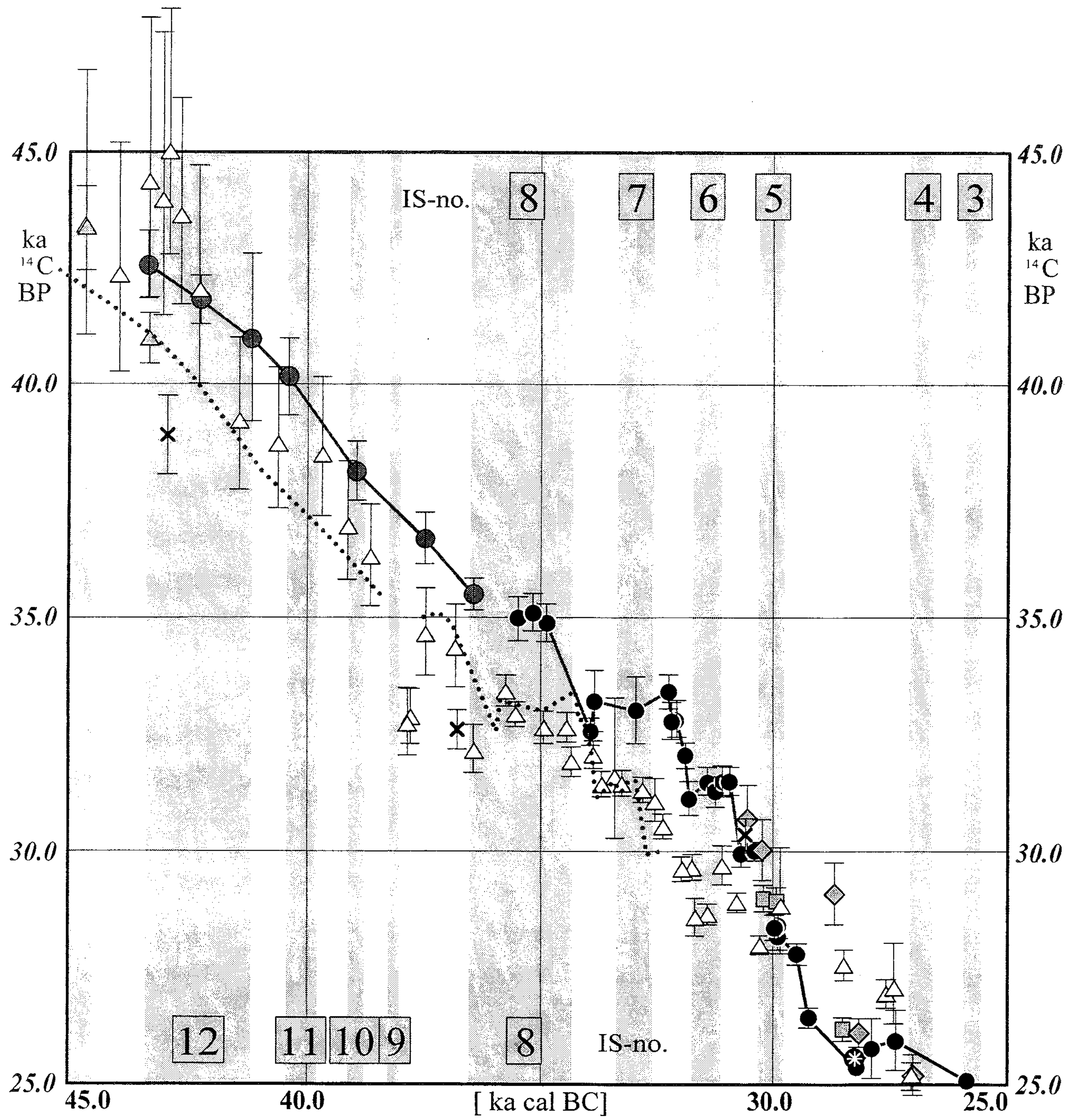

Fig. 2 : Data as in Fig. 1, but expanded timescale 25-45 calBC giving close-up view of data from Lake Suigetsu and PS2644. The data are seen to differ systematically by ca. 2000 calyr, for ages prior to 30 ka calBC. This may imply a (horizontal) shift of the early section of the Suigetsu varve chronology (solid lines) to older calendric ages (dotted lines). As an alternative, a (vertical) shift of the PS2644 data to older ^{14}C-ages (implying variations of marine reservoir values for foraminifera samples older than ca. 30 ka calBC), does not improve the data fit.

To circumvent such difficulties, but nevertheless retaining the wish to make use of the dating accuracy and precision offered by the ice-core chronologies, as an alternative ^{14}C-ages can be measured on the carbonate skeleton of marine foraminifera, in which case the calendric age of the dated samples may be derived independently via comparison and correlation with the ice-core ^{18}O/^{16}O records. The underlying idea here is to make use of all proxy data available from marine records e.g. ice-rafting detritus, foraminifera abundances, and δ^{18}O-measurements, in order to obtain a time-scale for the marine sediments via synchronisation with the ice-cores. The feasability of this approach has recently been demonstrated by Jöris and Weninger (1998), as well as by Völker *et al.* (1998), giving the results shown in Fig. 1. We observe good agreement between the marine ^{14}C-data, and the U/Th-measurements of Bard *et al.* (1993), and note that the timescales for the marine ^{14}C-data shown on fig. 1 are related to the GISP2-chronology. The GRIP timescale shows deviations from the U/Th-data, increasing with age. However, to complicate any hopes for a simple choice between ice-core timescales, for the later stages of IS1 through to the end of the Younger Dryas (not shown in fig. 1), it seems that the application of the GRIP timescale may be preferable over GISP2, as has been demonstrated by compiling a variety of tree-ring sequences, terrestrial and marine varves, and comparisons with the GISP2 and GRIP timescales in the Late Glacial (Jöris and Weninger, in press).

GLACIAL ^{14}C CALIBRATION DATA DERIVED FROM ANNUALLY LAMINATED LACUSTRINE SEDIMENTS

The most important drawback of ^{14}C-calibration data derived from coral and foraminifera samples (both from a marine habitat) is the necessity of applying a marine reservoir correction. This correction is often (pragmatically) assumed to be constant (ca. 400 BP), but is known to vary over the water surface of the globe e.g. from core to core, and presumably also through time, depending on many complex factors such as ocean circulation, sea surface temperature, and ice-coverage, all of which may influence foraminiferal habitat (Völker *et al.*, 1998). To check on the question of applying a constant reservoir correction to marine ^{14}C-data, it is most fortunate that carbon samples can be extracted from laminated terrestrial (lacustrine) sediments, which are not suscept to this problem. With the advent of AMS-dating, even minute (>50 µg) samples can be submitted for direct ^{14}C-measurement.

Recently, the existence of a lacustrine varve sequence from Lake Suigetsu (Japan) of unprecedented length and thus of major importance for Glacial extension of the ^{14}C-calibration curve has been demonstrated (Kitagawa and van der Plicht, 1998a and 1998b). The present state-of-research is that the Lake Suigetsu varves have been counted back to 36.0 ka calBC, with some 250 Radiocarbon dates now available (*cf.*, van der Plicht, this vol.). The Lake Suigetsu varve sequence covers the almost 30 ka long timespan from 6,880 to 35,980 calBC, with counting errors less than 1.5 % (Kitagawa and van der Plicht, 1998a) i.e. the age error is 437 yrs at 35,980 calBC. For older varves, annual counts are not yet available, but approximate calendric ages are derived relying on a constant sedimentation rate. Varve interpolation age error is estimated to be 2000 yrs around 40 ka (pers. comm. van der Plicht, 1998). It is fair to say that the Lake Suigetsu data (fig. 1) represents one of the most complete and detailed terrestrial records of atmospheric ^{14}C-variations during the Glacial periods presently available, and perhaps even for some time to come.

DISCUSSION : AGREEMENT AND DISCREPANCIES BETWEEN THE DIFFERENT GLACIAL ^{14}C CALIBRATION DATA SETS

For the entire range of overlap all marine data sets, reviewed here, are in good agreement until ca. 30 ka calBC (fig. 1). The few readily apparent outlying values are derived from the North Atlantic core ODP-644 (Fronval *et al.*, 1995). These outliers may be the result of technical difficulties in correlating the marine stratigraphy with the ice-cores for specific foraminifera samples (Jöris and Weninger, 1998, tab. 1). Most notably, with the exception of ODP-644, all marine ^{14}C/calendric age data pairs (with calendric ages derived from GISP2) also agree well with the U/Th-coral data. Thus, we have concluded (Jöris and Weninger, 1998), the U/Th-coral data give support to the GISP2 timescale (fig. 1).

For ages older 30 ka calBC only two extended records remain to give insight into Glacial Δ^{14}C-variations (figs. 2, 3) : First, the Japanese Lake Suigetsu varve sequence (Kitagawa and van der Plicht, 1998b). Second, the North Atlantic PS2644 foraminiferal core (Völker *et al.*, 1998). Both records deviate from the geomagnetic calibration curve and, in addition, deviate from each other for ages beyond 30 ka calBC (fig. 1). However, a close-up look at the data structure (fig. 2) implies good agreement, if the Lake Suigetsu varves could be shifted en-block to older ages by 2000 yrs for data prior to ca.30 ka calBC (fig. 3). This would either imply an unobserved 2 ka hiatus in the Lake Suigetsu varve sequence around 30 ka calBC (covered, in large, by the error estimate in the varve record), or else extreme Glacial variations of the ocean surface age correction for the Planktic foraminifera from PS 2644 (covered by complementary measurements showing unusal Benthic/Planktic ^{14}C-age inversions *cf.* Völker *et al.*, 1998). Futher studies are necessary to resolve these questions.

CONCLUSION

Evaluating the arguments pro and contra Glacial ^{14}C-calibration to be applied e.g. in Upper Palaeolithic chronology and corresponding palaeoenvironmental studies, there are important reasons which imply that even preliminary calendric conversion of Glacial ^{14}C-ages would seem more advisable than to await further data. First, Palaeolithic chronologies based simply on conventional ^{14}C raw-data are known to be wrong, with errors increasing with sample age, and amounting to many thousands of years for ^{14}C-ages at 30-45 ka BP. Using the available age conversion data would help in reducing this error, down to a more or less constant level of precision of ca. ± 1,000 yr around 45 ka BP (fig. 3), which for most applications is the end of the ^{14}C-scale. A second argument pro Glacial calibration is that a meaningful correlation of archaeological events with local/global palaeoclimate data can now already be achieved. To this purpose we have tested the GISP2 ice-core timescale, as mentioned above using the U/Th-ages, with satisfactory results. Finally, to switch back from the calendric to the uncalibrated ^{14}C-scale at the Younger Dryas/Holocene boundary, simply because this is where the present tree-ring sequences end, would introduce an artificial break between Late Palaeolithic and Early Mesolithic cultural traditions.

Nevertheless, the present state-of research is such that some type of compromise between our perhaps all too wishful (archaeological) hopes, and the technical limitations of the available empirical data, does seem necessary. Perhaps a reasonable compromise is to follow the recommendation of Pieter Grootes (pers. comm. 1998), that is to avoid the expression ^{14}C-calibration, which may be misleading for the Glacial periods, and instead proceed (cautiously) with calendric age conversion of Glacial ^{14}C-data. To conclude, ^{14}C-calibration (based on dendrochronology) is now possible in the case of Holocene ^{14}C-data, and (preliminary) calendric age conversion can be applied to Glacial ^{14}C-data, back to the limits of the Radiocarbon method. But the two cases are identical, at least from the view-point of engineering calibration methods applicable to archaeological ^{14}C-data, in that in both cases due care must be taken in the realistic evaluation of overall dating and age transfer errors.

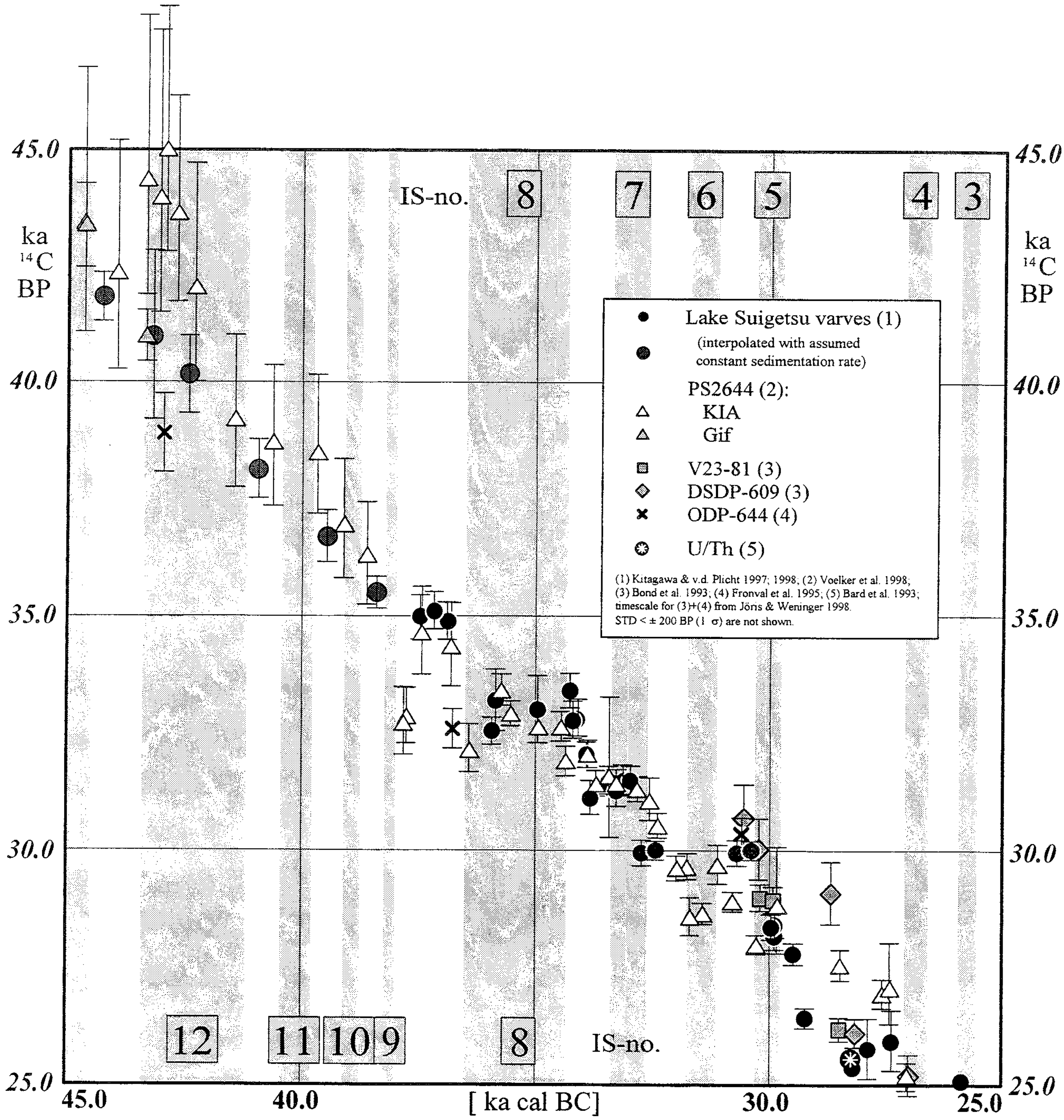

Fig. 3 : Expanded timescale 25-45 calBC. Data from PS2644 as in Fig. 2, but Lake Suigetsu ^{14}C-data shifted 2000 calendric yrs to older ages. With this shift, good agreement between PS2644 and Lake Suigetsu data is obtained. The two data sets, combined, confirm the existence of an extended (flat) ^{14}C-plateau at 32.0 ± 1.0 ka ^{14}C-BP, as predicted (Jöris and Weninger, 1998), but now recognisable as being even more devastating for archaeological applications because it contains inversions. The plateau has a total length of ca. 4000 calyr. It starts with a strong ^{14}C-age inversion around 38 ka calBC (32.5 ka BP), with a jump back to older ^{14}C values of 35 ka BP (ca. 37.5 calBC), before flattening out to values again ca. 32.5 ka BP (37-34 calBC).

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ARCHAEOLOGICAL AND GEOPHYSICAL EVIDENCE OF A 2400 YEAR CYCLE IN NATURAL PROCESSES DURING THE HOLOCENE

Valentin DERGACHEV and Ganna ZAITSEVA***

Abstract : At present, the radiocarbon calibration curve is extended into the Late Glacial. The most outstanding shape of calibration curve is around 300, 2400, 4500, 7500 and 9500 BP. Most of these "wiggles" in the calibration curve are caused by anomalously high values of the ^{14}C concentration which recur in a period of 2300-2400 years. Cycles in the ^{14}C concentration of different duration can be connected with alterations in the sun activity, the climate and the magnetic field of the earth. The highest amplitudes in the ^{14}C concentration seem to correspond to colder conditions during the Holocene. We examine the ~ 2400-year cycle in various natural records : reconstruction of temperature and rainfalls in several regions of Northern Eurasia from lake and bog sediments data, transgressions and regressions in the basin of the Baltic and Caspian seas, historical records of valleys and mountain glaciers advancing and retreating, ice core data, appearance of prehistoric man, and so on. In general, the variations observed on these data correspond to the 2400-year cycle observed in the variations of ^{14}C concentration.

Résumé : La courbe de calibration s'étend actuellement jusque dans le cours du tardi-glaciaire. Ses principales perturbations se situent autour de 300, 2400, 4500, 7500 et 9500 B.P. La plupart de ces « wiggles » correspondent aux plus fortes concentrations en C-14 dans l'atmosphère et peuvent être mis en parallèle avec les changements de l'activité solaire, du climat et du champ magnétique terrestre. On a pu constater que les fortes concentrations en C14 coïncident avec des périodes froides de l'Holocène. L'existence de cycles de 2400 ans a été vérifiée avec une haute précision dans des processus fort divers, notamment les variations de température et de précipitation, les transgressions et régressions des mers Baltique et Caspienne, les données des carottes dans les calottes glaciaires, les fluctuations des glaciers de montagne et l'expansion des peuplements humains.

Key-words : Radiocarbon variations, 2400-year cycle, Holocene climatic fluctuations, evolution of nature and society.

Mots-clés : Variations de la concentration du C14, cycles de 2400 ans, fluctuations climatiques de l'Holocène, évolution du milieu naturel et de la société humaine.

INTRODUCTION

The accuracy of dating based on radiocarbon depends both upon the accuracy of ^{14}C activity measurements and upon the fluctuations of the ^{14}C rate in the earth's past atmosphere. These fluctuations complicate the conversion of radiocarbon ages into calendar ages. The most outstanding shape of calibration curve is around 300, 2400, 4500, 7500 and 9500 BP. For these radiocarbon ages, precise radiocarbon measurements do not bring higher accuracy in radiocarbon dating. Wiggles in the calibration curve are caused by fluctuations of the ^{14}C rate in the earth's atmosphere, connected with large-scale changes in the sun activity, with the climate or with the magnetic field of the earth. Human civilization is very sensitive to climatic alterations.

The aim of the present paper is to find millennium-scale cycles in various natural processes during the Holocene, and try to connect these with human prehistory and climate fluctuations, as the course of human prehistory in the northern hemisphere is likely to have been influenced by climatic conditions.

A 2400-YEAR CYCLE IN RADIOCARBON RATE DURING THE HOLOCENE

A large number of publications deal with the spectral analysis of radiocarbon time series (e.g., Stuiver *et al.*, 1991 ; Damon and Sonett, 1992). Three types of variations are detected in the long-time series of atmospheric ^{14}C rate during the last *ca.* 11,400 years : 1) a long-term slow trend, 2) short-term (~11, ~22 years)

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and medium-term (~90, ~ 210 years) periodicities, 3) a longer, millennium-scale (~2400 year) cycle. Heliomagnetic modulation of the cosmic ray flux causes variations in the ^{14}C production rate on time scales from decades to hundreds of years. Akhmetkereev and Dergachev (1981) showed that ocean-related ^{14}C redistribution between carbon reservoirs as a result of long-term climatic change plays a minor role in the atmospheric ^{14}C variations compared with the geomagnetic field intensity during the Holocene. The 2300-2400 cycle shows more pronounced in the ^{14}C record after filtering of the raw data (fig. 1) (Dergachev *et al.*, 1996).

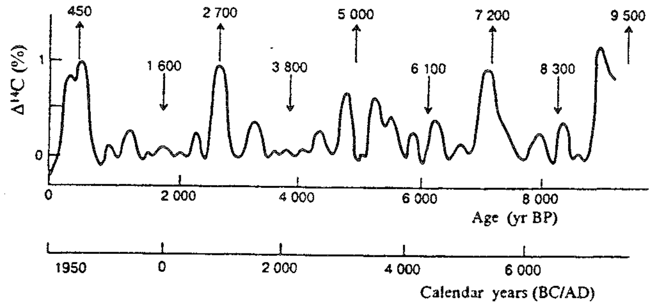

Fig. 1 : Large-scale variations of the radiocarbon rate during the past 10,000 years smoothed by the band-pass filtering. The arrows show the vicinity of extrema of the ~ 2400-year periods.

At present, an unambiguous quantitative interpretation of ~2400-year cycle cannot be made. It is possible that these changes occurring in the atmospheric ^{14}C rate are due to the complicated climatic processes and solar variability (Damon and Jirikowic, 1992). There are several references in which the 2400-year cycle is studied, both in the cosmogenic ^{14}C and regarding climate. Dergachev and Chistyakov (1993) showed that for the 2400-year cycle, the high amplitude of the ^{14}C rate in the tree-ring series correlates with a cooler climate, and the low amplitude with a warmer climate. In general, there is an inversed relation between the large-scale changes of solar activity and the ^{14}C rate, and a direct proportionality between these solar fluctuations and the global temperature. Furthermore, a 2400-year periodicity in the ^{14}C data strongly modulates the well-known sun 210-year cycle (Damon *et al.*, 1989).

The new and nearly continuous record of ^{10}Be data from the GISP2 Greenland ice core (Finkel and Nishiizumi, 1997) helps perceive the relation between the observed millennial-scale ^{14}C and ^{10}Be variations during the Holocene. Fig. 2 shows an expanded plot of the ^{10}Be rate for the period 5000-8000 cal BP (calibrated years before 1950 AD), which the authors interpret as a climatic effect. In the bottom of fig. 2, there is a ^{14}C rate (Stuiver and Reimer, 1993), expressed in $\Delta^{14}C$. We note two rather large events in the ^{10}Be rate at 5200-5600 and at 7100-7600 cal BP. The wiggles persist in both ^{10}Be and ^{14}C curves. These variations correlate well with fig. 1 and could indicate that they correspond to a cooler climate. Since ^{14}C is affected by biological and ocean circulation processes, whereas ^{10}Be is not, the observed ^{14}C and ^{10}Be variations might imply that the variations reflect real changes in solar activity and climate.

PATTERNS OF HOLOCENE CLIMATIC FLUCTUATIONS

The climate of the last 10,000 years falls within the interglacial part of the last glacial maximum. In the northern hemisphere, climatic data for the Holocene exist in documents, tree rings, lake and peat sediments, ice cores and so on. Detailed AMS radiocarbon chronologies for two North Atlantic cores indicate these cooling events recur on millennial time scales (Bond *et al.*, 1993).

Until recently, the Holocene climate was thought to be extremely stable with none of the abrupt variations that are characteristic for the cold climates of glacial times (Dansgaard *et al.*, 1993 ; Stuiver *et al.*, 1995). The most prominent events, rapid transitions from periods of cold stadials to warmer interstadials, reveal major changes only before the Holocene (Bond and Lotti, 1995). The authors found in marine sediments older than 10,000 years that the abundance of ice-rafted debris in sediment cores increase every 2000 to 3000 years. Such millennium-scale oscillations have sometimes been observed before, but the latest work shows a presence in the Holocene as well (Bond *et al.*, 1997).

Klimanov and Klimenko (1995) have reconstructed the temperature and precipitation rate in a number of regions of Northern Eurasia during the Holocene on the basis of data from lake and bog sediments. They deduced four warming maxima during the intervals : 6700-5700, 4500-3200, 2300-1600 years ago and during the 12th-13th centuries (the Medieval Climatic Optimum). These warm periods are separated by cold stages. It is also established that the largest amplitudes for both cooling and warming are found in the northern regions of Eurasia. Substantial global climatic changes are generally more pronounced at a higher latitude. Comparison between the series of generalized palaeoclimatic curves for the Holocene, based on a study of sediments from Karelia (Klimanov and Klimenko, 1995), and the temperature curve in the centre of the Russian Plain (Velichko, 1989) reveals that the warming periods generally correspond to the minima of the ~2400-year cycle in the tree-ring radiocarbon rate. Palaeoclimatic indicators are a proxy for regional and local weather parameters. Pollen evidence from a number of high-latitude localities indicates that mid to late Holocene temperature variations were generally less than 2°C, whereas ice core evidence indicates that the sharp early Holocene cooling event may have been up to 6°C cooler in Greenland (Alley *et al.*, 1997).

There are several elements indicating that temperature plays an essential role in the upper limit of the distribution of the forest. Changes in temperature can also lead to movements of the timberline. However, the effect of temperature changes is very complicated due to the influence on numerous physiological processes. The present state of palaeoclimatological research is mainly based on qualitative information. It is necessary to the study of the fluctuations in the arboreal and non-arboreal pollen analyses in local and regional sensitive areas. For its palynological palaeoclimate research, Burga (1993) used non-arboreal pollen analysis as an evidence for Holocene climatic fluctuations in the European Central Alps. Fig. 3 shows the relation between records of non-arboreal pollen phases at different altitudes and during different times. The areas located at a higher altitude show cyclic palaeoclimatic changes. The magnitude of climatic oscillations during the Holocene was different and decreased from the Early Holocene to the present time.

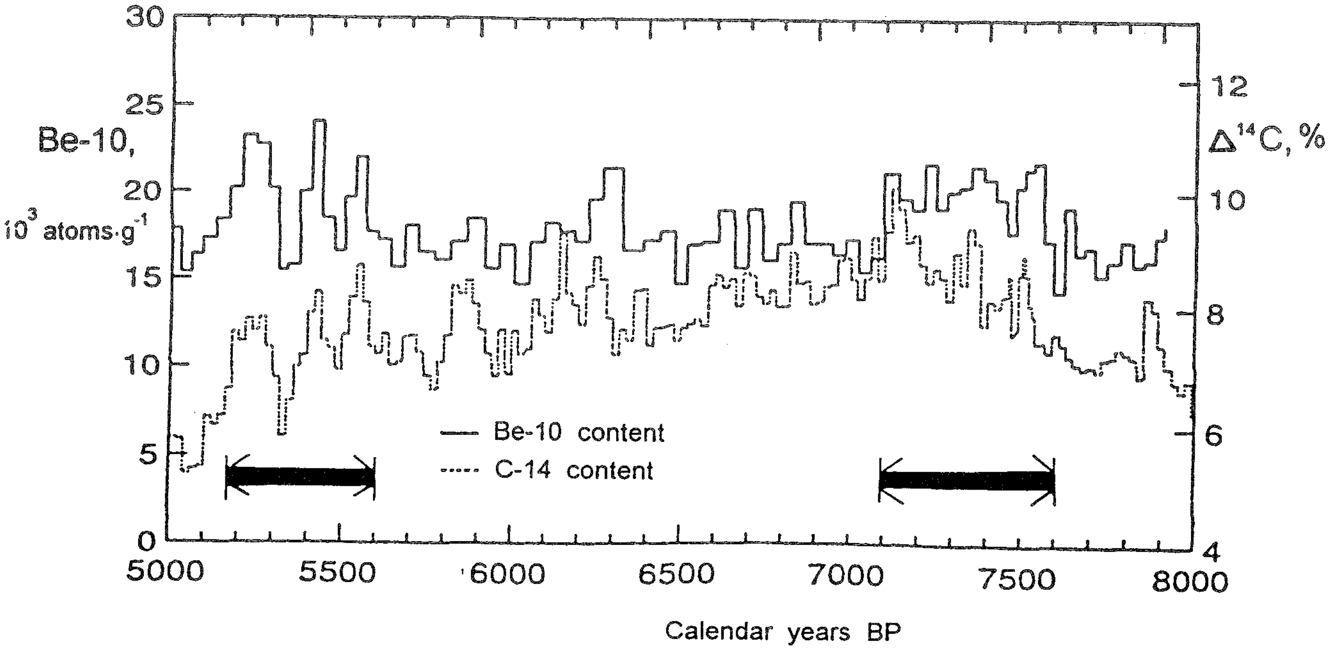

Fig. 2 : Beryllium-10 rate (atoms per gram of ice) in the GISP2 ice core compared with radiocarbon rate (per mil) in tree-rings for the time between 5000 and 8000 cal BP. Data from Finkel and Nishiizumi (1997). In the bottom part of the figure two intervals of increased rate of cosmogenic isotopes are marked.

Numerous ^{14}C dates obtained for subfossil pines found above the present pine limit in Swedish Lapland and Southern Sweden indicate that the favourable conditions for the pines were a sequence of cyclical climate changes at about 4000, 6000 and 8000 BP (Karlen, 1976 ; Kullman, 1990b). The climatic evidence from Northern Fennoscandia (Eronen and Hyvarinen, 1982) and Southern Sweden (Kullman, 1990a) indicate a long-term cyclical climatic deterioration at about 7000, 5000 and 3000 BP. However, there is always a risk that one precise element of anthropogenic "noise" was introduced into the palynogical record. Therefore, archaeological information has to be taken into account as well.

Rothlisberger (1986) published a record of glacial fluctuations in both the northern and southern hemispheres from 12 regions for the past 10,000 years. Apparently, glaciers behave very similarly near-synchronous word-wide in their reaction to major climatic changes, leading to the belief that they represent global climatic effects. A comparison between these glacial fluctuations with secular changes in cosmogenic radiocarbon rate showed that glacial retreats and advances occur at a time when ^{14}C rate is high. As a consequence, millennium-scale radiocarbon rate fluctuations could be an indicator for glacial oscillations.

Dergachev and Chistyakov (1993, 1995) examined the appearance of the ~2400-year cycle in different solar-terrestrial phenomena : they reconstructed temperature and rainfalls in a number of regions of Northern Eurasia based on data from lake and bog sediments, transgressions and regressions in the basin of the Baltic and Caspian seas, historical records of valley and mountain glacier advances and retreats, ice core data, first settlements of man, and so on. Most of the observed variability from

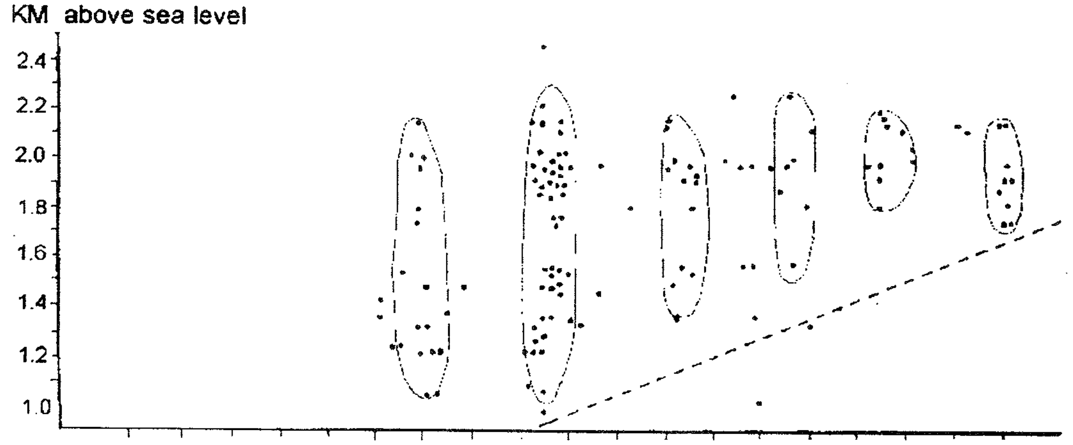

Fig. 3 : Records of non-arboreal pollen (NAP) phases for Swiss Central Alps and Prealps during the Holocene. The extended intervals of NAP phases are displayed. The dotted line is the boundary for climatic fluctuations.

these numerous natural records corresponds to a 2400-year cycle in the variations of ^{14}C concentration.

New terrestrial, marine and ice core data document the abrupt changes during the warm interglacial climate of the last 12,000 years. These Holocene palaeoclimate records indicate that the Holocene was punctuated by a series of millennial-scale cooling events. Glaciochemical time series developed from Summit, central Greenland document extended periods of winter-like conditions during the periods AD 1900-1420, 450-1150 BC, 3050-4150 BC, 5850-6850 BC and 11,300 to 12,900 years ago (O'Brien *et al.*, 1995). The most recent increase, and also the most abrupt one, coincides with Little Ice Age. These events may correlate with glacial ice advances during the Holocene in Greenland and mountain glaciers.

Using several independent spectral analysis techniques for study of ice cores from both hemispheres, Yiou *et al.* (1997) found recurrent common patterns between Greenland and Antarctica. They also established the significant oscillations of the Holocene period and concluded that these oscillations could hardly be associated with glacial events or ice sheet oscillations.

These new results document significant climate instabilities during "our time".

LITTLE ICE AGE MODES IN NATURAL DATA DURING THE HOLOCENE AND THE IMPACT OF CLIMATIC FLUCTUATIONS ON MAN

Historical evidence indicates that the estimated ~ 1° - 2 °C Little Ice Age (LIA) cooling (from about 1400 to about 1900 AD) was sufficient to choke European ports with sea ice, freeze European rivers, force abandonment of Viking colonies in Greenland and cause glaciers to overrun alpine village (Bond *et al.*, 1993 ; Dansgaard *et al.*, 1993).The LIA coincides with the Maunder minimum in sunspot activity and with an increase of the ^{14}C rate amplitude (fig. 1). Because the LIA happened relatively recently, it has the best geographic monitoring. This allows us to make some generalizations that may be applied to other similar oscillations. The study of these oscillations may contribute to a greater understanding of the climate of cold periods and of the possible climatic influence upon human migration.

The availability of precise dating by tree rings, especially the numerous historical data in Europe, suggests that during the LIA glacial fluctuations were nearly synchronous in the European Alps and in all mountainous regions in the world (Grove, 1988). Kuniholm (1990) discusses archaeological evidence for climate change in Mediterranean and Aegean archaeology. This oscillation mode of 2400 years runs through the Holocene.

The following increase in the level of ^{14}C rate back in time happens at 750-850 BC (fig. 1). In addition, an increase of the ^{10}Be rate (Beer *et al.*, 1991) in ice cores, and climatic cooling is observed at this time interval (Kilian *et al.*, 1995). Based on archaeological, palaeoecological and geomorphological data, van Geel *et al.*, (1996) showed evidence of a global climate change around 800 B-C in both hemispheres.

To assess the role of climate change in three different cultural transformations which took place in north-western Alaska during the mid to late Holocene, Mason and Gerlach (1995) examined the existing palaeoenvironmental evidence from Alaska. They investigated to understand which environmental and ecological parameters influenced organizational processes of stability and changes of these cultural transformations. The authors concluded that coastal sites were more intensively occupied during the warmer periods before 1200 BP (the short-term warmer weather prevailing during 4000-3000 and from 1700-1200 BP), while inland areas were occupied more intensively during the short-term cooled periods prevailed at 3300-3000, 2000-1700, 1200-800 and 600 200 BP. The archaeological record shows that climatic changes caused the migration of peoples. However, in spite of many correlations at the appropriate temporal and spatial scales between various cultures and climate change, archaeological evidence for climate change is still disputable. Concerning the relation of migration of peoples with climatic changes, it is necessary to stress that numerous facts may have happened : catastrophic, epidemic, economic, and so on.

Strong contradictions occur in the next 2400-year interval (around 4500 BP), and therefore it is impossible to conclude unambiguously that climatic change was followed by regular events as mentioned above. Furthermore, the pattern of the 2400-year interval in the radiocarbon rate is strongly jagged. It means that the short cold saw tooth-like pulses can be possible during the warmer period of the Holocene. Rothlisberger (1986) showed that the widespread "Neoglacial" cooling happened between 3500 and 4500 BP. This cold period in Europe, lasting from about 4500 BP to 2500 BP, is superimposed with the development of civilization ; it is called the Iron Age cold period.

Ivanov and Vasiliev (1995) studied the natural evolution of the sandy region of the Near-Caspian Lowland as well as the settling of tribes and peoples on this territory during the Holocene. This region is very sensitive to sharp climatic changes. The authors noted that during the interval 5000-6000 years ago (Neolithic epoch), atmospheric rainfalls were heavier compared with the present ones, and that a population from the steppes settled there. During the 2700-1700 BC interval (Early and Middle Bronze periods), climate became more continental, causing the migration of tribes. Humidification happened during the 1300-600 BC time interval, and the density of population increased. There was no settled population during the aridization era in 300-1200 AD. In the last period, from 1300 to 2000 AD, humidification increased. In this region, there is usually evidence for a co-evolution of both nature and society in connection with climatic changes. It seems necessary to find new detailed data from different locations for this time interval.

CONCLUSION

Millennial scale fluctuations of cooler climate occured during the Holocene, and in some cases, there is archaeological evidence for climate changes. It is necessary to re-evaluate archaeological data, especially from sites and regions that can provide high-resolution records and good chronologies.

The most prominent events recur about every 2300-2400 years and may correlate with Holocene glacial ice advances in Greenland, Scandinavia and northern Europe. It is also important to correlate data from different areas in order to determine the levels of global or regional variability of climate. This may allow us to evaluate the role of environmental change on the past, present, and future human civilizations.

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DATATIONS RADIOCARBONES ET ÉTALONNAGE DENDROCHRONOLOGIQUE DES PÉRIODES PRÉHISTORIQUES DANS LE BASSIN PARISIEN : L'EXEMPLE DE PARIS-BERCY (France)

*Vincent BERNARD**

Résumé : La mise en place d'un référentiel dendrochronologique des périodes préhistoriques dans le nord de la France a été largement favorisé par le développement de l'archéologie de sauvetage. Cette étude porte sur l'analyse de plus de 360 échantillons de chêne, provenant de 10 sites du Bassin parisien. 260 séquences dendrochronologiques ont été intégrées dans différentes moyennes de sites et grâce au canevas des datations C14, plusieurs chronologies ont pu être constituées et datées. Une centaine de séquences composent actuellement trois références pour le Mésolithique, le Néolithique moyen et final.

Abstract : The building of a tree-ring chronology on prehistoric periods in north of France has been largely encouraged by recent archæology. This present study is based on the analysis of over 360 oak samples coming from 10 sites within the Parisian basin. 260 tree-ring sequences have been integrated in different mean chronologies and radiocarbon dating has been very helpful to date first local chronologies. About a hundred of these samples at present form three standard chronologies on Mesolithic, middle and late Neolithic.

Mots-clés : Dendrochronologie, datation C14, Bassin parisien, Néolithique.

Key-words : Tree-ring dating, radiocarbon dating, Parisian basin, Neolithic.

1 - CADRE DE LA RECHERCHE

La multiplication des travaux dans les vallées et les plaines alluviales du nord de la France a entraîné, depuis plus de 20 ans, la mise en place de programmes de surveillance et de sauvetage archéologiques. En tant que participant à un tel projet sur la vallée de l'Oise, nous avons échantillonné depuis 1987 la totalité des troncs subfossiles extraits des sablières, de même que l'ensemble des pièces de bois exhumées à l'occasion des fouilles menées dans cette zone. Par exemple, sur le site protohistorique d'Houdancourt (Oise), environ 80 troncs de chênes ont été prélevés dans le fond d'un paléochenal détruit lors de l'exploitation d'une sablière.

Ces chênes subfossiles, qui correspondent de toute évidence à des dépôts naturels, présentent de nombreux avantages pour constituer une chronologie préhistorique. Ces arbres sont tombés sur place, comme l'atteste très souvent la présence d'aubiers intacts. En effet, cette partie, la plus fragile du bois, a tendance à disparaître facilement. Ces individus subfossiles, découverts ensemble et souvent en grand nombre, ont donc réagi de la même façon aux conditions générales lors de leur développement. Une chronologie locale, mise en place dans ce type de contexte, pourra ainsi trouver une origine géographique précise, d'autant plus précieuse lorsque l'on veut suivre l'évolution d'un milieu ou d'un climat dans une région particulière. De plus, avec un signal climatique fort et un nombre de cernes relativement élevé, les séquences tirées de ces chênes sont bien souvent faciles à synchroniser.

Actuellement, nous poursuivons l'échantillonnage de ce matériel. Les séquences, qui ne sont pas encore datées de façon absolue, intègrent la banque de données régionales et sont confrontées aux autres chronologies moyennes, dès que de nouvelles données nous parviennent. Ainsi, toutes ces séquences participeront, prochainement, à la mise en place d'un référentiel préhistorique continu.

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Dans le Bassin parisien, les échantillons dont nous disposons à l'heure actuelle proviennent de 10 principaux sites répartis le long des vallées de l'Oise et de la Seine. Un millier d'échantillons environ ont été prélevés pour le Mésolithique et le Néolithique dans divers paléochenaux et sites archéologiques (fig. 1). Nous avons mesuré aujourd'hui 360 séquences, dont 260 sont intégrées à des moyennes, datées ou non.

2 - MÉTHODE

Pour établir des chronologies locales de base, nous avons comparé chaque série de cernes avec toutes les autres appartenant au même site. Chaque séquence individuelle est, en fait, la moyenne de deux ou trois rayons. Cette moyenne par échantillon permet d'atténuer l'imprécision de la mesure et la représentativité médiocre du rayon au regard de la croissance réelle. Cette procédure a été suivie jusqu'à ce que des groupes d'arbres synchronisés soient isolés. Dans la recherche des synchronismes, nous avons utilisé le test «W» et le calcul de la distance euclidienne (Gassmann *et al.*, 1996). Aucune transformation n'a été appliquée aux données brutes. Grâce à ce premier «filtre», nous avons écarté les échantillons présentant des croissances trop marquées. Ceci nous assure une certaine sécurité dans les montages successifs des séquences. De plus, nous n'avons pris en compte que les «W» supérieurs à 3,60 (risque d'erreur de 1 pour 10 000).

Une fois les chronologies locales élaborées, toute la difficulté réside dans leur mise en synchronisation, en vue de constituer une référence régionale. Cette étape ne peut pas être dissociée des datations par radiocarbone effectuées sur les échantillons traités en dendrochronologie, ou sur des éléments issus du même contexte. Dans toute la mesure du possible, nous avons fait faire des datations C14 conjointement à l'analyse dendrochronologique. Malheureusement, cela n'a pas pu être vraiment systématique. La confrontation de datations obtenues par C14 et par dendrochronologie sur un même échantillon révèle parfois des écarts importants. Aussi, lorsqu'une moyenne de site est constituée, et seulement à ce stade du travail, nous sélectionnons sur deux échantillons datés en chronologie relative quelques cernes de bois (5 à 10) situés dans l'aubier, par exemple, pour les soumettre à une datation C14. Après quoi, il est possible de comparer les résultats C14 entre-eux, puis les résultats C14 et la datation dendrochronologique, et enfin, les résultats obtenus avec le calage typo-chronologique (fig. 2). Par déduction, il est alors possible d'avancer une proposition de datation pour la chronologie locale, dans la mesure où les référentiels dendrochronologiques le permettent.

Le second point à éclaircir est de savoir si les chronologies préhistoriques établies sur le Bassin parisien sont fiables et si leur datation est définitivement acquise. L'échelle du temps pour ces périodes est donnée par la courbe de référence allemande «A200» (Université de Stuttgart-Hohenheim ; Becker *et al.*, 1985). Cette référence comporte environ un millier de bois provenant, pour la plupart, de terrasses alluviales du Rhin, du Danube, du Main et de Suisse. Néanmoins, nous avons pu mesurer à plusieurs reprises la parfaite cohérence de l'étalon de Stuttgart.

Une mise en commun des données néolithiques du Jura français et suisse a été effectuée à Besançon (Lambert, 1993). Cette courbe, qui regroupe notamment les chronologies de Clairvaux-les-Lacs et de Chalain en France, et de Hauterive-Cortaillod en Suisse, constitue un solide relais aux datations opérées dans le Bassin parisien. En effet, en dépit de synchronisations parfois peu éloquentes visuellement, certaines signatures (suite d'années caractéristiques) significatives atténuent le bruit de fond pour permettre de dater sans ambiguïté des séquences issues des vallées du nord de la France, même assez courtes (Bernard *et al.*, 1998).

On comprendra qu'une bonne définition préalable du contexte archéologique est indispensable à la datation dendrochronologique. La collaboration entre archéologue et dendrochronologue est donc souhaitable et sans doute nécessaire.

3 - RÉSULTATS

En 1998, les chronologies préhistoriques construites à partir de chênes subfossiles du Bassin parisien se regroupent autour de trois périodes principales :

3.1 - La première chronologie, longue de 521 ans, est attribuée au Néolithique final. Cette moyenne est com-

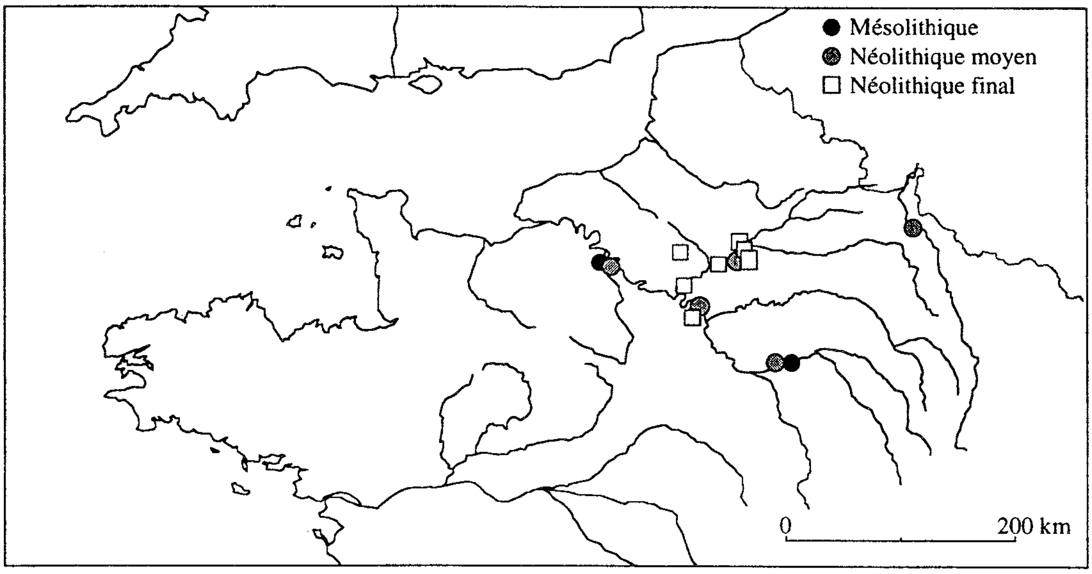

Fig. 1 : Localisation des sites préhistoriques du Bassin parisien étudiés en dendrochronologie.
Fig. 1 : Location of prehistorical sites in the Parisian basin studied in dendrochronology.

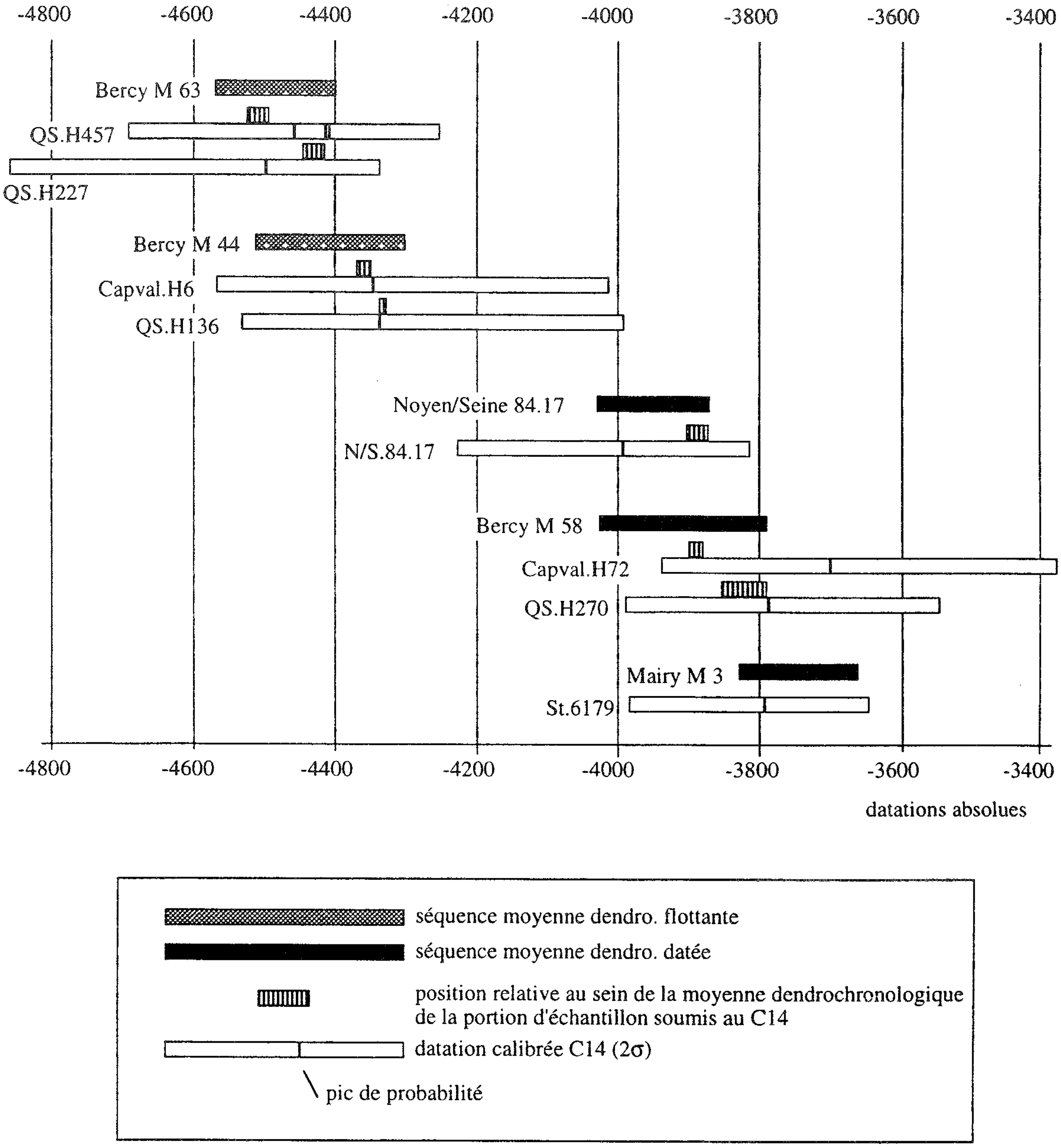

Fig. 2 : Datations dendrochronologiques et datations C14 pour les sites du Bassin parisien attribuables au Néolithique moyen. La calibration des datations C14 a été effectuée au moyen du programme Stuiver et Reimer, 1993. Les limites de l'intervalle standard de $\pm 2\sigma$ ont été présentées avec les pics de probabilité.

Fig. 2 : Tree-ring and radiocarbon dating for middle neolithical sites of the Parisian basin. Radiocarbon calibration has been made with the software «Stuiver and Reimer, 1993». We have represented the $\pm 2\sigma$ standard interval with peaks of probability.

posée de 45 échantillons provenant de 7 sites. Elle couvre la période comprise entre 3228 et 2708 av. J.-C. Sa couverture moyenne est de 7 cernes par an.

3.2 - La deuxième chronologie, longue de 366 ans, est attribuée au Néolithique moyen. Cette moyenne, appelée «Néolithique Moyen Bassin parisien 5» («NéoMBP 5»), est composée de 18 échantillons provenant de 4 sites. Cette séquence couvre encore de façon virtuelle la période comprise entre 4027 et 3662 av. J.-C. Cette chronologie correspond, en fait, à un assemblage de 2 moyennes principales, datées indépendamment. A l'appui de datations dendrochronologiques relayées par plusieurs datations par radiocarbone, nous avons regroupé les 4 moyennes de sites pour ne former qu'une courbe, malgré des jonctions parfois très courtes. Cette chronologie doit donc être utilisée avec prudence, comme le souligne E. Jansma (1995, 55) : «when the Mean Correlation Technique is applied to long chronologies that largely consist of series that do not overlap at all, it is therefore advisable to treat the results with caution» (lorsque de longues chronologies, constituées essentiellement de séquences dont les recouvrements sont inexistants, il est donc conseillé d'utiliser les résultats avec précaution). Nous comptons, bien évidemment, sur de nouvelles études dendrochronologiques pour confirmer et améliorer l'étalonnage de cette courbe. Sa couverture n'est, en effet, que de 4,5 cernes par an.

3.3 - La troisième chronologie, longue de 265 ans, est attribuée au Mésolithique. Elle est composée de 13 échantillons provenant de 2 sites. Les calages chronologiques dont nous disposons à l'heure actuelle pour cette séquence ont été obtenus par C14.

4 - L'EXEMPLE DE PARIS-BERCY

L'opération archéologique, menée à l'emplacement des anciens entrepôts à vin de Paris-Bercy, a permis de suivre la fréquentation des berges de la Seine pendant le Néolithique. D'importants rejets de matériel au fond d'un chenal fossile mettent en évidence des occupations prolongées de cette zone depuis le Néolithique moyen («Cerny») jusqu'au Néolithique final («Seine-Oise-Marne»). Les vestiges les plus nombreux, associés à des structures d'habitat, sont attribuables culturellement au «Chasséen» (Lanchon, 1994).

Les niveaux de comblement du chenal ont piégé de grandes quantités de pièces de bois, parmi lesquelles figurent un arc en if, une dizaine de pirogues en chêne, et un aménagement de berge (appontement ?) constitué de pieux de chêne. Des poches de matériel chronologiquement homogène ont également conservé des troncs flottés (Chêne et Frêne), qui sont à la base des séquences dendrochronologiques établies à Paris-Bercy. A l'issue de l'étape de synchronisation des séquences individuelles, quatre moyennes principales se sont distinguées : trois pour le Néolithique moyen et une pour Néolithique final.

- la moyenne «Bercy 40» : Parmi les pirogues découvertes à Bercy en 1992 (Lanchon, *op. cit.*), la pirogue 3 a fait l'objet de trois datations par radiocarbone. Les résultats sont les suivants :

(GIF-9226) : 4180 ± 50 BP = [2892 (2868, 2805, 2770, 2719, 2703) 2585] cal. BC

(GIF/LSM-9226) : 4140 ± 20 BP = [2870 (2856, 2818, 2690, 2688, 2665, 2632, 2629) 2612] cal. BC

(Ly-6023) : 4125 ± 55 BP = [2881 (2852, 2824, 2657, 2642, 2623) 2494] cal. BC

Ces fourchettes de datations convergent toutes pour placer cette embarcation dans le Néolithique final. 266 cernes ont pu être mesurés, dont 30 cernes d'aubier. 4 échantillons provenant du paléochenal ont été synchronisés à cette séquence pour donner la moyenne appelée «Bercy 40». Malgré les datations avancées par les C14 et l'abondance de références dendrochronologiques régionales, nous ne pouvons pas proposer de datation pour «Bercy 40» (Gassmann *et al.*, *op. cit.*). Le recouvrement avec les moyennes datées des autres sites est sans doute encore trop court pour livrer un élément de réponse dendrochronologique.

- la moyenne «Bercy 44» regroupe 12 individus pour une longueur de 210 ans. Un très bon résultat de datation a été obtenu à partir de la référence dendrochronologique établie sur le Jura français et suisse, appelée «Jura Néolithique 5» (Lambert, 1993) : en valeurs naturelles, le test «W» s'élève à 5 (risque d'erreur <1 sur 250000). Le contrôle visuel sur table lumineuse révèle un bon niveau de concordance entre «Bercy 44» et les références néolithiques («JuraNéol.5» et «A-200») à la date de 3764-3458 av. J.-C. Pourtant, les datations C14 pratiquées à partir de deux échantillons provenant de «Bercy 44» nous donnent un tout autre éclairage :

CAPVAL.H6 (Gd-6943) : 5500 ± 120 BP = [4567 (4345) 4010] cal. BC

QS.H136 (Gd-6944) : 5460 ± 120 BP = [4531 (4334) 3993] cal. BC

Une proposition de datation concurrente à celle de 3764-3458 av. J.-C. est donnée par l'étalon «JuraNéol.5». Il placerait ainsi le premier cerne de «Bercy 44» en 4213 et le dernier cerne en 4004 av. J.-C. (fig. 3). Bien sûr, cette proposition de datation correspond mieux au cadre chronologique des radiocarbones. Cependant, nous rappelons que le référentiel utilisé dans ce cas débute en 4086 av. J.-C. Le recouvrement des deux séquences n'est donc que de 83 ans. Dans l'attente de nouvelles chronologies, nous proposerons donc, mais avec réserve, la date de 4213 à 4004 av. J.-C. pour «Bercy 44».

- La moyenne «Bercy 58» est longue de 235 ans et regroupe 13 échantillons dont 8 proviennent de «Quartier Sud». La position stratigraphique et topographique très cohérente des bois qui composent «Bercy 58» placerait cette chronologie dans une phase du Néolithique moyen. Une bonne proposition de datation, 4023-3789 av. J.-C., est donnée par le référentiel de Stuttgart «A-200» pour cette moyenne (fig. 3). Bien qu'aucune confirmation ne puisse être apportée par d'autres références dendrochronologiques, les C14 opérées sur deux échantillons de cette moyenne conforteraient cette attribution chronologique. Les résultats C14 sont les suivants :

CAPVAL.H72 (Gd-6950) : 4860 ± 100 BP = [3931 (3647) 3374] cal. BC

QS.H270 (Gd-6946) : 5000 ± 100 BP = [3986 (3782) 3547] cal. BC

Cette chronologie peut être mise en relation directe avec l'occupation chasséenne du site.

- La moyenne «Bercy 63», de 172 ans, comporte 11 individus. Elle n'a pas pu être datée à partir des différentes références néolithiques disponibles dans notre banque de données. Les datations par radiocarbone portant sur deux échantillons intégrés à «Bercy 63» placeraient ces éléments de la chronologie dans la phase d'occupation attribuée au «Cerny», un peu plus ancienne que celle définie par «Bercy 44» :

QS.H457 (Gd-7405) : 5600 ± 100 BP = [4687 (4455, 4411, 4408) 4248] cal. BC

QS.H227 (Gd-6949) : 5670 ± 90 BP = [4755 (4496) 4343] cal. BC

Ceci explique l'absence de proposition dendrochronologique acceptable pour cette période du Néolithique.

BILAN ET PERSPECTIVES

Dans ce long travail d'élaboration d'une courbe de référence dendrochronologique, nous avons opté pour l'analyse par radiocarbone d'un nombre restreint de cernes. Malheureusement, pour des raisons de coût financier, la mise en œuvre de méthodes performantes, telle que la mesure d'activité C14, par exemple tous les 10 cernes («wiggle matching»), sur des séries de quelques centaines d'années calées sur les enregistrements dendrochronologiques C14 n'a pu être effectuée. De ce fait, si les datations carbone 14 n'infirment pas nos calages dendrochronologiques en raison des larges intervalles des dates calibrées, elles permettent néanmoins, dans l'amalgame des troncs recueillis au sein d'un paléochenal, de distinguer les bois du Néolithique moyen de ceux du Néolithique final.

On s'étonnera tout de même des marges d'erreur importantes des datations C14, pourtant effectuées à partir d'un nombre restreint de cernes. En effet, le nombre des échantillons qui devaient être confiés au C14 avait été limité au préalable par l'étude dendrochronologique ; elle déterminait ainsi les dendro-groupes à caler dans le temps et permettait de situer précisément les cernes datés par rapport à l'échantillon d'origine et par rapport à la séquence moyenne à laquelle l'échantillon s'intègre. On

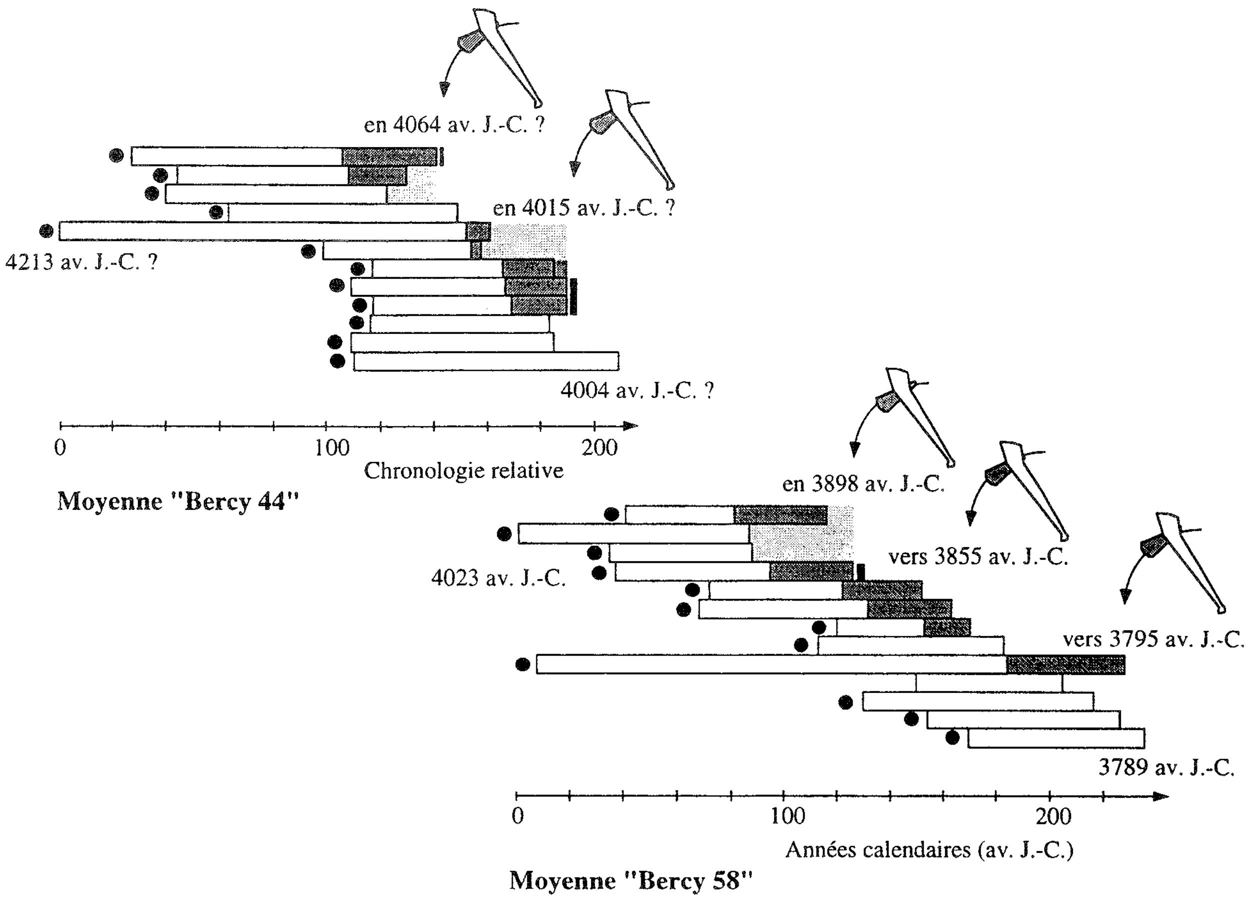

Fig. 3 : Bloc-diagramme des moyennes dendrochronologiques «44» et «58» de Paris-Bercy. La présence de la moelle est signalée par un point noir, celle de l'aubier par un rectangle gris-foncé ; en gris-clair, les estimations de phase d'abattage.
Fig. 3 : Bar chart of tree-ring mean chronologies «44» and «58» from Paris-Bercy, with marked pith (black circle left), sapwood (dark grey area right) and estimated sapwood (light grey area).

obtient ici des analyses C14 avec des âges moyens très approximatifs, alors que la précision aurait sans doute pu atteindre ± 20 ans.

Les C14 pratiqués sur des bois découverts à Paris-Bercy et intégrés à d'autres moyennes révèlent l'existence de séquences dendrochronologiques situées entre 4800 et 4200 av. J.-C. et entre 3500 et 3000 av. J.-C. La mise en place d'un référentiel continu pour le nord de la France et couvrant les Ve, IVe et IIIe millénaires avant notre ère est en bonne voie d'accomplissement. L'absence de courbe dendrochronologique de référence au delà de 4100 av. J.-C. marque actuellement les limites de notre entreprise. Désormais, nous devons impérativement obtenir des échantillons de périodes spécifiques, de façon à combler les hiatus de cette chronologie préhistorique. Ceci ne semble pas insurmontable, au regard de l'extraordinaire potentiel en site humide que dévoile chaque jour un peu plus cette région.

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Actes du colloque « C14 Archéologie », 1998, p. 105-111.

THE «DATING» OF THE TINIÈRE TRENCH BY A. MORLOT IN 1856-1866 : ONE OF THE FIRST ATTEMPTS OF ABSOLUTE DATING IN ARCHEOLOGY AND QUATERNARY GEOLOGY

Philippe SCHOENEICH et Pierre CORBOUD***

Summary : Between 1856 and 1866, the building of the Simplon railway led to the digging of a deep trench through the alluvial cone of the Tinière river, at Villeneuve, at the upper end of the Lake of Geneva. The trench uncovered three remarkably parallel archeological layers which have been attributed to the roman period, the end of the Bronze age and the Neolithic respectively. Basing on the depth of sediment accumulated over the roman level of known age and on the perfect parallelism of the layers, the geologist and archeologist Adolphe Morlot calculated the age of the Bronze Age and of the Neolithic, for which he obtained values of 3 to 4000 years and of 5 to 7000 years respectively, and of about 10,000 years for the whole holocene alluvial cone. These estimations represent one of the very first tentatives of absolute dating, as well in prehistoric archeology as in quaternary geology, and they caused a very large stir. Almost 140 years later, the accumulated knowledge on the age of the archeological periods shows that Morlot's estimations were remarkably right, despite of the unaccuracy of the method he used. Archeological verifications, a better knowledge of the sedimentological context and a radiocarbon date show that these results had been obtained on the base of partly erronous data.

Résumé : Entre 1856 et 1866, la construction de la ligne de chemin de fer du Simplon entraîna le creusement d'une profonde tranchée à travers le cône de déjection de la Tinière, à Villeneuve, à l'extrémité amont du lac Léman. La tranchée mit au jour trois couches archéologiques remarquablement parallèles à la surface du cône, et attribuées respectivement à la période romaine, à la fin de l'Age du Bronze et au Néolithique. Partant de l'épaisseur de sédiments accumulés sur la couche romaine d'âge connu et du parallélisme parfait des couches, le géologue et archéologue A. Morlot a calculé l'âge des couches du Bronze et du Néolithique, pour lesquelles il obtient des valeurs respectives de 3 à 4000 ans et de 5 à 7000 ans, et de 10 000 ans environ pour le cône holocène entier. Ces estimations représentent une des toutes premières tentatives de datation absolue, tant en archéologie préhistorique qu'en géologie du Quaternaire, et elles eurent un large retentissement. Près de 140 ans plus tard, les connaissances accumulées sur l'âge des périodes archéologiques montrent que les estimations de Morlot sont remarquablement justes malgré la méthode utilisée. Des vérifications archéologiques, une meilleure connaissance du contexte sédimentologique et une datation ^{14}C montrent que ces résultats ont été obtenus sur la base de données en partie erronées.

Key-words : Science history, absolute dating, sedimentation rates.

Mots-clés : Histoire des sciences, datation absolue, taux de sédimentation.

INTRODUCTION

The question of dating was central since the beginning of geology, and even more in archeology. The first absolute dating attempts were all based on sedimentation rate calculations. The case we present here was one of the very first age calculations in the field of archeology and Quaternary geology, and probably the most famous of the 19th century. It is due to the geologist and archeologist Adolf Morlot (fig. 1), in 1856-1866.

In 1856, the construction of the Simplon railway lead to the digging of a trench through the alluvial cone of the Tinière river, at Villeneuve, at the upper end of the Lake Leman (Lake of Geneva, fig. 2). Three fossil soil layers with archeological artifacts were found at different depths below the surface of the cone. Morlot took the opportunity to make observations, and then followed the works step by step during ten years. This site gave him the material for age calculations of the mean archeological periods and of the Holocene. This famous

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Fig. 1 : Adolphe Morlot, from his full name Karl Adolf von Morlot (22.3.1820-10.2.1867). He contributed pioneer work to both Quaternary geology and prehistoric archeology. Photograph taken in 1862 (Bernisches Historisches Museum).

case has allready been discussed by Wolf (1993). New investigations in the personal archives of Morlot and in the archeological collections allow us to give new highlights on the data and to try a verification of Morlot's conclusions.

THE OBSERVATIONS

The Tinière river has actually three cones (fig. 2) :

- a great fossil perched cone, called «diluvial» cone by Morlot, representing an ancient delta sedimented at a higher lake level during the Lateglacial ;
- a smaller stacked cone, called «modern» cone by Morlot, representing the Holocene sedimentation ;
- a «recent» cone, superposed to the right side of the «modern» cone, due to the deviation of the river by damming in the 16th or 17th century, and representing the recent historical sedimentation.

The railway trench cuts through the «modern» and the «recent» cones, but all the depth indications are related to the surface of the «modern» cone. The works for the railway trench lasted almost ten years, from 1856 to 1866, du to the fact that the trench had to pass below the Tinière river, which was canalised in a «canal-bridge» over the railway.

Three distinct archeological layers have been observed (fig. 3). They were remarkably parallel to the surface of the «modern» cone, and at constant depth. All three layers consisted of a fine grained soil layer, with charcoals, and they were separated by coarse gravelly alluvial deposits. In all layers, archeological artifacts allowed a relative age attribution :

- the Roman layer, at a depth of about 90 cm, contained tile fragments, burials, a coin, two iron axes ;
- the «Bronze» layer, at a depth of about 2.70 m, contained numerous pottery fragments, two bronze axes, a bronze pin ;
- the «Stone» layer (which was not yet called Neolithic), at a depth of about 5.3 m, contained pottery fragments, two skeletons, numerous animal bones.

The three archeological layers appeared to have a very constant depth below the surface of the cone, suggesting a regular sedimentation. Since the age of the first, Roman layer, was approximately known, Morlot had the idea to use the sedimentation rates to calculate the age of the two lower layers, and so the age of the Bronze and of the Neolithic.

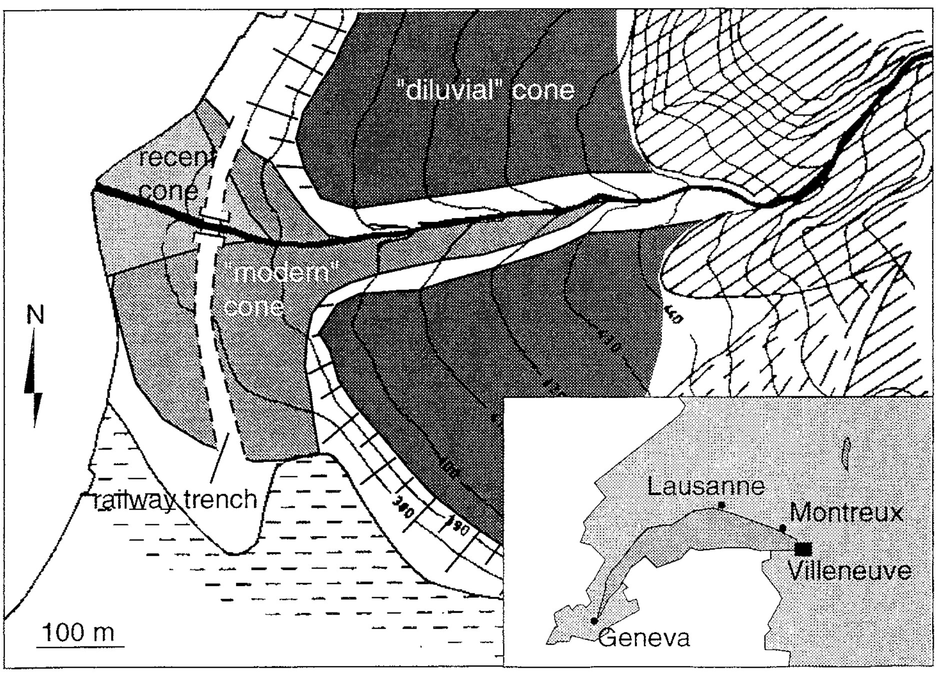

Fig. 2 : Location of the Tinière railway trench and morphology of the alluvial cones (modified after Burri, 1962).

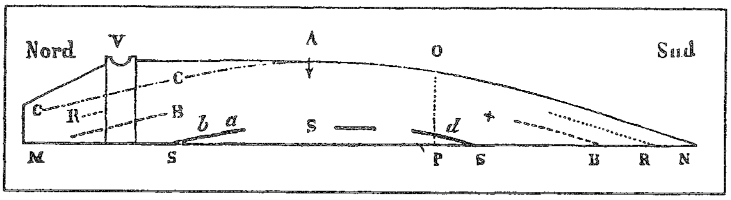

Fig. 3 : Profile of the trench and main observations, as published by Morlot (1861a).
R = Roman layer ; B = Bronze layer ; S = «Stone» layer ; C = surface of modern cone ; A = axis of modern cone ; V = aqueduct of the Tinière ; a = skull ; b = pottery ; d = bones ; + = bronze pin.
Total length of the profile about 350 m, maximum height about 7 m.

THE CALCULATIONS

The basic data for Morlot's age calculations were the following :

- time ellapsed since damming of the river (= end of sedimentation on the «modern» cone and beginning of the «recent» cone) : 2-3 centuries, to be added to the results obtained on the «modern» cone ;
- time ellapsed between the top of the Roman layer and the top of the «modern» cone (= damming of the river) : 10-15 centuries, for 0.92 m of sediments ;
- sediments accumulated between the top of the Bronze layer and the top of the «modern» cone : 2.72 m, for an unknown time ;
- sediments accumulated between the top of the Neolithic layer and the top of the «modern» cone : 5.25 m, for an unknown time ;

Cône de la Tinière.

calcul qui a fourni les chiffres du texte.

Rayon extérieur admis = 270 mètres = 900'.

Inclinaison, ligne de plus forte pente. moyenne de 40 mesures = 4°

couche romaine 1,14 m. moins 0,15 m. moins 0,07 m. = 0,92 m

parceque le torrent est formé en partie aux dépens du sous sol.

couche du bronze 2,97 m. − 0,18 m. − 0,07 m. = 2,72 m

couche de la pierre 18',3 + 2' − 2',8 (torrent) = 5,25 m

0,92 tg.86° = 13,15 m.
2,72 — — = 38,90.
5,25 — — = 75,08.
soustrait de 270 m: 270 ; 256,8 ; 231,1 ; 194,9 × tg 4° = 18,88 ; 17,96 ; 16,16 ; 13,63

$270^2 \cdot \frac{\pi}{3} \cdot 18{,}88 = 1{,}441{,}300 = a.$

$256{,}8^2 \cdot \frac{\pi}{3} \cdot 17{,}96 = 1{,}240{,}300 = b.$

$231{,}1^2 \cdot \frac{\pi}{3} \cdot 16{,}16 = 903{,}800 = c.$

$194{,}9^2 \cdot \frac{\pi}{3} \cdot 13{,}63 = 542{,}200 = d.$

(a − b) : (a − c) = 10 : 26,2
26,2 + 3 = 29,2 siècles
13,1
39,3 + 3 = 42,3 siècles

(a − b) : (a − d) = 10 : 44,7
44,7 + 3 = 47,7 siècles
22,3
67,0 + 3 = 70,0 siècles

(a − b) : a = 10 : 71,7
71,7 + 3 = 74,7 siècles
35.8
107,5 + 3 = 110,5 siècles.

et 100 siècles environ pour le cône total. nous admettons, en chiffres ronds pour la couche de l'âge du bronze 3 à 4 mille ans de date et pour celle de la pierre 5 à 7 mille. Si la couche de la pierre appartient effectivement au commencement de celle du bronze, cela donnerait pour l'âge du bronze une durée de 2 à 3 mille ans.

en déduisant 2 siècles pour les digues et en accordant à la couche romaine une antiquité de 16 siècles on trouve pour la couche de l'âge du bronze une date de 38 siècles et pour celle de l'âge de la pierre 64 siècles.
Lisch. Man soll vorerst nur nach Jahrtausenden rechnen.

Fig. 4 : The definitive age calculations of Morlot, after his notebooks.

- external radius of the «modern» cone : 270 m.
- slope of the cone surface : 4°.

Morlot made three successive calculations. They are not explained in detail in the publications, but could be found in the notebooks (fig. 4). The first was simply based on the thickness of the different layers (published in Morlot, 1857b). After Dufour (1858) objected that the volume growth of a cone was proportional to the radius elongation and not only to the thickness, Morlot passed from a one-dimensional to a tri-dimensional model, and remade the calculation with a simplified formula : $V=\pi \cdot r^3$, which respects the proportionality (probably 1858, unpublished), then with the true formula for the volume of a cone: $V=\pi \cdot r^2 \cdot h/3$ (Morlot, 1860a and following publications).

It is important to notice that Morlot didn't calculate the actual volumes accumulated, but was interested only in their relative proportions. He therefore made his volume calculations on whole cones and not on cone sections.

In this way, he obtained age estimations for the three archeological layers and for the whole «modern» cone, which he considered as representing the «post-glacial» time (table 1).

He tried later to extrapolate his calculation to the «diluvial» cone, and obtained a duration of 100,000 years for the time between the melting of the ice after the last glaciation and the beginning of «alluvial» (Holocene) times (Morlot, 1862b). For this, he used a very rough estimation of the volume of the «diluvial cone» (based on estimated thickness, mean radius, slope angle and opening angle of the cone), and compared it to that of the «modern cone».

Morlot's age calculation was not the first, and was soon followed by others. Troyon (1855) and Gilliéron (1861) both tried to calculate the age of neolithic lake dwellings by lateral progradation rates of the lake shores, at the upper ends of the Lake of Neuchatel near Yverdon, and of the Lake of Biel respectively (see Wolf, 1993 for more details). Troyon found an age of 3300 years before 1850, and Gilliéron an age of 6750 years, the latter being very consistent with Morlot's result for the «Stone» layer. The Tinière trench remained however the only place where Bronze age, Stone age and the whole Holocene could be calculated on the same profile. After Morlot's death, de Ferry (1868) and Arcelin (1868) published calculations for the Bronze age, the Neolithic and the beginning of the Holocene, based on observations in the Saône valley (France) with results which are rather consistent with Troyon's younger ages.

A WORLDWIDE PUBLICATION

Morlot's results were published in 11 short notes and 5 longer papers, mainly in the *Bulletin de la Société vaudoise de Sciences naturelles* between 1857 and 1866. Two of the more general papers have been reprinted in France, translated and published in England (Morlot, 1860b), in the United States (Morlot, 1861c, 1863a) in Italy (Morlot, 1863b) and in Germany (Morlot, 1865), giving it an international audience.

The case gave rise to intense discussions and to an abundant correspondance between Morlot and other specialists in archeology and geology. Many scientists came from whole Europe to Villeneuve, to visit the trench.

To understand the broad interest for Morlot's results, it is important to see the scientific context of these publications. The first half of the 19th century has seen the development of the glacial theory, then of the prehistoric archeology, both relying on relative chronologies. Morlot himself contributed by his above mentionned publications to the diffusion of the danish periodisation in Stone, Bronze and Iron ages.

In 1859 was published Darwin's *Origin of species*, while on the other hand, calculations based on the Bible still assigned an age of about 6000 years to the creation of man. In the discusion on its origin, the age of mankind was of central concern. The calculations of Morlot, Troyon and Gilliéron provided important arguments for Lyell's essay on *The antiquity of man* (Lyell, 1863) and for Lubbock's *Prehistoric times* (Lubbock, 1865).

For the Quaternary research, the age and duration of the glaciations was also an open question. Morlot's calculations provided to Penck & Brückner (1909) one of their very few age estimations for the end of the last glaciation.

THE CONTRADICTORS

The publication of Morlot's results gave rise since the beginning to an intense discussion about the validity of the calculation method and of the age estimations. This debate took place mainly in the scientific meetings of the *Société vaudoise de Sciences naturelles* at Lausanne and in its allready quoted *Bulletin*.

The first serious contradictor was Charles Dufour (1858). He objected that the sedimentation on a torrential cone is not regular enough to allow sedimentation rates calculations. Native of Villeneuve, Dufour used as examples some floods he had seen himself on the river.

The counterargument of Morlot based on a timescale consideration : if the torrential sedimentation is very irregular on a short period, the spreading of the sediments

	after Morlot		verification	
	1860	1861	attribution	age cal BP
Roman layer	13-18 cent.		<IInd cent.	
Bronze layer	29-42 cent.	3'000-4'000 y.	Final Bronze-Early Iron	2'800-2'500
Stone layer	47-70 cent.	5'000-7'000 y.	Early Bronze ?	
"modern" cone	74-110 cent.	10'000 y.	Holocene	< 11'500
"diluvial" cone	1'000 cent.	100'000 y.	Lateglacial	ca 18'000-11'500

Table 1 : Ages calculated by Morlot, compared with the present state of verification.

over the cone surface, considered on a millenial scale, will produce a more or less regular sedimentation. As evidence of this, he mentionned the parallelism and the constant depth of the three layers.

Rütimeyer (1861) and Uhlmann (1868) examined the animal bones found in the so-called «Stone» layer, attributed to the Neolithic by Morlot, and argued that the domestic animals belonged to more evolved and recent types than the known neolithic ones.

Finally, Forel (1870) discussed all the results of Troyon (1855), Morlot, Gilliéron (1861), de Ferry (1868) and Arcelin (1868). He based his discussion on three fundamental conditions :

- the regularity condition : sedimentation rate calculations are only possible if the sedimentation process is regular over a certain time ;
- the determination condition : the archeological attribution of the layers must be unequivocal, and the artifacts used for this must be caracteristic ;
- the localisation condition : the artifacts used for relative dating must be exactly positionned in the evolution of the process, for this they must be in situ.

He concludes that none of the conditions is fullfilled in the case of the Tinière trench, and that the ages calculated by Morlot are therefore not reliable.

After the death of Morlot in 1867, the discussions ceased soon. The papers of Uhlmann (1868) Forel (1870) and Chavannes (1872), published after Morlot's death closed the debate.

TODAY'S KNOWLEDGE

The discussions on datings stopped almost completely for more than 40 years. One of the reasons might be that the «antiquity» of man and of the world was now not definitely but generally accepted. The main reason however was certainly the unreliability of the methods. Only two further attempts of datings based on sedimentation rates are known to us : René Kerviler (1876) calculated the age of a Bronze age layer and the duration of the «actual» period in the St-Nazaire bay (France), on the base of the estuarine sedimentation of the Loire. Jakob Nuesch (1896) calculated the age of the Neolithic and of the Upper Paleolithic on the base of peat accumulation rates in a bog near Schaffhausen (Switzerland) (see Wolf, 1993). It has to be mentionned that Kerviler still defended the «biblic» chronology, and that his calculations, resulting in a very younger Bronze age and a shorter «modern» period, had a large audience among french traditionalists (Giot, pers. com.).

It was only with De Geer's varve chronology (De Geer, 1910) that the dream of a reliable age control, based on an annual count, could be obtained. Due to the special conditions required by the method, varve counting provided a general chronological framework for the deglaciation and the holocene environmental evolution, but no direct dating method for archeology. Archeological sites could only be relatively dated by correlation with dated pollen profiles.

One had to wait the development of the radiocarbon dating and of the dendrochronology to get reliable dating tools. Dating of the archeological periods was one of the first applications of radiocarbon (Libby *et al.*, 1949), while the first dendrochronological datings of the Bronze age and for the Neolithic were obtained only in the early 1980"s (Becker *et al.*, 1985).

That means that Morlot's results were among the only available age estimations for almost one century. The modern results show that at least the general age estimations for the Bronze and Neolithic periods were remarkably accurate, despite the methodological problems. The estimation of the duration of the Holocene is remarkably close to the present knowledge too.

The age calculation for the «diluvial» cone in turn was totally wrong : Morlot considered the same sedimentation rate than for the «modern» cone. The geomorphological processes however were not the same during the Lateglacial and the Holocene, and the sedimentation rates of the former were an order of magnitude higher. Pecularily, this age estimation, which was obviously exagerated, gave rise to no discussion in the debate except a short comment by Forel (1870).

THE VERIFICATION

The real age and duration of the archeological periods are well known today, and it was tempting to try to verify if the calculations are true also for the Tinière trench or if Morlot's results were only the fact of good fortune.

Morlot's calculations have been challenged on three main points :

- archeological attribution of the animal and human bones (Rütimeyer, 1861 ; Uhlmann, 1868),
- possibe reworking of the artifacts (Forel, 1870),
- irregularity of the sedimentation on a torrential cone (Dufour 1858, Thury 1862).

The animal bones, if they are preserved, have not been found yet. Human bones are preserved in the archeological collections at Lausanne, but they are not of great utility. Several archeological artifacts could be found in the archeological collections of Lausanne and Berne and compared to sketches in Morlot's notebooks and with published descriptions. The notebooks, preserved in the library at Lausanne, provided detailed indications and sketches on discovery dates and conditions of most of the pieces, so that the attribution of the singular pieces to the layers can be reliably reconstructed. The Geological Museum of Lausanne preserved a soil sample of the «Bronze Age layer» containing small charcoal pieces, as well as mollusc shells from different layers. We give only a summarized overview of the results. A more detailed report will be published elsewhere.

The reworking of the artifacts has to be considered on two levels : the age of the artifacts themselves, and the age of the layer in which they have been found. We will consider each layer successively.

THE ROMAN LAYER

The following artifacts have been found in the Roman layer :

- two iron axes (Museum of Berne) ;
- a coin (Roman Museum of Lausanne) ;
- several pieces of tiles (id.).

The axes allow no precise age attribution, and could date from the beginning of the iron age to the middle of the Roman period. The tiles necessarily indicate the Roman period. The most precise indication is given by the coin : it is considered to be older than the 2nd century. Therefore an age between the 1st and the 2nd century AD seems most likely. There is no evidence of reworking of the artifacts, and the presence of burials of presumed roman age would indicate that the layer is in situ.

THE BRONZE AGE LAYER

The following significant artifacts have been found in the Bronze layer :

- a bronze axe of the «Les Roseaux» type (Museum of Berne), typical for the early Bronze age IV ;
- a bronze axe (only sketch in notebook), of middle Bronze type ;
- a pin (archeological collections Lausanne) of late Bronze type.

The artifacts indicate an inhomogeneity of the layer, which could be interpreted in two different manners : either the layer is a soil which formation lasted the whole Bronze age and is a complex layer, or the early and middle Bronze pieces are reworked.

A mixed sample of small charcoal pieces, all extracted from the same soil sample from the Geological Museum, was submitted to AMS radiocarbon dating and gave an age of 2535 ± 60 ^{14}C BP (ETH-18455). Considering the broad calibration range of 810 to 410 cal BC, it is not incompatible with a very final Bronze age, as assumed by Morlot, and does not necessarily indicate a reworking of the layer.

THE NEOLITHIC LAYER

No significant artifacts have been found in the so-called «Stone layer». Only one pottery fragment could be found (Museum of Berne) and seems to be rather of Bronze age style. Two sketches corresponding to published descriptions of other pottery fragments lead to the same conclusions, so that an early to middle Bronze age seems the most likely for this layer. But it has to be considered as hypothetical until more convincing arguments can be found.

The human bones give no usable indication. Rütimeyer's and Uhlmann's arguments about the animal bones give support for a younger age than Neolithic. In his last papers, Morlot himself admitted that this layer could be of early Bronze age rather than Neolithic (see the vertical note on fig. 4).

THE IRREGULARITY OF THE SEDIMENTATION

No new data allows us to check the regularity or irregularity of the sedimentation on the Tinière cone. But what we know about torrential activity through the Holocene indicates a great general irregularity. The evolution of torrential activity begins to be well known in the french Alps (Ballandras, 1997). The general pattern shows first a intense activity at the beginning of the Holocene, then a phase with pedogenesis on the cones during the Boreal and Atlantic climatic optimum, and finally an alternation of activity and release during the period which interests us. There is probably a similar evolution in the Swiss Alps, and this would signify that, besides the spatial irregularity of the torrential sedimentation pointed to by Dufour (1858), there was a temporal, climatically controlled irregularity.

Another factor influences the Tinière cone : the cone represents the aereal part of a small delta arriving in the Lake of Geneva. We know today that the lake level fluctuated by several meters from the Neolithic to the Roman period (Corboud, 1996). The lake base level necessarily influenced the torrential processes on the cone, determining most probably erosion during low levels (allowing pedogenesis on the cone ?) and spreading of sediments on the cone during high levels (covering the soil layers ?).

This means that the assumption of a regular sedimentation rate, even on a millenial scale, is not likely. Much more, the profiles indicate a alternation of sedimentation and pedogenesis periods. In turn, the site would be very suitable for the inverse calculation : from the known age of the layers, we can infer changes in the Holocene torrential activity.

CONCLUSIONS

The verification of the data give the following results :

- the archeological attributions are right for the Roman and more or less for the Bronze age periods, but wrong for the lower layer, which is probably of early Bronze and not Neolithic age ;
- the oldest Bronze age artifacts are possibly reworked ;
- the sedimentation on the Tinière cone was irregular, alternating sedimentation and incision/pedogenesis phases, and was therefore not suited for sedimentation rate calculations.

Nevertheless, Morlot's general age estimations for the main archeological periods and for the duration of the Holocene were remarkably right, even almost exact ! In other words, everybody was right, Morlot about what concerns the results, as well as his contradictors for what concerns the method !

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TOWARDS *BCal* : AN ON-LINE BAYESIAN RADIOCARBON CALIBRATION FACILITY

Caitlin E. BUCK, J. Andrés CHRISTEN** and Gary N. JAMES****

Abstract : Full implementation of the complex statistical methods required for Bayesian radiocarbon calibration need high performance computing resources, not usually available to most archaeologists. Our aim is to develop World-Wide Web based software, known as *BCal*, that will allow archaeologists to define radiocarbon calibration problems, which can be submitted, via the Internet, for calibration on our dedicated UNIX machine. Once calibration is complete, the software will present probabilistic calendar date information in the form of graphs and tables. With increased ease of access to the World-Wide Web, we hope that the facility will be accessible to researchers around the world.

Résumé : L'équipement informatique performant demandé par la mise en oeuvre complète des méthodes bayesiennes de calibrage de radiocarbone n'est pas disponible à la plupart des archéologues. Notre but est de développer un logiciel World Wide Web, *BCal*, qui permettra aux archéologues de définir des problèmes de calibrage de radiocarbone, et de les soumettre à notre ordinateur UNIX. La calibration faite, le logiciel aura la capacité de fournir des statistiques, en forme de table ou de graphique, sur les probabilités de datation. Nous espérons que, grâce à la progression de l'Internet, ce logiciel sera accessible aux chercheurs dans le monde entier.

Key-words : Radiocarbon dating, calibration, Bayesian method.

Mots-clés : Datation radiocarbone, calibration, méthode Bayesienne.

1 - INTRODUCTION TO *BCal*

1.1 - BAYESIAN RADIOCARBON CALIBRATION

Due to variations in the amount of ^{14}C in the atmosphere, results obtained from all radiocarbon laboratories need to be calibrated onto the calendar scale. Indeed, this calibration is usually necessary before the results can be used to aid in the archaeological interpretation of past human activity.

A recent advance in calibration is provided by the Bayesian radiocarbon calibration framework. This approach combines both radiocarbon data and chronological information to arrive at a coherent interpretation of all the available dating evidence. Formally, we combine : *a priori* chronological information with radiocarbon data and the calibration curve within a coherent statistical framework to arrive at posterior probability distributions for the calendar dates of interest (Buck *et al.*, 1996).

The only software currently publicly available for Bayesian radiocarbon calibration is known as OxCal (Ramsey, 1995) which runs on IBM-compatible machines in the Microsoft® Windows environment. Consequently, the CPU available to most users is not great. By contrast, *mexcal* is software designed and written for UNIX machines by the researchers who developed the Bayesian radiocarbon framework. As such *mexcal* contains implementations of all published calibration options, see for example (Buck *et al.*, 1994, Buck *et al.*, 1992, Buck *et al.*, 1991, Christen, 1994a, Christen, 1994b, Zeidler *et al.*, in press), some of which cannot reasonably be implemented to run on typical desktop IBM-compatible machines available to most archaeologists.

1.2 - GENERAL PURPOSE CALIBRATION SOFTWARE

mexcal is software written in C++, that allows definition of a wide range of radiocarbon calibration problems, using language and syntax devised specifically for the purpose. Within *mexcal*, C++ objects exist to allow definition and description of radiocarbon determinations, groupings of associated determinations (including pha-

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ses and sequences), and other chronological events whose location in the temporal sequence is important, but does not sit within the groupings already established. With these basic objects defined, *mexcal* also allows for a selection of radiocarbon calibration curves, ΔR reservoir corrections to marine curves, inclusion of *a priori* chronological information, and outlier detection.

In its original form, *mexcal* could only be used by experienced researchers with some familiarity with structured programming languages. This fact, along with the need for large amounts of CPU, for at least some of the calibrations that can be defined, meant that simply publicly releasing the C++ code or executables would not provide a tool for the majority of archaeologists with radiocarbon data requiring calibration.

1.3 - MAKING SUCH SOFTWARE WIDELY AVAILABLE

Although *mexcal* can be thought of as general purpose calibration software, it really requires a more user-friendly front end and substantial CPU, before widespread adoption is likely. As a result, we sought and obtained funding from Cardiff University for a powerful UNIX server on which we can provide a calibration facility via the Internet : this service is known as *BCal*.

A graphical user interface is being developed to allow user definition of calibration problems. Once a calibration problem has been defined it can be submitted for calibration. A *mexcal* process, running on our high performance server, will then conduct the calibration on behalf of the user. Once the calibration is complete, results will be made available for users to download and include within their own documents.

The name *BCal* thus refers to a collection of user interface tools and the *mexcal* software itself. The structure of *BCal* is shown in figure 1.

1.4 - SOME TERMINOLOGY

To avoid confusion we introduce some terminology that is used by *BCal* and referred to later in this paper.

• *determination :* A single radiocarbon determination consists of a radiocarbon age and associated standard error as provided by a radiocarbon dating laboratory.
• *group :* A group is a coherent collection of radiocarbon determinations. For example, but not limited to, determinations found within the same archaeological phase or sequence.
• *group boundary :* Each group has two boundary dates (early and late). Such dates are used to bound determinations within that group.
• *abutting :* If the adjoining boundaries of two neighbouring groups in the archaeological sequence are equal then the groups are referred to as abutting.
• *a priori chronological information : A priori* chronological information arises from both relative and absolute temporal knowledge available about groups and determinations before calibration takes place. This information is usually recorded during archaeological excavation or other research.

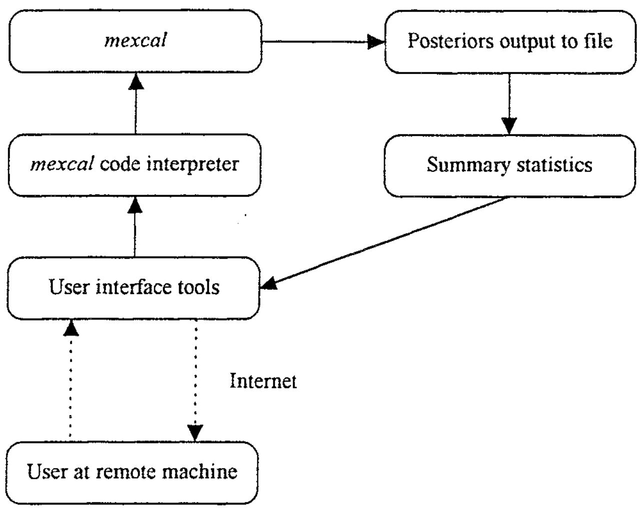

Fig. 1 : The structure of *BCal*. Users at remote machines work with user interface tools that create and run *mexcal code*.

2 - USER INTERFACE TOOLS

The user interface tools provide users with all they need to define, submit and manage their radiocarbon calibration problems. To access these tools, a user must have a connection to the World-Wide Web, and a standard Web browser such as Netscape (http://www.netscape.com/).

The tools are provided in the form of a series of Web pages. Like most resources on the World-Wide Web, they are written in HTML (Hypertext Mark-up Language). HTML allows hypertext documents to be created, with images and links to other Web pages. To add interactivity to Web pages, HTML forms are often provided which allow users to submit data back to the server for processing via Common Gateway Interface (CGI) scripts. For example, resources may use HTML forms which send information to CGI scripts that allow searching or adding to a database. Virtually all Web browsers support the HTML/CGI interface. Thus by adopting such an interface for *BCal*, we will allow access to the widest possible user base.

In the remainder of this section we introduce each tool that is currently under implementation as part of *BCal*. We then discuss the largest of these tools, the problem design software, in more detail in Section 3.

2.1 - USER ACCOUNTS

User accounts will be implemented so that each user has their own personal work space. A work space consists of file space on our server and will be used to store any calibration projects users choose to create. Projects consist of : the determinations, *a priori* chronological information, details of calibration and (once available) the calibration results for a particular archaeological problem.

2.2 - PROJECT MANAGEMENT

The project management tool will allow users to manage the calibration projects that reside in their work space. Operations range from deletion to modification of calibration projects. The former operation is straightforward, the latter however, requires that the project management tool launches the problem design software, with the selected calibration problem loaded.

2.3 - PROBLEM DESIGN SOFTWARE

The problem design software is the largest of the tools. It allows users to define their own calibration problems (see Section 3). Such definitions are constructed from various components, for example, determinations and groups.

A question and answer based approach is used to elicit both radiocarbon and chronological information from the user. A series of questions are presented, the answers to which are used to construct the problem definition. A variety of options are also available, so that users can make changes to the problem definition, away from the flow of questions. These provide users with more control over the definition process, should they require it.

2.4 - SUBMISSION TO MEXCAL

BCal's submission tool is activated once the problem design is complete. This tool performs the required steps to submit *mexcal code*, generated from a user's calibration project, to *mexcal* for calibration. On submission, the *mexcal* calibration process will either be started immediately, or started after a delay, if the server already has a heavy load. The user will be provided with an estimate of when the calibration process will commence and the expected completion time.

2.5 - CALIBRATION CONTROL

The calibration control tool will check the progress of each calibration process running on the server. The calibration methodology used by *mexcal* is based on Markov chain Monte Carlo (MCMC) simulation and is thus iterative (see Litton and Buck, 1996). As a consequence, convergence checking will be an essential part of the calibration control, to ensure that the calibration results returned are reliable.

2.6 - RESULT VIEWING

On completion of each calibration, results are made available on Web pages within the facility. These results, only available to the user who defined the calibration, consist of both textual and graphical representations of the posterior distributions computed by *mexcal*.

Users will be given some control over the appearance of the tables and graphs that make up the results, so they can be customised to suit users' tastes or conform to publication standards. Once the user is satisfied with the format, the results will be made available for downloading. They will be provided in a variety of popular file formats for quick and easy inclusion within documents or reports that the user wishes to produce.

3 - PROBLEM DESIGN SOFTWARE

We now turn to consider the largest component of the user interface, the problem design software, in more detail. The problem design software allows users to define their own calibration problems. Due to the potentially complex nature of calibration problems, the tool is very large. Our aim is that this tool be as easy to use as possible, for all sizes of calibration problems. In order to achieve this, *BCal* takes the inexperienced user (or expert should they so wish) through the steps needed to reliably define each calibration problem. This process starts with setting up the calibration problem and then moves to eliciting any relative and absolute *a priori* chronological information in the manner outlined below.

3.1 - SETTING UP THE CALIBRATION PROBLEM

BCal offers a question and answer based approach by which the user can define their calibration problem. Questions are asked in a sequential manner until the problem is fully defined. Initially, the software elicits from the user the basic outline of the calibration problem. Once the outline is defined the software moves on to ask more detailed questions about the radiocarbon data within the calibration problem.

We use as an illustration a simplified representation of the site Loko Kunana on the island of Oahu, Hawai'i (see tables 1 and 2). The software allows the user to set up the calibration problem thus :

Question : How many distinct groups (phases or sequences) are there in your chronology?

User response : 2.

Question : Give a name for the earliest group (phase or sequence) within your chronology.

User response : *Layer III.*

Question : How many determinations are there in "Layer III" ?

User response : *1.*

Similar questions are asked for the remaining groups within the calibration problem. When eliciting radiocarbon data, for the same example, the questions asked by the software include :

Question : Give the laboratory number for the earliest determination within "Layer III".

User response : *Wk 4128.*

Question : Give the radiocarbon age for determination "Wk 4128".

User response : *2816.*

Question : Give the radiocarbon error for determination "Wk 4128".

User response : *74.*

Again, similar questions are asked for the remaining determinations within the calibration problem.

Layer	Event	Depth (in cms.)	Phase Boundary	Absolute Prior Information
			α_1	None
III	θ_1	372-374		
			$\alpha_2=\beta_1$	None
II	θ_2	355-359		
	θ_3	363-367		
	θ_4	368-372		
	θ_5	370-374		
			β_2	= 1941 AD

Tab. 1 : The relative chronological information for Loko Kunana, Oahu, Hawai'i. There are two groups. The oldest is Layer III which has one determination. The youngest is Layer II which has four determinations.

3.2 - ELICITING A PRIORI CHRONOLOGICAL INFORMATION

The elicitation of *a priori* chronological information is more complicated than setting up the calibration problem. Relative *a priori* chronological information provides insight into the ordering of the groups and determinations that have been defined, and, where it exists, absolute *a priori* chronological information helps locate parts of the chronology under investigation.

When eliciting relative chronological information *BCal* asks the user to identify the chronological relationship between each group within the calibration problem. This

Event dated	Laboratory number	Radiocarbon determination (BP)	$\delta^{13}C$ estimate	Material dated	Calibration curve adopted
θ_1	Wk 4128	2816±74	-10.0±0.20	humus	atmospheric
θ_2	Wk 4127	440±160	-14.2±0.20	sediment	marine
θ_3	Wk 4125	370±140	-14.1±0.20	sediment	marine
θ_4	Wk 4126	630±150	-14.1±0.20	sediment	marine
θ_5	Wk 4124	360±180	-14.2±0.20	sediment	marine

Tab. 2 : The radiocarbon data for Loko Kunana, Oahu, Hawai'i.

relationship can be one of earlier, later, abutting and earlier, abutting and later, overlapping and earlier, overlapping and later, contemporary or no relationship. For the Loko Kunana example (see table 1), *BCal* would elicit the relative chronological information by presenting the question :

Question : What is the chronological relationship between "Layer III" and "Layer II" ?

User response : *Abutting and earlier.*

Absolute *a priori* information can take many forms, examples include exact dates of historical events and date ranges fixed by other types of scientific dating such as dendrochronology. Absolute information can be in the form of single dates, date ranges and more complex prior distributions.

For the Loko Kunana example, Hawai'i National Archive photographs show this pond being filled in 1941 AD. So, for the group boundary β_2, there is absolute *a priori* information in the form of a precise date : 9 cal BP. During the elicitation of relative information, the user is given the option to provide absolute information. Since the absolute information for β_2 is an exact date, the user would select the "exactly known" option and enter 9 cal BP into the text field presented.

3.3 - A GRAPHICAL REPRESENTATION OF THE CALIBRATION PROBLEM

As part of the elicitation of the chronological information, users are also provided with an illustration of the calibration problem being defined. We hope that graphical representation of the information will give users extra confidence in their interactions with the facility. It is intended that users compare the graphical representation with their own perception of the archaeological record and make adjustments to the calibration problem definition until the two coincide.

The graphical representation mechanism currently implemented in *BCal* is similar to a representation the authors have been using in consultancy work for some time. It combines a graphical representation with some mathematical notation commonly adopted in Bayesian radiocarbon calibration. Figure 2 shows an example of such graphical representation for the Loko Kunana example.

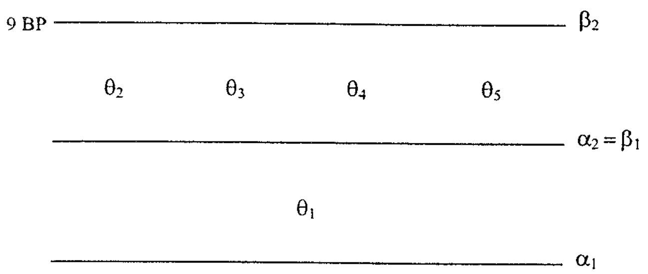

Fig. 2 : An example of the current mechanism for graphically representing radiocarbon data and chronological information within *BCal*. The *θ*s mark locations of radiocarbon determinations, the *α*s and *β*s represent group (phase and sequence) boundaries.

3.4 - CREATING A GREATER LEVEL OF FLEXIBILITY

For most users the question and answer based approach should be sufficient for defining even the most complex calibration problems. However, there may be times when mistakes are made, or users wish to define particular information away from the flow of the questions. Consequently, *BCal* features a variety of additional options that can be performed on the problem currently being defined. These options are intended to complement the question and answer based approach rather than replace it.

Each stage in the problem definition process uses a Web page to show the current information associated with the problem, and new information required for the definition to continue. Alongside this there will be a list of options that the user can use to perform tasks not connected to the current questions being asked. For example, if the user decided that they actually had 3 groups not 2 in the present calibration problem, they could choose an option to add a new group. This would break the current flow of questions and ask for information about this new group. Once the required information for the group has been added, the user can continue with the definitions they were working on before. The changes made are noted by *BCal* so that, where necessary, they may affect future questions posed.

Options are available to add, delete and modify all the components of a calibration problem. More advanced options are also being developed so that expert users can modify properties of the calibration that would normally be handled by *BCal*. Such properties relate to the Markov chain Monte Carlo (MCMC) simulation methodology (Litton and Buck, 1996) used by *mexcal* and include the number of simulations used to estimate the calendar date information.

4 - LOOKING AHEAD

We expect *BCal* to be ready for testing early in 1999 and to be available for general use by the summer of 1999.

4.1 - WHERE TO FIND US

The server that houses the *BCal* facility is already accessible via the World-Wide Web. We invite prospective users to visit the site (http://bcal.cf.ac.uk/) where there is general information about the project, and a user survey to help us shape *BCal* to suit our users' needs. Respondents to the survey will be notified when *BCal* is ready for testing, and when the facility is ready for general use.

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HIGH PRECISION ^{14}C DATING OF A NEW TREE-RING BRONZE AGE CHRONOLOGY FROM THE PILE-DWELLING OF FRASSINO I (Northern Italy)

Nicoletta MARTINELLI and Bernd KROMER***

Abstract : Dendrochronological investigations carried out on the Bronze Age site "Frassino I" on Laghetto del Frassino (Northeastern Italy) led to the construction of a 194 years local oak chronology, dated by using the 'wiggle-matching' method in the period between between 1830 and 1637 BC ± 12 years.
The different felling phases found in the piles allowed us to reconstruct the development of the village trough a chronology of annual precision during a period of about 70 years between 1709 and 1637 cal. BC.
As the archaeological findings are ascribed to the end of Early Bronze Age and to the beginning of Middle Bronze Age, the dating of «Frassino I» seems to provide a date for the beginning of the Middle Bronze Age back to the first half of the XVIIth Century BC at the latest.

Résumé : L'étude dendrochronologique du site du Bronze "Frassino I" sur les rivages du lac Laghetto del Frassino (Italie du Nord-est) a permis la construction d'une chronologie locale pour le chêne de 194 ans. La chronologie, datée par la méthode "Wiggle Matching", se situe dans la période entre 1830 et 1637 BC ± 12 ans.
Les différentes phases d'abbattage des pieux nous ont permis de reconstituer avec une précision annuelle le développement du village pendant une période d'environ 70 ans entre 1709 et 1637 cal. BC.
La datation du site Frassino I, dont les matériaux archéologiques sont attribués à la fin du Bronze Ancien et au début du Bronze Moyen, semble permettre de situer le début du Bronze Moyen au plus tard dans la première moitié du XVIIe siècle BC.

Key-words : Tree-ring analysis, radiocarbon dating, Early Bronze Age, Middle Bronze Age, pile dwellings.

Mots-clés : Analyse de cernes, datation radiocarbone, Age du Bronze ancien, Age du Bronze moyen, sites littoraux.

The prehistorical village named «Frassino I» was built during Bronze Age along the south western shore of Laghetto del Frassino, a small lake situated only 1 km to the south of the Lake Garda (fig. 1).

In the area, where submerged remains of the pile dwelling settlement have been observed, no systematical excavation has taken place up to date. In contrast, underwater research has been carried out between 1989 and 1997 by Soprintendenza Archeologica del Veneto that permitted to collected a large number of archaeological findings from the lake bottom, a part of them ascribed to the end of Early Bronze Age and the rest to the beginning of Middle Bronze Age (Evans, Fozzati & Salzani, 1991 ; Salzani, 1989) (fig. 2).

Due to the importance of the site for the study of the period of transition from the Early Bronze Age to the Middle Bronze Age, a group of samples was taken from 100 posts for tree-ring analysis.

Dendrochronological investigations led to the construction of a local oak chronology, which is 194 years long. The presence of sapwood rings in most of the samples and the preservation of bark and *Waldkante* in some of them allowed us to recognize the existence of, at least, 5 felling phases during a period of about 70 years.

A peculiarity of the village "Frassino I" was observed already in making wood analysis : the posts of the pile-dwellings were mostly made either with trunks of *Quercus* Sectio *ROBUR* (49) or with trunks of *Quercus* Sectio *CERRIS* (38) [(1)].

(1) The differences between the two types of wood are either macroscopical (in color and consistence), or microscopical, according to the Cambini (1967a and 1967b) description.

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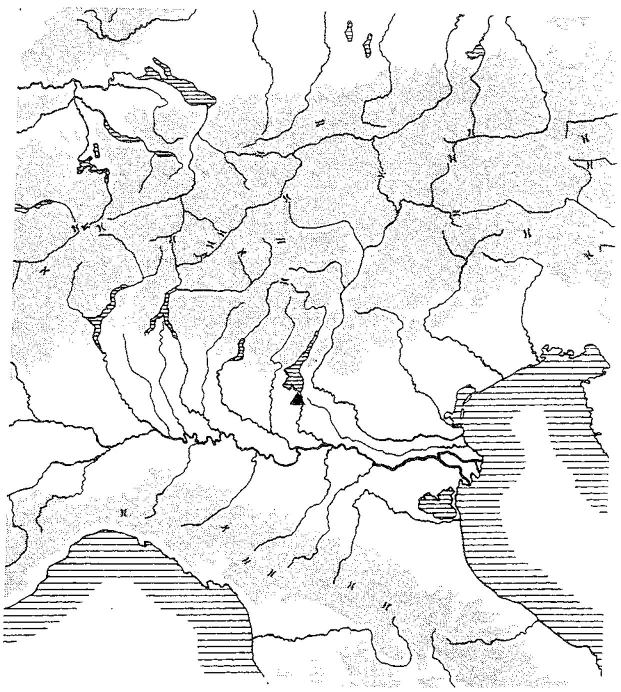

Fig. 1 : Location of the study site.
Fig. 1 : Situation de la station littorale étudiée.

It was surprising to discover that the inhabitants of the village did not employ the two types of oak wood at the same time. The use of *Quercus* Sectio *ROBUR* wood was exclusive in the first two phases, while the use of *Quercus* Sectio *CERRIS* wood was exclusive in the last three phases.

As the cross-dating between our curve from Frassino I, the regional Bronze Age chronology GARDA 1 and the German oak standard chronology could not bring to satisfying results, we had to refer to high precision ^{14}C dating. A series of four ^{14}C dates was obtained from different segments of the tree-ring sequence (tab. 1).

Using the wiggle-matching option of OxCal (Ramsey, 1995) we obtained the best position of the Frassino sequence using the decadal calibration curve of Stuiver and Becker, 1993. Allowing for systematic errors up to ± one decade, the calibrated range of ring 1 is between 1842 and 1818 BC (fig. 3).

According to wiggle-matching results the mean curve from Frassino I covers the period between 1830 and 1637 BC ± 12 years. The different felling phases found in the curve are placed at the end of the XVIIIth Century BC and during the XVIIth Century BC, between 1709 and 1637 cal. BC (tab. 2).

These new data together with the results coming from the construction of the chronology GARDA 1 (Martinelli, 1996) allow us to follow the development of population dynamics in the Lake Garda Region from Early Bronze Age to the beginning of Middle Bronze Age : the first Bronze Age settlements seem to spread in the bogs of the hilly moraine region during a short time (from 2050 to 2010 cal. BC), then suddenly disappear in the years from 2000 to 1950 cal. BC, when new villages are founded along the Lake Garda shores. About a century later (1870-1830 cal. BC) the first lakeside sites are abandoned, while building activity begins again in the bog settlement of Barche di Solferino ; finally, at the end of the XVIIIth century cal. BC a new village is founded in the small Lake Frassino, not far from the effluent river Mincio.

Site	Years	Sample Code	δ^{13}C	^{14}C Date BP	1σ Calibrated Date BC
Frassino I	17 -25	Hd - 19593	-26.37 ‰	3487 ± 20	1870 - 1835 1810 - 1805 1780 - 1745
Frassino I	60 - 80	Hd - 19596	-27.02 ‰	3499 ± 20	1875 - 1835 1820 - 1795 1785 - 1750
Frassino I	90 - 100	Hd - 19818	-27.47 ‰	3450 ± 17	1745 - 1695
Frassino I	126 - 135	Hd - 17957	-28.08 ‰	3495 ± 20	1875 - 1835 1815 - 1800 1780 - 1745
Frassino I	166 - 175	Hd - 17895	-28.38 ‰	3386 ± 25	1730 - 1725 1685 - 1670 1665 - 1630

Tab. 1 : ^{14}C dates of samples coming from the mean sequence of Frassino I.
Tab. 1 : Dates radiocarbone des échantillons dans la courbe moyenne du Frassino I.

Pile and wood species	Indicator	Felling year in relative chronology	Felling year cal. BC ± 12 years
P357 *Quercus* sp. Sez. *ROBUR*	*Waldkante*	year 122	1709 BC
P225 *Quercus* sp. Sez. *ROBUR*	*Waldkante*	year 136	1695 BC
P228 *Quercus* sp. Sez. *CERRIS*	*Waldkante* (?)	year 175	1656 BC
P176 *Quercus* sp. Sez. *CERRIS*	*Waldkante*	year 185	1646 BC
P227 *Quercus* sp. Sez. *CERRIS*	*Waldkante* (?)	year 194	1637 BC

Tab. 2 : Felling phases found in the tree-ring chronology of Frassino I.
Tab. 2 : Phases d'abattage dans la chronologie du Frassino I.

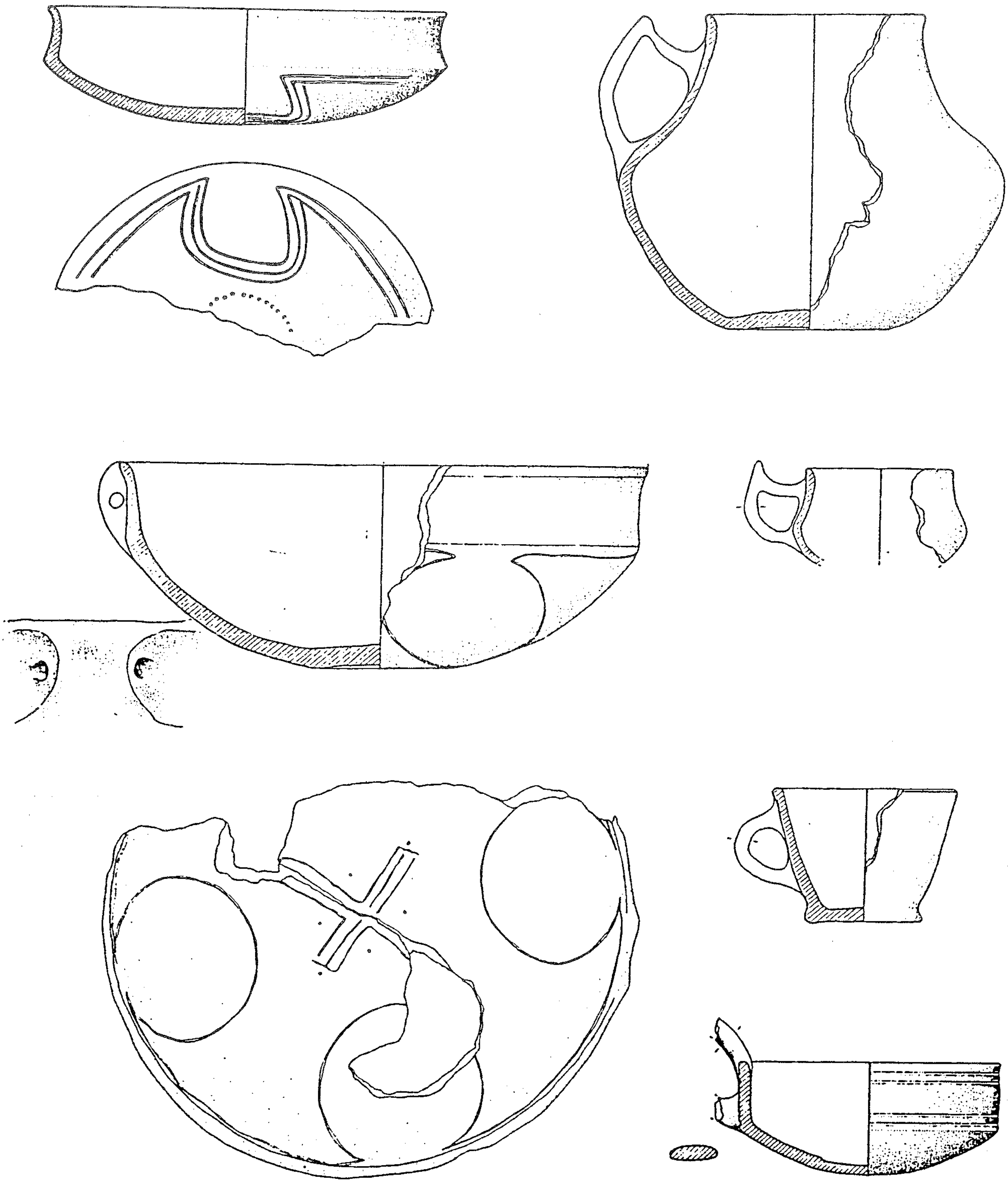

Fig. 2 : Pottery from the site Frassino I.
Fig. 2 : Poterie du site Frassino I.

Despite the problems encountered in associating the absolute dates derived from the wooden structures to the ceramic artefacts related to a phase of transition from late Early Bronze Age to early Middle Bronze Age - we remind that no excavation has been performed yet in the site - it is interesting to note that the dating of "Frassino I" to the period 1709 - 1637 BC ± 12 years, seems to provide a date for the beginning of the Middle Bronze Age back to the first half of the XVIIth Century BC at the latest.

A possible confirmation are the dates obtained by using the 'wiggle-matching' method for two other Italian sites, Canàr di San Pietro Polesine and Fiavè Carera zone 4, both attributed to the late phases of the Early Bronze Age (Marzatico 1996 ; Salzani *et al.*, 1996). For the former an occupation could be hypothesized between 1920 and 1850 cal. BC, from the second comes an oak table used after 1828 cal. BC (Martinelli, 1996).

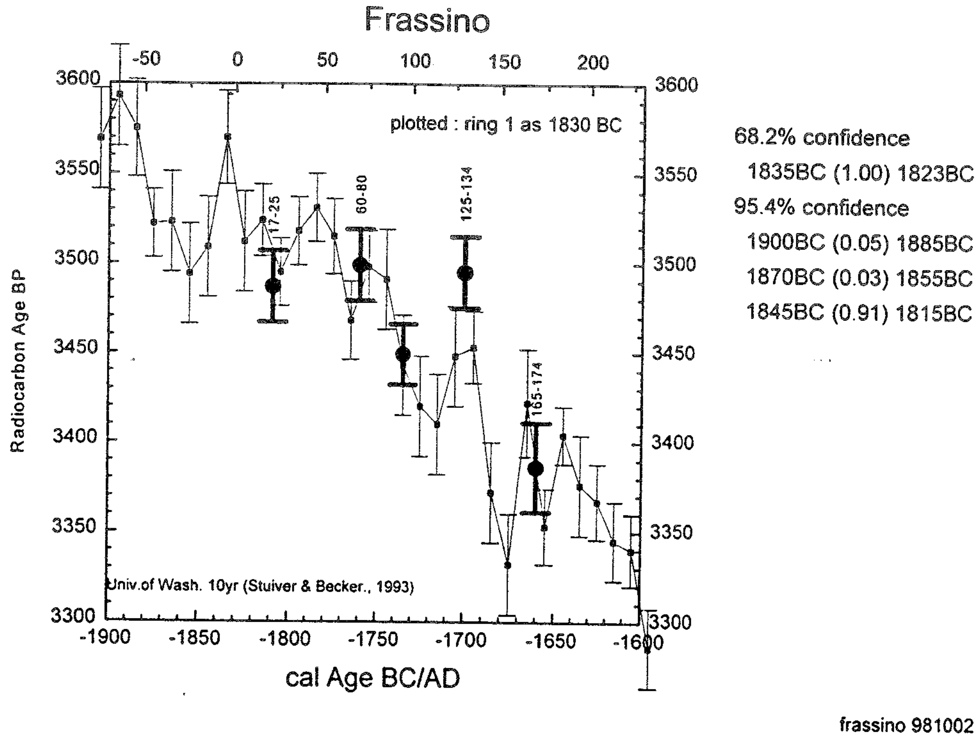

Fig. 3 : Wiggle-matching : plot of the match with the calibration curve.
Fig. 3 : Wiggle-matching : intersection avec la courbe de calibration.

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L'APPORT DU RADIOCARBONE
A LA RESOLUTION DE QUESTIONS IMPORTANTES
EN ARCHEOLOGIE

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LES DATATIONS C14 SUR LES HABITATS DE LA GRANDE PLAINE RUSSE ORIENTALE

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Résumé : L'ensemble des datations ^{14}C du Paléolithique supérieur de la grande plaine de l'Europe orientale est analysée et resituée dans le cadre chronostratigraphique, paléoclimatologique et typologique des niveaux archéologiques datés. Il est alors possible de constater que l'amélioration continue des techniques de datations radiométriques, et en particulier la méthode AMS, permet de dater avec de plus en plus de précision les différentes étapes chronologiques du peuplement paléolithique de l'Europe orientale.
Ainsi l'occupation du peuplement du Paléolithique supérieur ancien est actuellement confirmé à partir de 38 000 B.P. jusqu'à 28 000 B.P. pour différentes cultures du bassin du Don : le Strélétien, le Spitsynien, le Gorotsovien et l'Aurignacien à Kostienki. Ensuite, l'occupation du Gravettien est le peuplement le plus important en Europe Orientale entre 24 000 et 22 000 B.P. Pendant l'époque du maximum glaciaire du Würm récent, de 22 000 B.P. à 17 000 B.P. la grande plaine reste occupée par plusieurs peuplements. Pendant cette période, le peuplement se réduit cependant aux zones du bassin du Dniestr et du versant nord-est des Carpates, au pourtour de la Mer Noire dans la zone des steppes, avec des incursions dans la grande plaine dans le bassin du Dniepr et du Don. Le Paléolithique supérieur récent voit alors la réoccupation de la grande plaine dès 15 000 B.P.

Abstract : The total set of recorded ^{14}C dates of Upper Palaeolithic of eastern Europe is analysed and relocalised in the chronostratigraphic, palaeoclimatic and typological frame of the dated archaeological layers. It is then possible to say that the continuous evolution of the technics of radiometric datations, and particulary the AMS method, is allowing to date with more and more accuracy the different chronological steps of the palaeolithic peopling of eastern Europe.
Therefore, the peopling of early upper Palaeolithic is beginning between 38 000 B.P. and 28 000 B.P with Streletian, Spitsynian, Gorotsovian, Aurignacian industries in Kostienki in the Don valley. Then, during the middle upper Palaeolithic, the Gravettian is the most important peopling of eastern Europe around 24 000 B.P.- 22 000 B.P. During the maximum of the würmian ice age, between 22 000 B.P. and 17 000 B.P., the great plain is always occupied by several peopling, but restricted to the Dniestr basin and the north-east side of the Carpatians, and around the northern coast of the Black Sea, in the steppic area, with raids in the Dniepr and Don basins. The late upper paleolithic is seeing then the repeopling of the great plain from 15 000 B.P.

Mots-clés : Paléolithique supérieur, Europe orientale, Datations, ^{14}C.

Key-words : Upper Palaeolithic, Eastern Europe, dates, ^{14}C.

INTRODUCTION

En Europe orientale, plusieurs régions possèdent des concentrations de sites de différentes périodes du Paléolithique supérieur, situées dans les bassins des grandes rivières. Les régions les plus riches sont la région du bassin du Dniestr moyen, les régions du bassin du Dniepr moyen et supérieur avec son affluent la Desna, et la région du bassin du Don moyen.

Les études stratigraphiques des sites de ces régions faites par les géologues complétées par les études de coupes géologiques de référence et les séries de datations C14 de différents laboratoires, ont mis en évidence l'existence des grandes étapes chronologiques de l'occupation de la grande plaine pendant le Pléistocène supérieur.

La territoire de l'Europe orientale a livré aussi plusieurs sites avec différents types de structures d'habitat de plein air relativement élaborées. Ce sont en particulier les habitats gravettiens et épigravettiens des bassins du Dniepr et du Don. Ces habitats ont été trouvés sous 3 à 5 m de remplissage de loess de la deuxième ou de la première terrasse de la vallée de la rivière. Les sites de Kostienki, Gagarino, Khotilevo 2, Mezine, Gontsy, Dobranitchevka, Meziritche ont une importance particulière de par l'état de conservation de leurs structures d'habitat, qui n'ont pas été modifiées par des processus de cryoturbation, comme celles situées plus au nord. La bonne conservation de ces sites a permis non seulement de reconstituer les structures d'habitat, mais également de préciser la distribution spatiale des différents types d'artefacts et en particulier des objets d'art figuratifs et décoratifs, qui

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sont nombreux sur ces sites. Ces sites peuvent donc être considérés comme des sites de référence bien connus dans l'espace et dans le temps.

LE PALÉOLITHIQUE SUPÉRIEUR ANCIEN

Les sites du Paléolithique supérieur ancien ne sont bien connus que dans la zone exceptionnelle à nombreux sites stratifiés de Kostienki, sur le versant du Don, où les multiples corrélations stratigraphiques ont permis à A.N. Rogatchev et son équipe, avec l'aide de géologues, de bâtir une chrono-stratigraphie relative du Paléolithique supérieur du bassin du Don (Praslov et Rogatchev, 1982).

Cette chrono-stratigraphie est construite sur la présence de deux sols fossiles de l'interpléniglaciaire würmien séparés par un niveau de cendres volcaniques considéré comme provenant d'une des éruptions du volcan de Campi Flegrei près de Naples en Italie, daté entre 35 000 B.P. et 32 000 B.P., et définissant trois ensembles de niveaux d'occupation paléolithiques :

- le premier ensemble concerne les niveaux paléolithiques appartenant au sol fossile inférieur, considérés comme antérieur au moins à 32 000 B.P. (fig.1). À cet ensemble appartiennent les industries du Strélétien (Kostienki 1, couche V ; Kostienki 6), du Spitsynien (Kostienki 17, couche II), et du Gorotsovien (Kostienki 12, couche III ; Kostienki 14, couche IV).
- le deuxième ensemble concerne les niveaux paléolithiques appartenant au sol fossile supérieur, considérés comme compris entre 32 000 B.P. et 28 000 B.P. (fig. 2). À cet ensemble appartiennent les industries de l'Aurignacien (Kostienki I, couche III) et du Gravettien ancien (?) ou Thalmannien (Kostienki 8, couche II).
- le troisième ensemble concerne les niveaux paléolithiques des dépôts colluviaux de loess sur la deuxième et la première terrasse du versant de la vallée, situés au-dessus des sols fossiles interstadiaires, et plus récents que 27 000 B.P. Ce sont les niveaux du Gravettien récent et de l'Epigravettien.

Les autres régions d'Europe orientale ont fourni peu d'autres sites du Paléolithique supérieur ancien. Sur la vallée du Dniestr, les sites de Molodova V et de Korman IV ont fourni une industrie pauvre attribuée au Gravettien ancien (Chernysh, 1961) et datée par des datations trop anciennement faites pour ne pas avoir à être vérifiées rapidement.

En Crimée, des fouilles récentes (Otte *et al.,* 1996) ont confirmé l'existence de niveaux de l'Aurignacien postérieurement à la présence importante d'un Moustérien tardif.

LE GRAVETTIEN RÉCENT

L'étape chronologique suivante située entre 25 000 B.P. et 22 000 B.P. a été révélée par de grandes séries de datations C14 anciennes et récentes (fig. 3), qui ont été

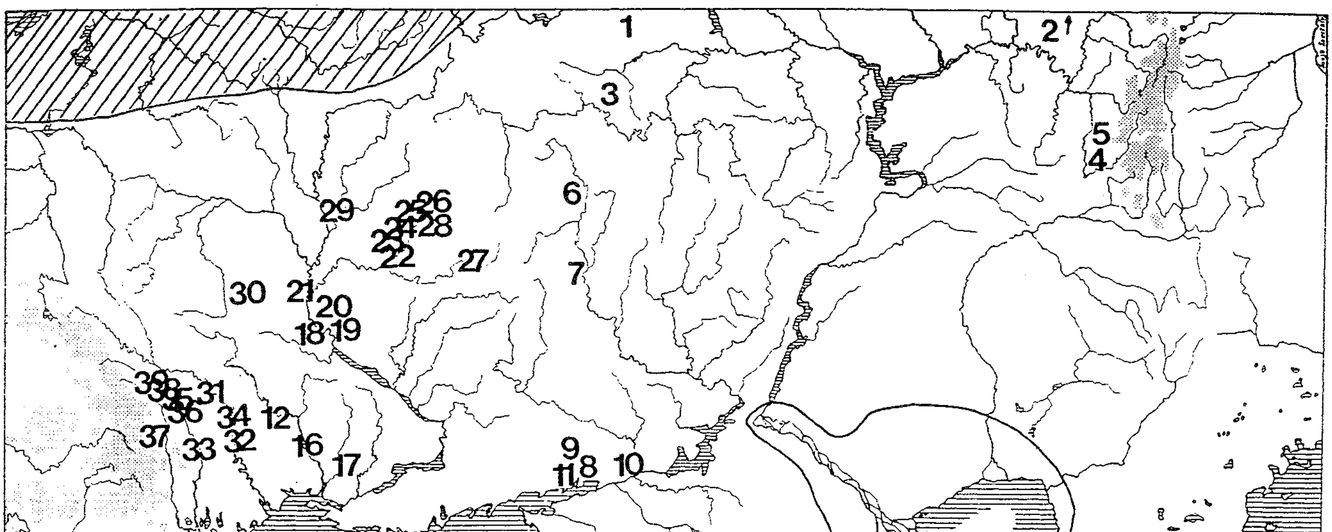

Fig. 1 : Carte d'une sélection de sites du Paléolithique supérieur d'Europe orientale.
1. Sungir, 2. Bysovaia, 3. Zaraisk, 4. Kapova, 5. Ignatievska, 6. Gagarino, 7. Kostienki-Borschevo, 8. Kammenaia Balka, 9. Amvrosievka, 10. Zolotovka, 11. Muralovka, 12. Leski, 13. Siuren, 14. Skalisky, 15. Buren Kaya, 16. Anetovka II, 17. Sagaidak I, 18. Mezeritche, 19. Gontsy, 20. Dobranitchevka, 21. Kiev-Kirilovskaia, 22. Mezine, 23. Pouchkari I, Pognon, Novgorod-Severskii, 24. Ioudinovo, 25. Timonovka, Suponevo, 26. Elisseevitchi, 27. Avdeevo, 28. Khotylevo II, 29. Berdysh, 30. Radomyshl, 31. Molodova I, V, Korman IV, 32. Rachkov 7, 33. Korpatch, Brinzeni, Ciuntu, 34. Cosaoutsy, 35. Mitoc Malul Galben, 36. Ripiceni-Ivzor, 37. Bistriciorara-Lutarie, Lespezi-Lutarie, 38. Ceahlau-Podis, Ceahlau-Dirtu, 39. Crasnaleuca, Cotu-Miculinti.

SÉLECTION DE DATES POUR LE PALÉOLITHIQUE SUPÉRIEUR ANCIEN

BASSIN DU DON

STRELETIEN

- KOSTIENKI I (Poliakov site, Voronej, Russie)

V	ch	32 300	±	220	BP	GrA 5557
V	ch	34 900	±	350	BP	GrA 5245
V	ch	37 900	±	2800/2100	BP	GrA 5245

- KOSTIENKI 6 (Streletskaia 2 site, Voronej)

	os	31 200		500	BP	GIN 8572

SPITSYNIEN

- KOSTIENKI 17 (Spitzyn site, Voronej, Russie)

II	ch	32 200	±	2 000/1600	BP	GrN 10512
II	ch	36 780	±	1 700/1400	BP	GrN 12596
II	os	32 780	±	300	BP	LE 1436

GOROTSOVIEN

- KOSTIENKI 12 (site Volkov, Voronej, Russie)

III	ch	36 280	±	360	BP	GrA 5551

- KOSTIENKI 14 (site Markina Gora, Voronej, Russie)

IVa	ch	33 280	±	650	BP	GrN 22277

AURIGNACIEN

- KOSTIENKI 17 (Spitzyn site, Voronej, Russie)

1	ch	26 750	±	700	BP	GrN 10511

- KOSTIENKI I (Poliakov site, Voronej, Russie)

3	ch	32 600	±	400	BP	GrN 17117
	os humain	32 600	±	1 100	BP	OxA 7073

GRAVETTIEN ANCIEN ? (THALMANIEN)

- KOSTIENKI 8 (Telmanskaia site)

2	ch	27 700	±	750	BP	GrN 10509
2	os	24 500	±	450	BP	GIN 7999
2	os brulé hum	23 020	±	320	BP	OxA 7109

VALLEE DU DNIESTR

GRAVETTIEN ANCIEN

- KORMAN IV

sol	ch	27 500	±	1000	BP	GIN 832

- MOLODOVA V

9	ch	28 100	±	1 000	BP	LU 15b
9	ch	29 650	±	1 320	BP	LU 15a

CRIMÉE

AURIGNACIEN

- SIUREN I (Crimée)

Fb1	os	29 550	±	700	BP	OxA 5155
Ga	os	28 450	±	600	BP	OxA 5154

Fig. 2.

effectuées dans différents laboratoires européens (Praslov & Rogatchev, 1982 ; Svezhentsev, 1993, Sinitsyn & Praslov, 1997).

Dans le bassin du Dniestr, le Gravettien récent est présent dans les sites de Molodova V, couche 7 et Korman IV, couche 7.

Dans le bassin du Dniepr supérieur, et plus précisément de son affluent la Desna, le Gravettien récent est présent dans les sites de Berdysh, Khotilevo 2 et Avdeevo.

Dans le bassin du Don, le Gravettien récent est présent dans les sites de Zaraisk, Gagarino, Kostienki 1, couche 1, Kostienki 11, couche 3 & 2, Kostienki 21, couche 3 & 2 et Kostienki 18, couche 4.

Suivant l'hypothèse de l'existence de la grande unité culturelle de Willendorf-Kostienki, la présence de ces sites sur la Desna et sur le Don révélerait une migration du Gravettien d'Europe centrale vers l'Est vers 24 000-23 000 B.P. (Grigoriev, 1979, 1993).

On peut actuellement constater que les sites importants du Gravettien oriental ont été datés par plusieurs échantillons effectués dans le même habitat, qui nous permettent la comparaison des datations entre les différentes structures de ces habitats, et la comparaison des datations entre ces sites. Dans ce contexte, précisons que plus la série des datations est grande, plus la fourchette chronologique est large. Cette remarque est évidente pour les deux plus grandes séries de datations C14, sur le site de Kostienki 1, couche 1 et sur le site de Avdeevo. Il est ainsi important de préciser que les prélèvements des échantillons de Kostienki 1, couche 1 fouillés par A.N. Rogatchev et N.D. Praslov et aussi les prélèvements des échantillons du site de Avdeevo fouillé par M.D. Gvosdover et G.P. Grigoriev ont été effectués dans les différentes parties de ces grands gisements, et sur une très longue période de temps de fouilles et d'études de ces gisements.

Ces deux sites, qui appartiennent à la même culture, ont fourni des structures d'habitat semblables. Ces structures d'habitat, qui sont relativement complexes, possèdent une large surface d'habitat ovale avec des foyers ali-

SÉLECTION DE DATES POUR LE GRAVETTIEN RÉCENT DE LA GRANDE PLAINE

BASSIN DE LA DESNA						
- KHOTYLEVO 2						
	dent	23 300	±	300	BP	GIN 8497a
	os	23 660	±	270	BP	LU 359
	os	23 870	±	160	BP	GrN 22216
	mêmos	24 220	±	110	BP	GrN 21889
	dent	24 960	±	400	BP	IGAN 73
- AVDEEVO						
	dent	23 400	±	700	BP	GIN 7729
- BERDYSH						
	dent	22 500	±	200	BP	GIN 2695
	dent	23 430	±	180	BP	LU 104
BASSIN DU DON						
- GAGARINO						
	défense	21 600	±	140	BP	GIN 7989
	os brulé	21 800	±	300	BP	GIN 1872
- KOSTIENKI I (Poliakov site, Voronej, Russie)						
1	dent	23 010	±	300	BP	LE 3276
1	dent	23 260	±	680	BP	LE 3289
1	ch	23 600	±	400	BP	GrA 5244
1	défense	23 640	±	320	BP	LE 3283
1	dent	23 770	±	200	BP	LE 2951
- KOSTIENKI 4 (site Alexandrovskaia, Voronej)						
1	os	22 800	±	120	BP	GIN 7995
1	os	23 000	±	300	BP	GIN 7994
- KOSTIENKI 5 (site Sviatoi Log, Voronej)						
2	os	22 920	±	140	BP	GIN 8571
- KOSTIENKI 8 (Telmanskaia site)						
1	os	22 000	±	160	BP	GIN 7988
1	dent	22 900	±	120	BP	GIN 7997
- KOSTIENKI 11 (site Anosovka 2, Voronej)						
3	os	22 760	±	340	BP	LE 1638
2	os brulé	21 800	±	200	BP	GIN 2531
- KOSTIENKI 14 (site Markina Gora, Voronej)						
1	os	22 780	±	250	BP	OxA 4114
- KOSTIENKI 18 (site Khvoikovskaia, Voronej)						
sépulture	os humain	21 020	±	180	BP	OxA 7128
- KOSTIENKI 21 (site Gmielin, Voronej)						
3	mêch	22 270	±	150	BP	GrN 7363
3	argile cuite	26 785	±	200	BP	TA-TL
2	os	22 900	±	150	BP	LE 1437c
BASSIN DU DNIESTR						
MOLODOVA V						
7	ch	23 000	±	800	BP	MO 11
sol 7	hum	23 700	±	320	BP	GIN 10
- KORMAN IV						
7	ch	25 140	±	350	BP	LU 586
7	ch	24 500	±	510	BP	GIN 1099

Fig. 3.

SÉLECTION DE DATES POUR L'EPIGRAVETTIEN ANCIEN

ZONE DES STEPPES

- LESKI						
	dent	19 200	±	200	BP	LE 2946
- ANETOVKA II						
	os brulé	18 265	±	1650	BP	LE 4066
	os	18 040	±	150	BP	LE 2424
	os	19 170	±	120	BP	LE 2947
	os brulé	19 090	±	980	BP	LE 4610
- AMVROSIEVKA						
I	os	18 700	±	200	BP	OxA 4890
I	os	18 860	±	220	BP	OxA 4891
II-III	os	18 700	±	220	BP	OxA 4892
II-III	os	18 620	±	200	BP	OxA 4893
IV	os	18 220	±	200	BP	OxA 4894
VI	os	18 660	±	200	BP	OxA 4895
- MURALOVKA						
	os	18 780	±	300	BP	LE 1438
	os	19 630	±	200	BP	LE 1601
- ZOLOTOVKA						
	os brulé	17 400	±	700	BP	LE 1968
- SAGAIDAK I						
	dent	21 240	±	200	BP	LE 1602a
	dent	20 300	±	200	BP	LE 1602b
- POKHLIEBIN 1						
	os	17 790	±	260	BP	GIN 8569

VALLÉE DU DNIESTR

- MOLODOVA V						
6	ch	16 750	±	250	BP	GIN 105
5	ch	17 100	±	180	BP	GIN 52
- KORMAN IV						
5a	ch	18 560	±	1 000	BP	SOAN 145
5	ch	18 000	±	400	BP	GIN 719

VALLÉE DE LA DESNA

- POUCHKARI I						
	os brulé	19 010	±	220	BP	AA 1389
	dent	20 600	±	1300	BP	GIN 8529
	os brulé	21 100	±	400	BP	GIN 3382
- POGON						
	os	18 690	±	770	BP	LU 361
- NOVOGOROD-SEVERSKII						
	dent	19 800	±	350	BP	OxA 698

VALLÉE DU DON

- KOSTIENKI 2						
	os	17 300	±	160	BP	GIN 8570
	os	23 800	±	150	BP	GIN 7992
- KOSTIENKI 3						
	os	19 800	±	210	BP	GIN 8022
- KOSTIENKI 11 (Anosovka 2)						
1a	os brulé	19 900	±	350	BP	GIN 2532
1a	os	18 700	±	80	BP	GIN 8079
- KOSTIENKI 19						
	os	18 900	±	150	BP	LE 1705b
	os	18 700	±	600	BP	GIN 8577
- BORSHCHEVO 1						
	os	17 200	±	150	BP	LE 3727

Fig. 4.

SÉLECTION DE DATES POUR L'EPIGRAVETTIEN RÉCENT DU BASSIN DU DNIEPR

- MEZERITCH						
?	dent	14 320	±	270	BP	QC 897
2	dent	14 400	±	250	BP	OxA 712
4	os brulé	14 300	±	300	BP	GIN 2596
3	dent	14 420	±	190	BP	AA 1317
2	os brulé	14 350	±	300	BP	GIN 2595
2	dent	14 700	±	500	BP	GIN 2593
- MEZINE						
1	dent	15 100	±	200	BP	OxA 719
- ELISSEEVITCHI 1						
	os brulé	14 080	±	70	BP	GIN 4135
	dent	14 100	±	400	BP	GIN 4139
	os brulé	14 240	±	120	BP	GIN 5475
	dent	14 470	±	100	BP	LU 126
	dent	14 590	±	140	BP	GIN 4186
- ELISSEEVITCHI 2						
	dent	15 620	±	200	BP	IGAN 556
- TIMONOVKA I						
	dent	14 750	±	120	BP	GIN 8413
	dent	14 530	±	120	BP	GIN 8414
- TIMONOVKA II						
	os	15 110	±	530	BP	LU 358
- IOUDINOVO						
	os brulé	14 300	±	110	BP	ISGS-2084
	os	14 470	±	160	BP	AA-4801
	os brulé	14 500	±	200	BP	GIN 5588
	os brulé	14 610	±	60	BP	GIN 5661
	os	14 650	±	105	BP	AA 4802
	dent	14 870	±	150	BP	LE 3835
- SUPONEVO						
	dent	14 260	±	120	BP	GIN 3719
- CHULATOVO I						
	dent	14 700	±	250	BP	OxA 715
- GONTSY						
Fouilles Sergin (1979-1984)						
	dent	14 600	±	200	BP	OxA 717
cendres U21	os brulé	14 350	±	190	BP	ISGS-1739
Fouilles Iakovleva Et Djindjian (1993-1997)						
Fosse 10 de la cabane 1						
inf	os	14 550	±	150	BP	OxA 5932
inf	os	14 400	±	110	BP	OxA 5933
Foyers Est de la cabane 1						
inf	os	14 180	±	110	BP	OxA 6601
inf	os	14 590	±	120	BP	OxA 6602
Coupe 10 au sud du site						
sup	os	14 120	±	90	BP	OxA 7387
inf	os	14 420	±	100	BP	OxA 7609
Amas d'ossements dans la paléoravine						
inf	os	14 110	±	120	BP	OxA 6729
inf	bois	14 250	±	110	BP	OxA 5934
inf	dent mam	14 670	±	110	BP	OxA 6142

Fig. 5.

gnés suivant leur grand axe. Autour de cette surface, en position périphérique se répartissent plusieurs grandes fosses de formes variées, qui selon des critères morphologiques, ont été interprétées soit comme des habitations semi-souterraines, soit comme des fosses de stockage d'ossements et de différents types d'objets. À Avdeevo, deux de ces structures ont été retrouvées. À Kostienki 1, couche 1, quatre de ces structures ont été reconnues (Praslov & Rogatchev, 1982 ; Gvosdover, 1995).

Actuellement à Kostienki 1, couche 1, 42 datations C14 ont été publiées (Praslov & Soulerjytsky, 1997). Dans cette série de datations, même après avoir exclus la trop jeune datation de 14 000 B.P., la série de datations varie dans une fourchette trop large entre 19 000 B.P. et 24 000 B.P. Cet exemple de série de datations de Kostienki 1, couche 1 illustre le fait, que pour cette seule structure d'habitat, qui a été considérée par les fouilleurs

VALLÉE DU DNIESTR

- MOLODOVA V						
3	ch	13 370	±	540	BP	GIN 9
2	ch	12 300	±	140	BP	GIN 56
ZONE DES STEPPES						
- KAMENNAIA BALKA II						
	os brulé	15 400	±	1 200	BP	GIN 2940
	os brulé	15 350	±	550	BP	GIN 3472
	os brulé	15 100	±	700	BP	GIN 3772
	os brulé	14 800	±	400	BP	GIN 2940a
	os brulé	14 670	±	105	BP	AA 4797
CRIMEE						
- ABRI SKALISKY (SKALISTOYE, CRIMEE)						
VII	ch	14 880	±	180	BP	OxA 5161
VI	ch	15 020	±	150	BP	OxA 5167
V	ch	15 510	±	310	BP	Lv 2133
IV	ch	14 570	±	140	BP	OxA 5166
VALLÉE DU DON						
- BORSHCHEVO 2						
h2	humus	14 030	±	200	BP	LE 4867
I		13 480	±	720	BP	LE 4837
III		13 540	±	300	Bp	LE 4834

EPIGRAVETTIEN FINAL

CRIMEE (CULTURE DE SHAN-KOBA)						
- ABRI BURAN-KAYA III (AROMATNOYE, BELOGORSK, CRIMEE)						
6.8	os	11 900	±	150	BP	OxA 4126
6.9	os	11 950	±	130	BP	OxA 4127
- ABRI SKALISKY (SKALISTOYE, CRIMEE)						
III-3	os	12 820	±	170	BP	OxA 4888
III-3	ch	11 750	±	120	BP	OxA 5165
III-2	ch	11 620	±	110	BP	OxA 5164

Fig. 6.

comme une structure d'habitat contemporaine, sans aucune interruption remarquée de la couche culturelle entre ses différentes zones, il reste toujours à décider d'une date précise d'occupation de cet habitat.

La série des 14 datations d'Avdeevo présente également une fourchette trop large entre 12 000 B.P. et 23 400 B.P., et serait plus probablement datée autour de 23 000 B.P.

Les autres sites du Gravettien, qui ont seulement quelques dates, ont également une assez large variation de datations. Seul le site de Khotilevo 2, avec 10 datations, est situé entre 23 000 B.P. et 25 000 B.P.

Enfin, en revenant sur la question de la précision globale du cadre chronologique du Gravettien Oriental, à partir des datations du C14, on remarquera que cette question est toujours liée avec celle de la liaison entre le Gravettien d'Europe centrale et celui d'Europe orientale, et de la migration du Gravettien vers l'Est et de ces étapes d'installation et de développement dans la grande plaine. Actuellement, on considère les datations entre 22 000 B.P. et 24 000 B.P. comme les plus fiables, en accord avec l'hypothèse de la migration des chasseurs gravettiens vers l'est et le nord-est.

L'ÉPIGRAVETTIEN

La période chronologique de 21 000 B.P. à 13 000 B.P. connaît des peuplements appelés actuellement Epigravettien au sens large, qui réunit différentes cultures et faciès, qui occupent largement le territoire de la grande plaine.

Le peuplement au maximum glaciaire du Würm récent

Un changement important apparaît à une date encore imprécise vraisemblablement vers 21 000 B.P., au moment de l'arrivée du maximum glaciaire, et qui va se traduire par un abandon partiel de l'occupation de la grande plaine entre 21 000 B.P. et 17 000 B.P.

La vallée du Dniepr semble désertée d'occupations importantes et ne se signale que par la présence de faibles installations, comme dans la région de Novgorod-Severskii (Pouchkari, Pogon, Novgorod-Severskii), si les dates connues sont confirmées, peut-être spécialisées dans l'approvisionnement en silex local.

Le versant nord-oriental des Carpates, en Ukraine, Moldavie et Roumanie, est, au contraire, une région de peuplement toujours importante, sur le Dniestr (Molodova V couches 4, 5, 6 et Korman IV), sur le Prut (Cosaoutsi) et sur la Bistrita (Bistricioara-Lutarie, Lespezi-Lutarie, Ceahlau, etc...).

Dans la vallée du Don moyen, les sites de cette période à Kostienki sont en nombre et en importance plus limités (Kostienki 2, Kostienki 11, couche 1, Kostienki 19).

Un peuplement très important est localisé sur l'ensemble du pourtour de la mer Noire, dans la zone des steppes, avec des industries encore insuffisamment datées présentant des faciès variés (fig. 4) : faciès aurignacoïdes (Anetovka II, Muralovka, Zolotovka, Sagaidak I) et des faciès gravettoïdes (Amvrosievka). Les résultats récents sur Amvrosievka, site d'abattage de bisons fouillé par A.A. Krotova, montrent que des datations C14 AMS répétées dans différentes zones du site, peuvent préciser à la fois la chronologie et la périodisation de l'occupation, d'une fourchette large d'occupation comprise entre 15 500 B.P. et 21 500 B.P. à une occupation multi-saisonnière aux environs de 18 500 B.P. (Hedges *et al.*, 1996 ; Krotova, 1996).

L'épigravettien récent du bassin du Dniepr

Si le peuplement du territoire de la zone des steppes laisse encore bien des questions à préciser (Djindjian & Iakovleva, 1997), le bassin du Dniepr supérieur et moyen est actuellement suffisamment bien étudié par plusieurs chercheurs, qui ont mis en évidence l'occupation principale de ces peuplements épigravettiens à partir de 15 000 B.P. (Abramova & Grigorieva, 1997 ; Iakovleva, 1996 ; Velichko *et al.*, 1996).

Le territoire des sites épigravettiens est bien connu depuis les sites situés plus au nord dans le bassin du Dniepr supérieur, comme Suponevo, Eliseevitchii 1,2, Timonovka 1,2, Ioudinovo, Mezine, dans le bassin du Dniepr moyen comme Kiev-Kirilovskaia, Dobranitchevka, Semenovka, jusque plus au sud à Gontsy, et Meziritche.

Un des traits les plus significatifs de ce groupe de sites, est la présence de structures d'habitat semblables, construites avec des ossements de mammouths, et installés sur un versant de terrasse de rivières affluentes du bassin du Dniepr. Malgré certaines différences qui peuvent être observées dans l'industrie lithique, osseuse et dans les objets d'art mobilier de ces sites, qui sont parfois interprétés comme l'existence de faciès multiples, il faut souligner l'homogénéité des structures d'habitats, et leur existence sur une assez courte période de temps (15 000 B.P.-14 000 B.P.) dans un territoire bien délimité (fig. 5 et 6).

Les datations C14 des sites épigravettiens récents présentent une variabilité parfois importante de quelques milliers d'années. Le grand site de référence de Gontsy est un exemple d'application systématique de C14 AMS à la datation d'un site à structure d'habitat complexe. Les objets datés ont été choisis suivant une procédure systématique d'échantillonnage dans les différentes structures spatiales fouillées du site (Iakovleva et Djindjian, 1995).

La présence épigravettienne est beaucoup moins connue dans les autres régions, notamment dans le bassin du Dniestr, ainsi que dans le bassin du Don, où la présence indiscutable de sites datés entre 16 000 et 13 000 B.P. n'est pas attesté. Dans la zone des steppes, le site de Kammenaia Balka II, fournit seul des datations dans cette fourchette de dates.

CONCLUSIONS

En Europe Orientale, l'occupation du peuplement du Paléolithique supérieur ancien est actuellement confirmé à partir de 38 000 B.P. jusqu'à 28 000 B.P. pour différentes cultures du bassin du Don notamment le Strélétien, le Spitsynien, le Gorotsovien et l'Aurignacien à Kostienki.

Les dates des niveaux parfois attribués à un Gravettien ancien à partir de 28000 B.P., pour les sites de Korman 4, Molodova 5, couche 9,10 sur le Dniestr et de Kostienki 8, couche 2 (Thalmannien) sur le Don, demandent à être confirmés par de nouvelles datations, sinon par de nouvelles fouilles.

C'est pourquoi il faut constater que l'occupation principale du Gravettien (culture de Kostienki-Avdeevo) en Europe Orientale entre 24 000 et 22 000 B.P., se traduit par un grand développement culturel de ces peuplements dont les traits les plus connus sont les structures d'habitat, les fameuses Vénus, les sculptures animalières, et les pointes de Kostienki. Pendant l'époque du maximum glaciaire du Würm récent, vers 22 000-17 000 B.P. en Europe Orientale, la grande plaine reste assez bien occupée par plusieurs peuplements. Pendant cette période, le peuplement se réduit cependant aux zones du bassin du Dniestr (et du versant nord-est des Carpates), au pourtour de la Mer Noire dans la zone des steppes, avec des incursions épisodiques dans la grande plaine dans le bassin du Dniepr (Pouchkari) et du Don (Kostienki).

Pendant la période du Paléolithique supérieur récent, la réoccupation systématique de la grande plaine se traduit par des peuplements épigravettiens, en particulier avec une série importante de sites sur le Dniepr moyen et supérieur. Les peuplements épigravettiens installés dans le bassin du Dniepr supérieur et moyen entre 15 000 B.P. et 14 000 B.P. montrent ainsi une grande capacité d'installation en plein air dans les conditions climatiques de la fin du Würm récent, qui se traduit par des campements semi-sédentaires avec des structures d'habitat très élaborées autour d'une cabane en os du mammouths. Les habitats de la même période dans la zone des steppes sont peu connus et encore plus rarement datés.

Au Paléolithique final, les occupations de l'Epigravettien final entre 13 000 B.P. et 11 000 B.P. n'ont pas laissé les traces d'habitats nombreux, et bien que présents, ils ne traduisent pas dans l'état actuel des connaissances, l'importance du développement démographique que l'on connaît à travers toute l'Europe, à la même période.

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IMPROVED RADIOCARBON CHRONOLOGY AND THE NEOLITHISATION OF EUROPE

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Summary : We discuss the Neolithisation of Europe using radiocarbon dates of Early Neolithic sites. We tested, using the χ^2 criterion, whether or not subsets incorporating culturally and/or geographically uniform data represented a Gaussian random variable with a unique mean date. It is shown that this is the case for Linearbadkeramik (LBK) sites in Central Europe, but not for early pottery sites in Eastern and Northern Europe. We conclude that two distinct modes of Neolithisation apparently occurred in the two areas, the former being a rapid colonisation of an empty ecological niche by a farming population ; and the second corresponding to a gradual acceptance or rejection of technological and social novelties by local non-farming groups.

Résumé : Une base de données contenant les datations par le carbone-14 a été développée visant à vérifier certaines hypothèses relatives à la Néolithisation de l'Europe. Les données ont été soumises à l'analyse statistique avec l'utilisation du critère χ^2, dont le but a été la vérification de l'hypothèse selon laquelle les datations dans chacune des listes ne formait que la distribution gaussienne randomisée d'une date moyenne unique. On a pu distinguer deux modèles de la Néolithisation : la première prenant la forme de l'immigration accélérée de la population agricole dans une niche écologique pratiquement vide, la deuxième étant vue comme l'acceptation ou la rejection des innovations technologiques et sociales par la population locale non-agricole.

Key-words : Neolithisation, database, Central Europe, Eastern Europe, statistical analysis.

Mots-clés : Néolithisation, base de données, Europe centrale, Europe de l'Est, analyse statistique.

1 - INTRODUCTION

The spread of economic, technological and cultural innovations summarily labelled by Gordon Childe as 'Neolithic revolution' remains a controversial issue in European Prehistory. The core of the problem is, firstly, to identify the Neolithic as a socio-cultural phenomenon and, secondly, to assess various scenarios of Neolithisation.

The model of Neolithisation as a result of a direct migration is omnipresent in the works of Gordon Childe (1958). In more recent times, this model appealed to processes of a 'demic expansion' or a 'wave of advance' (Ammerman and Cavalli-Sforza, 1973).

An alternative concept attributes the Neolithisation to a 'diffusive', or *reticulate* process (Moor, 1994) wherein cultural, linguistic and biological units emerge from intermarriage, assimilation and borrowing.

The first series of radiocarbon measurements appeared to confirm the Childean concept of *Ex Oriente lux*, indicating that the 'Neolithic way of life penetrated Europe from the south-east spreading from Greece and the south Balkans...' (Clark, 1965, 67).

More recent publications based on comprehensive radiocarbon data for Neolithic sites suggested a more balanced view. Tringham (1971, 216-7) discussed the spread of new techniques, and their adoption (or rejection) by the local groups, resulting from the expansion of population. Dolukhanov and Timofeyev (1972, 29-30), considered this process as a combination of diffusion and local inventions.

The aim of the present paper is to test various scenarios of Neolithisation against the available corpus of radiocarbon dates.

2 - THE DATABASE

Radiocarbon dates compiled by Dolukhanov and Timofeyev (1972), Gob (1990) and Lillie (1998) were combined into a GIS-oriented database of Early Neolithic

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measurements. The data referred to as 'dubious' by Gob were omitted. Since our aim is to assess early stages of Neolithisation, only the dates from the lowest strata of multi-stratified sites were included. When a series of radiocarbon measurements were available for the same site (or the same layer), the oldest date was selected. The data were calibrated with the calibration curve of Stuiver *et al.* (1993) using OxCal 3.2.

The data were organised into the following four subsets having common cultural and/or geographical features : (1) early agricultural sites of South-Eastern Europe, (2) Linear Pottery sites from Central (and partially Western) Europe ; (3) Mediterranean Impressed Ware sites, and (4) early pottery from Eastern and Northern Europe. In each case the following attributes were included into the database : (i) the site name ; (ii)–(v) geographical coordinates (longitude and latitude in degrees and minutes) ; (vi) the uncalibrated date (t_i), (vii) its uncertainty (σ_i), (viii) the calibrated date (T_i), and (ix) its uncertainty (Σ_i).

3 - STATISTICAL ANALYSIS

In order to quantify the spread of Neolithisation, we tested the hypothesis that the dates in each individual subset are coeval. In other words, we checked whether or not the radiocarbon dates in a subset represent a single date contaminated by Gaussian random noise. If the data are compatible with this hypothesis, one can conclude that the Neolithisation proceeded fast (in the sense of radiocarbon dating) ; if this is not the case, the spread of the Neolithisation was gradual.

We first calculated the most probable common date T_0 of the subsample using weighted least squares. Then the hypothesis of contemporaneity was assessed using the χ^2 test,

$$\sum_{i=1}^{n} \frac{(t_i - T_0)^2}{\Sigma_i^2} \leq \chi^2_{n-1},$$

where n is the number of measurements in the subset. The dates deviating most strongly from the current value of T_0, were discarded one by one until the χ^2 test was satisfied. This procedure results in a "coeval subsample". The published errors of some measurements are rather small. Therefore, the uncertainty of the dates was adopted as $\Sigma_i = \max(\sigma_i, \langle\sigma_i\rangle)$, where angular brackets denote an average value over the subset. The results of the analysis for two subsets are presented in what follows.

4 - RESULTS

4.1 - LINEAR POTTERY FROM CENTRAL EUROPE

The subset contains 32 measurements from sites belonging to the Linear Pottery Culture (LBK) in the Czech Lands, Germany, Belgium and North-Eastern France shown in table 1. The statistical test for contemporaneity is satisfied for the whole subset without discarding any measurements. The resulting age of the subset is

$$T_0 = 5190 \pm 100 \text{ BC}.$$

Fig. 1(a) shows the age distribution for this subset.

4.2 - EARLY POTTERY SITES OF EASTERN AND NORTHERN EUROPE

The subset contains 44 measurements presented in table 2. The dated sites belong to pottery-bearing sedentary settlements with sufficient evidence of social complexity, yet with no or little indication of either agriculture or stock-breeding. These sites were located in southern Russia, Ukraine, Moldova, Central Russia, Eastern and Western Baltic area and in northern Scandinavia.

Twenty two measurements, shown boldfaced in table 2, satisfy the criterion of contemporaneity. The most probable age of the coeval subsample is :

$$T_0 = 5320 \pm 30 \text{ BC}.$$

Histograms of the occurrence rate for the whole date list and its coeval subsample are shown in fig. 1(b).

5 - DISCUSSION

Two basically different modes of Neolithisation in two ecologically distinct areas of Europe are indicated by our analysis. The spread of the LBK agricultural settlements across loessic plateaux of Central Europe apparently had a character of a momentary event in the sense of radiocarbon dating. Its duration is comparable with the uncertainty of individual measurements. This supports the model of accelerated colonisation with a demic expansion into a virtually empty ecological niche.

The analysis of the early pottery sites of Eastern and Northern Europe (ENE) suggests another type of Neolithisation. Firstly, the time span of these dates is noticeably longer, and starts earlier, than that of the LBK sites. The age distribution of the ENE sites exhibits two maxima. The earlier, more pronounced maximum, defining the formally obtained coeval subsample, occurs at about the same time as the LBK maximum, i.e., *c.* 5200–5300 BC. Furthermore, it seems plausible that the ENE data also indicate a later phase of Neolithisation at *c.* 4400 BC. Although the ENE data include sites belonging to different archaeological cultures, the sites belonging to each individual culture are spread in time as widely as the whole subset. This may imply a more active participation of the local pre-Neolithic groups. However, reliable assessment of this possibility requires further analysis that will be presented elsewhere.

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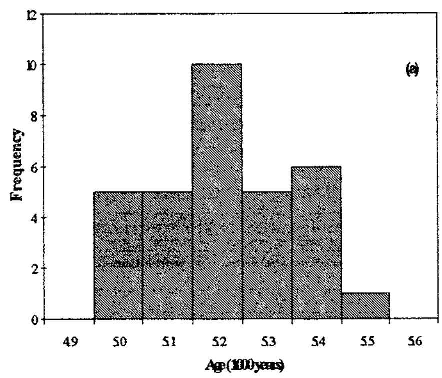
Site	X°	X'	Y°	Y'	Age, bp	σ, yr	Age, BC	Σ, yr
Bekes	47	50	20	30	6080	60	4990	116
Tarnaz	47	39	20	9	6155	80	5095	125
Templom	47	41	20	13	6280	100	5195	125
T-Vasvari	48	58	21	23	6305	100	5225	155
Pulkau	48	42	16	52	6215	100	5135	135
Eilsleben	51	29	11	31	6190	90	5115	125
Felsdach	48	20	9	34	6440	45	5375	116
Muddelsheim	50	47	6	28	6140	90	5075	135
Langweiler	51	52	6	21	6210	125	5130	140
Friedberg	50	20	8	45	6120	100	5065	145
Zwenkau	51	13	12	20	6160	70	5105	116
Bylany	50	58	15	18	6320	230	5215	235
Mohelnice	49	47	17	55	6405	100	5350	116
Sturovo	47	48	18	44	6260	100	5175	116
Zopy	49	20	17	35	6430	100	5355	116
Aubechies	50	33	5	53	6420	120	5340	120
Awans	50	43	5	27	6070	90	5020	180
Darion	50	39	5	11	6240	100	5165	116
Crisnee	50	41	5	24	6320	75	5235	145
Kanne	50	48	5	40	6260	75	5170	116
Liege	50	39	5	34	6460	60	5385	116
Oleye	50	41	5	13	6510	80	5430	116
Waremme	50	48	5	37	6300	95	5205	135
Wange	50	49	5	37	6310	75	5205	135
Vlijtingen	50	49	5	36	6160	95	5090	130
Berry	49	24	4	53	6030	130	4985	215
Cuiry	49	23	3	45	6000	120	4915	145
Evendorff	45	25	6	34	6050	200	4970	250
Menneville	49	25	4	1	6200	190	5115	205
Reichstette	48	38	7	45	6420	230	5325	255
Rufacher	48	2	1	35	6050	200	4970	250
Schwind	48	45	7	36	6230	300	5125	325

Tab. 1 : Radiocarbon dates for the Linear Pottery (LBK) sites.



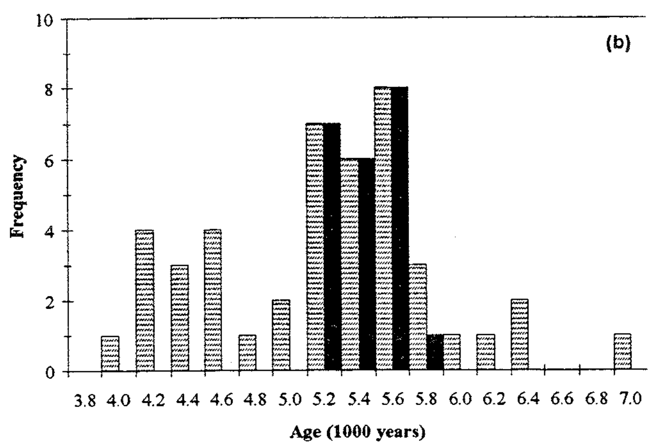


Fig. 1 : The rate of occurrence of radiocarbon dated sites for the subsamples of **(a)** the pottery from Central Europe (LBK) and **(b)** the early pottery sites of Eastern and Northern Europe. The coeval subsamples are shown shaded.

Site	X°	X'	Y°	Y'	Age, bp	σ, yr	Age, BC	Σ, yr
Sudensee	54	38	9	35	6025	90	4925	125
Brovst	**57**	**6**	**9**	**30**	**6510**	**100**	**5425**	**116**
Chrisiansholm	55	45	12	34	5370	100	4190	150
Ertebolle	56	48	9	10	5230	100	4090	140
Holmegaard	**56**	**16**	**10**	**46**	**6280**	**130**	**5215**	**165**
Norslund	56	1	10	44	5610	110	4450	120
Ringkloster	56	1	10	57	5610	110	4450	120
Salpetermose	56	55	12	18	6020	110	4925	135
Solager	56	56	12	54	5520	110	4350	120
Vaegne	56	8	10	31	5540	35	4400	116
Vejlenbro	55	41	9	35	5540	110	4380	130
Olby Lyng	55	30	12	13	5320	130	4155	165
Havtappan	**56**	**11**	**15**	**16**	**6280**	**80**	**5180**	**116**
Skateholm	**55**	**23**	**13**	**29**	**6290**	**170**	**5235**	**195**
Kemilarvi	**66**	**32**	**27**	**20**	**6750**	**170**	**5595**	**170**
Albusetra	**62**	**3**	**10**	**3**	**6100**	**120**	**5030**	**180**
Devdistavn	**69**	**47**	**19**	**40**	**6570**	**150**	**5460**	**150**
Gressvannet	66	3	12	30	6990	120	5835	125
Vralsbu	60	50	7	30	6880	140	5725	140
Zvidze	**56**	**47**	**26**	**59**	**6535**	**60**	**5455**	**116**
Osa	**56**	**51**	**24**	**35**	**6533**	**120**	**5450**	**120**
Soroca II	48	11	28	19	7515	120	6310	120
Rudnya	**55**	**38**	**31**	**34**	**6240**	**40**	**5165**	**116**
Matveev I	47	32	38	35	7505	210	6295	245
Ust-Rybezhna	**60**	**22**	**32**	**35**	**6380**	**220**	**5295**	**235**
Pogrema	**62**	**35**	**34**	**26**	**6510**	**90**	**5425**	**116**
Shettima	**62**	**20**	**37**	**3**	**6400**	**150**	**5310**	**170**
Mayak	68	20	38	17	5760	60	4615	116
Yazykovo	**57**	**16**	**37**	**22**	**6370**	**70**	**5340**	**116**
Ivanovskoye	**56**	**51**	**39**	**2**	**6210**	**50**	**5150**	**116**
Zhabki	**55**	**33**	**39**	**38**	**6460**	**160**	**5410**	**160**
Sakhtysh	**56**	**48**	**40**	**28**	**6560**	**250**	**5460**	**250**
Vashutanskaya	57	22	40	8	6820	80	5655	116
Berendeyevo	56	38	39	10	5730	120	4590	140
Rakush Yar	**47**	**33**	**40**	**40**	**6070**	**100**	**5020**	**180**
Osipovka	**48**	**59**	**34**	**35**	**6075**	**125**	**5020**	**190**
Vasilievka 3	**48**	**16**	**35**	**13**	**6805**	**60**	**5643**	**116**
Nikol'ski	**48**	**11**	**35**	**10**	**6225**	**75**	**5160**	**116**
Dereivka	48	55	33	40	7270	110	6085	116
Universitet	51	39	39	13	5080	125	3850	140
Cherkasska	52	21	39	5	5710	60	4565	116
Lipetskoe oz	52	35	39	41	5310	110	4120	130
Marievka	48	11	35	11	7955	55	6850	150
Yasinovatka	**47**	**55**	**35**	**15**	**6360**	**60**	**5335**	**116**

Tab. 2 : Radiocarbon dates for the early pottery sites in Eastern and Northern Europe.

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ON THE VALIDITY OF ARCHAEOLOGICAL RADIOCARBON DATES BEYOND 30,000 YEARS BP

Robert HEDGES and Paul PETTITT**

Abstract : We make a critical assessment of radiocarbon dates measured close to the age limit of the technique. We discuss and classify sources of error in the dating, as these dominate the ultimate age obtainable. We show that, in addition to errors that can be estimated by the laboratory, other evidence must be included. We discuss external evidence, assessing the archaeological and chemical consistency of dates that may be compared with each other. Our conclusion is that the great majority of dates, on all materials, can be trusted up to at least 40 ka BP. This holds specifically for Oxford AMS dates, but it is also very likely to hold more widely.

Résumé : Nous proposons ici une étude critique des datations radiocarbone obtenues en limite de détection. Nous étudions et classons les sources d'erreur de datation qui dominent dans l'obtention des âges limites. Nous démontrons qu'au-delà des erreurs que peut déceler un laboratoire, il existe d'autres preuves qu'il faut prendre en considération. Nous étudions les preuves externes, en estimant la cohérence chimique et archéologique de dates comparables entre elles. Nous concluons que l'on peut se fier à la majorité des dates comprises au minimum jusqu'à 40.000 BP, tous matériaux confondus.

Key-words : Radiocarbon dating, Upper Palaeolithic, validation.

Mots-clés : Datation radiocarbone, Paléolithique supérieur, validation.

INTRODUCTION

In this paper we set out to make a critical assessment of radiocarbon dates measured close to the age limit of the technique. For the most part we deal with dates measured at Oxford, but believe the conclusions are of fairly general applicability. We also believe that our approach could usefully be more generally adopted, and that this would help to provide more confidence in the dates published for this period.

The validity of an archaeological radiocarbon date can be seen as consisting of two parts ; whether the actual age of the sample is correct (within the quoted error range) ; and whether the age of the sample can be correctly taken to represent the date of the archaeological event or feature. In general, only the first part is dealt with here, although the two parts cannot be entirely disentangled. But the extent to which archaeological information is related to a sample's age depends on the particular circumstances of the sample - e.g. on the stratigraphic interpretation of its context - and it is impossible to make generalisations. Nevertheless, the relationship between sample and archaeological interpretation remains absolutely vital, and demands as critical an assessment as for the radiocarbon measurement itself. Therefore in this paper we are mainly concerned in assessing the evidence that quoted dates do truly lie within the quoted error uncertainties. This is of particular concern for dates beyond, say, 30,000 years, because the error terms become so much larger ; they need to be specially considered.

At 30,000 years, the ^{14}C content is reduced to 2.5 % of Modern (1950 AD) material. It is easier to consider measurement of this age range in terms of % Modern (pmc), and the importance played by error terms is demonstrated by the equation showing the ultimate age available by a radiocarbon measurement ; namely -

ultimate age (pmc) = 2 x estimated error (pmc)

Therefore the error terms dominate the ability to maintain the ultimate age.

ERROR TERMS

There are three main components to estimating the error in a radiocarbon date. These are, (a) the error due to finite counting statistics, (b) any additional random error in the measurement of the ^{14}C content of the sample as prepared, (c) the error due to uncertainty in changing the ^{14}C content as a result of laboratory processing (for example, there is nearly always a small additional conta-

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mination by carbonaceous material). In addition, there is (d) the error due to uncertainty in removing all the «contaminating» carbon in the sample that occurred during burial. Under normal conditions, error (a) is the dominant term for samples younger than 20 - 25 ka BP ; error (b) is usually only a minor term, and is certainly negligible for «old» dates ; error (c) is in fact the dominant term, here called the Laboratory Generic Background Error (LGBE). But error (d), which is specific to the sample, and here called the Sample Specific Error (SSE) must also be considered. However, the SSE cannot be reliably estimated for any specific date (this will be argued later).

The LGBE, since it is independent of the sample, can be estimated by measurements on laboratory blanks and controls, although it will depend on the specific kind of sample chemistry treatment. Quite often it contains a component which decreases as the sample mass increases. Most laboratories have an estimate for the LGBE of about 0.2 to 0.05 pmc. Usually the error is quite a large fraction (20 - 50 %) of the actual laboratory generic background itself, so that it is important to work to reduce the LGBE. A plot of the total quoted error against age, for both bone and charcoal, for OxA dates beyond 30 ka BP, is shown as figure 1.

Since the SSE is, by definition, specific to a sample, it cannot be estimated by carrying out measurements on controls. For example, measuring bones of known ages (or of very great age) can give some idea of how well chemical pre-treatment removes whatever contaminants might afflict the sample, but will not account for a bone that has suffered a different environmental chemistry. Obviously a laboratory tries to use pre-treatment methods that reduce the SSE to levels well below the LGBE, but this cannot be guaranteed.

Given the fundamental role played by laboratory errors, and bearing in mind the difficulty of estimating the degree of persisting contaminating radiocarbon, the validation of the dates on external evidence becomes increasingly important.

VALIDATION BY EXTERNAL EVIDENCE

There are four possible lines of evidence we can use : (a) comparison with other, «absolute» dating methods ; (b) consistency with archaeological horizons across a region ; (c) consistency with archaeological stratigraphy within a site ; (d) consistency with different sample materials or chemicals within a stratum. Only method (a) is completely independent. However, alternative dating methods, such as thermoluminescence and electron spin resonance, are subject to substantial error, and the comparison also suffers from substantial but not yet well-documented corrections from the calibration curve (Kitagawa and van der Plicht, 1998). Therefore absolute dating methods are not yet able to provide adequate control.

CONSISTENCY WITHIN AND BETWEEN ARCHAEOLOGICAL HORIZONS

Between 50 – 30ka in Eurasia one finds the late Middle and Early Upper Palaeolithic, and perhaps the most intensively studied phenomenon in current Palaeolithic research - the extinction of the Neanderthals and the spread of anatomically modern humans - archaeologically represented by the Middle to Upper Palaeolithic transition. In more specific terms, one is dealing with a variety of so-called 'transitional' industries such as the Châtelperronian of Northern Iberia and Southern France, in addition to the Aurignacian.

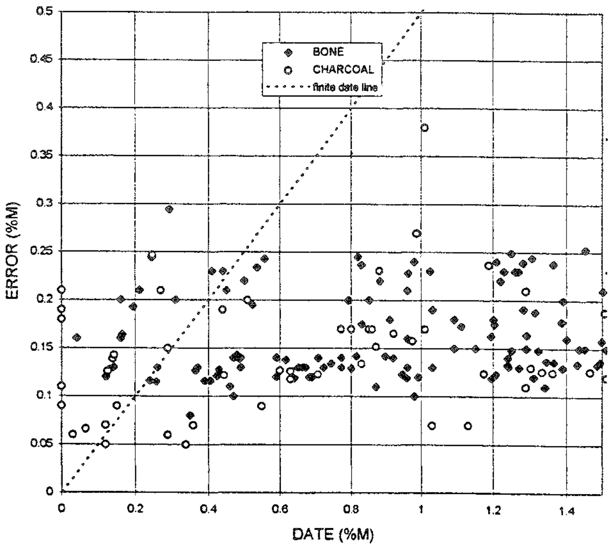

Fig. 1 : Estimated errors for dates on bone and charcoal plotted against the pmc (percentage modern carbon) for each sample. The dashed line defines the area (top left) in which any data point will be interpreted as a non-finite (i.e. «greater than») date.

Around 400 Oxford dates exist for the period > 30 ka, within which period sequences of dates can be compared for consistency, either internally or by comparison to other sites from a given region. This is the approach we have adopted here for late Mousterian and Early Upper Palaeolithic industries.

Spain : Oxford has undertaken the dating of samples from El Castillo, Arbreda, and Reclau Viver in Catalonia (Hedges *et al.,* 1994), and Vanguard and Gorham's caves in Gibraltar (Stringer *et al.,* forthcoming). At Castillo, a sequence of 6 charcoal dates are in good agreement with the stratigraphic sequence, ranging from c. 40 to c. 37 ka BP, confirming that the Upper Palaeolithic had reached northern Spain by 40 ka BP. At Arbreda results were once again internally consistent, although a little younger than those from Castillo. Two samples of bone from Reclau Viver bracket the oldest and youngest ages for the Aurignacian at these two sites, with a date of c. 30 ka for one Aurignacian horizon and a date of c. 40 ka for an archaic Aurignacian horizon 80 cm deeper. By contrast to these, a date on bone from a Middle Palaeolithic horizon at Ermetons indicated an antiquity of c. 33 ka, which is considered reliable by the excavators. At Vanguard Cave, Gibraltar, a small series of dates on both bone and charcoal are in agreement suggesting that the cave filled to its present level as early as 40 ka BP. A more comprehensive sequence of dates have been obtained on charcoal and bone samples from the upper deposits of Gorham's Cave, which, although the work is in early stages, are internally consistent, with the latest Middle Palaeolithic dating to c. 45 ka, and the earliest Upper Palaeolithic industries appearing sometime before 30 ka. Later Upper Palaeolithic industries above this horizon date to c. 30 ka (four samples from the same horizon are of statistically identical ages) and 25 ka BP. Furthermore, a sequence of five dates from Gabasa Cave are again consistent with stratigraphy, documenting ages of from >45 to >50 ka BP for the Mousterian levels at the site. Three dates on bone from Pena Miel indicate the persistence of the Mousterian to c. 40 ka and the appearance of the Aurignacian at the site around 37 ka BP.

Italy : At Riparo Mochi, five charcoal samples were dated from the level containing an early Aurignacian with Dufour bladelets (Hedges *et al.*, 1994) suggesting an antiquity of 33 – 35 ka for the Early Upper Palaeolithic of the region, which is later than that of Iberia and earlier than that of France. The dates are internally consistent, suggesting an age of c. 35 ka for the base of the level and 33/32 ka for the top. At Grotta di Fumane, however, an ongoing dating programme on charcoal fragments has yielded ages which are inconsistent with stratigraphy, and may be too young (certainly in comparison to other determinations undertaken at Utrecht). We believe this could be due to the taphonomy of the samples, and are currently investigating the problem further through a wider dating programme.

Southeast Europe : A series of 6 dates on charcoal, bone and tooth from Bacho Kiro, Bulgaria, was, with one outlier, stratigraphically consistent, indicating the appearance of the transitional 'Bachokirian' around 38 ka BP. This came from a horizon stratified above a sample dated by Groningen to > 43 ka (Hedges *et al.*, 1994). Dates from the Aurignacian horizons are consistent with the age of the Aurignacian elsewhere in Europe, i.e. to c. 33 ka BP. Six dates on charcoal samples from Temnata Cave, Bulgaria were again internally consistent and demonstrated the appearance of the Aurignacian at a similarly early age, i.e. c. 38 – 40 ka BP.

Ukraine : Oxford have measured samples from a number of sites in Crimea. The Early Upper Palaeolithic at Siuren I dates to c. 31-28 ka BP, which is consistent with the persistence of the Middle Palaeolithic down to c. 35-31 ka BP. A sequence of 8 bone and tooth samples from Buran kaya III are again internally consistent, falling into three age ranges : c. 29-27, 31-29 and 35-30 ka BP. The measurements in the youngest group are statistically the same age, and one cannot therefore eliminate the possibility that they relate to one (Kiik-Koban) occupation, as with the solitary measurement in the 31-29 ka BP range. Overall, the results suggest repeated use of the site by makers of the Kiik-Koba variant between c. 34 – 27 ka BP, or, at the very least, between c. 31 – 29 ka BP. But one cannot eliminate the possibility that two determinations OxA's –4129 (tooth) and –4130 (bone) are, at 33 – 32 ka, erroneously young for the Middle Palaeolithic here. Yanevichv *et al.* (1996, 318) suggest that these two results are '... *on the young side, but not impossible...* '. With regard to the Aurignacian at Buran Kaya II, Yanevichv *et al.* (1996, 318) have noted that the date of 28700 ± 620 is quite acceptable. At Starosel'e, two determinations on bone from the Middle Palaeolithic level were statistically identical in age, which overlap slightly with further samples from the recent excavations by the Southern Methodist University. Taken as a whole, the most cautious reading of the series of results is to take them as representing a *terminus ante quem* of at least 33 ka BP for the Middle Palaeolithic of Starosel'e. Some problems were encountered on two sites : in the dated sequence of Kabazi II, two discrete chronological sequences can be discerned : one of two determinations (on the Staroselian and Kabazian variants of the Middle Palaeolithic), and another of three on the Kabazian. That these two sequences are stratigraphically inconsistent with each other may indicate some sorting of dated materials at the site, but whether this is due either to residuality or intrusion is impossible to ascertain. Overall, one must simply conclude that the Middle Palaeolithic at Kabazi II dates to the period 35-31 ka BP. The site of Zaskalnaya has yielded a sequence of dates which, while in accord with stratigraphy, trending from ca 30 to 39 ka BP (Hedges *et al.*, 1996) are considered by the archaeologist, Kolosov, to be too young. Certainly the preservation of collagen in bone from this site is poor ; direct comparison with dates pre-treated by the collagenase method has not been made, but two bones dated by the collagenase method are amongst the older dates, and reinforce the impression that standard pre-treatment methods, in this case, are inadequate for dating the site, and at present it is impossible to elucidate the causes of the confusion further.

France : A total of 50 determinations have been made from the site of Combe Saunière, France. The sequence as a whole provides a good chronological range from *ca* 34 ka to 14 ka BP. Of some five outliers, four could be ascribed to stratigraphic disturbance, one potentially to the effects of low collagen preservation. The resulting ages for the various archaeological assemblages are in good agreement with those from other sites in France, notably with the Aurignacian and Upper Perigordian at Abri Pataud (Mellars and Bricker, 1986), and, with the Châtelperronian at the Grotte du Renne, Arcy-sur-Cure (Hedges *et al.*, 1994).

Germany : A large series of dates have been obtained for Geissenklosterle, Germany, many of which fall into the >30 ka range. Once again, these show considerably internal consistency, with the dates pertaining to the basal Aurignacian layer in good agreement with other sites in the region, such as Vogelherd and Hohlefels.

Israel : Numerous dates have been measured on charcoal samples [Hedges *et al.*, 1990 & 1994]. Taken together, the results suggest an early Ahmarian industry in the 43-37 ka BP period, and the Levantine Aurignacian in the 36-28 ka BP periods. Middle Palaeolithic levels dated by TL to 51.9 +/- 3.5 ka are dated by radiocarbon as > 44.8 ka BP.

CONSISTENCY WITH SITE STRATIGRAPHY

Ideally, a plot of radiocarbon age with depth should show a monotonous decrease to the estimated limit and then remain static. In practice, very few sites lend themselves to such treatment, and, when they do, usually too few dates are measured. The dating of Divje Babe I cave (Nelson, 1997) is a good example of what is possible. However, the results need careful interpretation ; is the levelling out of dates while still finite with depth due to a real levelling of the date of deposition, or is it in fact a limit in dating ?

The reverse can also occur ; a sequence of dates from Mousterian levels at the site of Gabasa (Oxa-5671 to OxA- 5675) were all non-finite, yet were stratigraphically ordered - behaviour which is in fact statistically reasonable and helps to confirm that these dates (on charcoal) appear to be correctly measured. One other site in which the limit of finite dating seems to be consistent with stratigraphic depth is Kebara (also on charcoal) (Hedges *et al.*, 1994) although the stratigraphy is not straightforward. Here the finite age limit is set at around 44,000 BP.

But for most sites, only a few levels are usually dated, or dateable, and the only evidence to help validate the dates is whether they are stratigraphically ordered. Deciding this can be made difficult by the occurrence of «outliers». It is not uncommon for a set of dates, within a single level, to produce an «anomalous» value, and this can generally be attributed to taphonomic processes. We have examined the stratigraphic integrity for all the sites we have dated with levels at over 30,000 BP. Of 27 such sites, 16 do not provide rigorous tests (too few samples or stratigraphy not well enough developed) ; of the remaining eleven, ten provide dates which are stratigraphically consistent (albeit with the occasional outlier). One is inconsistent, and we are not clear why this should be in this case (the samples are charcoal).

CONSISTENCY WITH DATING AT OTHER LABORATORIES

Different laboratories use somewhat different procedures, although all may be subject to more or less the same SSB error from the same levels of a site, and so produce equally incorrect dates. However, agreement is obviously a necessary if not sufficient criterion. Specific comparisons are not very common, but we note that dates > 30,000 BP produced at Oxford can be shown to be in agreement with those from Arizona (AA) at Castillo, with Gronigen (GrN) at Bach Kiro and at Gorham's Cave, and with the Gif Tandem (GIF-Tan) and Pretoria (Pta) at Kebara.

COMPARISON BETWEEN SAMPLE TYPES AND SAMPLE CHEMISTRIES

Figure 2 shows the overall distribution of dates (in pmc) measured at Oxford, divided into the categories of bone, charcoal and other. The form of the distribution reflects many factors - taphonomic, archaeological interest, etc. However, it is not surprising that samples which are too old to give finite dates (i.e. are < 0.2 - 0.3 pmc) tend to be in greater abundance. But this does not seem to apply to bone, and is perhaps an indication that, if bone samples follow a similar abundance distribution to charcoal and «other», they tend often to contain an extra 0.2 pmc or so. This may be due to unremovable contamination (as SSBE). The point here is that as there is no evidence that this potential SSBE is, on average, greater than about 0.25 pmc, and so helps to strengthen confidence in bone dates younger than about 0.4 pmc.

COMPARISON BETWEEN BONE AND CHARCOAL DATES FROM THE SAME CONTEXT

Relatively few sites contain suitable comparison suites of bone and charcoal at this period, and only a small number of points, from 4 different sites, can be plotted for comparison (fig. 3). They show no evidence for serious systematic differences between bone and charcoal «pairs» from the same site, even for ages > 40,000 yrs, although more data would strengthen this assertion.

COMPARISON BETWEEN BONE DATES PREPARED BY DIFFERENT TECHNIQUES

Figure 4 shows a comparison of measurements made on the same bone sample by the routine method (mainly a form of collagen extraction followed by gelatinisation and ion exchange purification (Law and Hedges, 1989) compare with the specific digestion of collagen to tripeptides and their subsequent purification by HPLC (Van Klinken *et al.,* 1994). In two cases the «tripeptide»

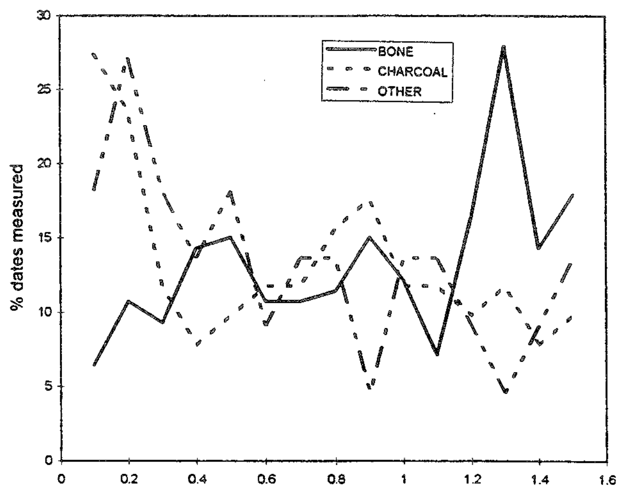

Fig. 2 : Distributions of dates measured for three sample types (bone, charcoal, other) for different ages (plotted as pmc). Note that a lower proportion of bone, dated from sites, gives dates at less than 0.3 % modern.

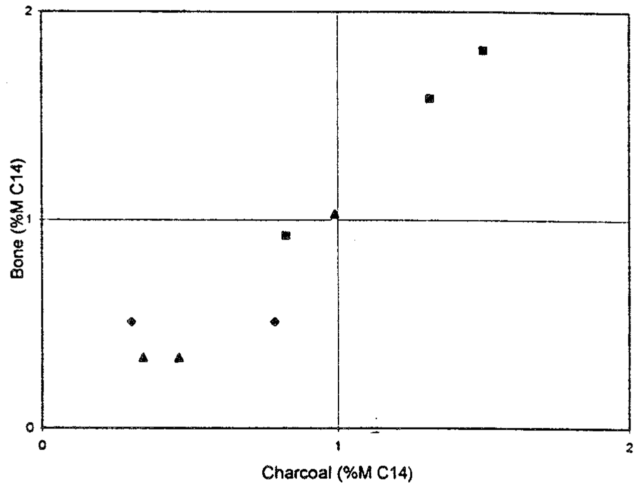

Fig. 3 : Comparisons of bone and charcoal samples from the same levels from three different sites.

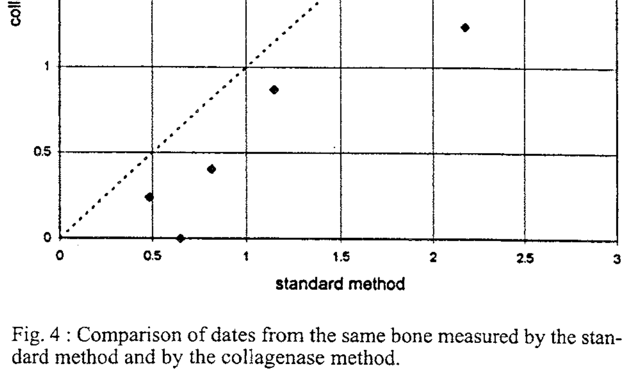

Fig. 4 : Comparison of dates from the same bone measured by the standard method and by the collagenase method.

treatment was significantly older, and the best line through the data suggests that on average the tripeptide treatment is older by about 0.2 pmc. However, the samples were not chosen randomly, and to perform a major comparison by the tripeptide method is very expensive. Nevertheless, the indication is that at least some bones, including those with substantial collagen remaining, may contain a small degree of SSB at a level of about 0.2 pmc. Of course, other samples may, and apparently do, contain much higher SSB levels (these are the significant differences in the figure), but these are probably quite infrequent. The need for further investigation and improvement in bone sample chemistry for dates >30,000 BP is clear.

SUMMARY

Nearly all the results considered here have been generated over the past 10 years by the Oxford Laboratory, and generalisations do not necessarily apply to other radiocarbon dates. However, given the general agreement between laboratories, and the overall similarity in methods and approaches, it is likely that much the same applies to dates by other laboratories.

The general conclusion we reach is that applying external evidence to validating radiocarbon dates gives strong support for the correctness of the dates up to about 40,000 BP. (In particular, that a finite date need not be regarded as really being a «younger than» date). That in the region of 40 - 45 ka BP, there is no evidence that bone or charcoal dates are consistently in error. On the whole, internal evidence agrees with the external evidence ; bone and charcoal «pairs» are in reasonable agreement ; but there is some evidence that bone radiocarbon content may be quite frequently (but not uniformly) overestimated by perhaps 0.2 pmc.

This study shows the continuing need to reduce both the laboratory generic background, and its associated uncertainty, and to attempt to assess sample specific backgrounds. We also hope that the methodology used here can be more generally applied, and so help to contribute to the critical assessment of radiocarbon dates in this time period.

ACKNOWLEDGEMENTS

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CHRONOLOGICAL PROBLEMS OF THE PALAEOLITHIC OF KOSTENKI-BORSCHEVO AREA : GEOLOGICAL, PALYNOLOGICAL AND ^{14}C PERSPECTIVES

*Andrei A. SINITSYN**

Résumé : Les bases de la division chronostratigraphique du Paléolithique supérieur de la région de Kostienki-Borschevo reposent sur plus de 150 dates radiocarbone provenant de 35 sites, sur des diagrammes polliniques pour les coupes principales et sur l'analyse comparative des séquences stratigraphiques. A partir de ces données pluridisciplinaires, on a mis en évidence trois ensembles chronologiques se succédant de 36 à 33 000 BP, puis de 32 à 27 000 BP et enfin de 26 à 20 000 BP. Le principal problème pour l'appréciation de la variabilité des dates absolues est l'estimation lorsque pas plus de 50 % des dates radiocarbone de deux groupes anciens et 70 % de celles d'un groupe récent sont en correspondance avec les évidences chronologiques.

Abstract : More than 150 radiocarbon dates for 35 sites, pollen diagrams for the main sections and comparative analysis of stratigraphic sequences are the base for chronostratigraphic division of the Upper Palaeolithic in the Kostenki-Borschevo area. Three chronological groups, 36-33 kyr, 32-27 kyr and 26-20 kyr, are identified on the background of these multidisciplinary data. The main problem for the appreciation of the variability of the absolute dates is the estimation of the situation when no more than 50 % of the ^{14}C dates for two ancient groups and 70 % of the dates for a recent group are in correspondence with the complex of chronological evidences.

Mots-clés : Paléolithique supérieur, Europe de l'Est, région de Kostienki-Borschevo, chronologie radiocarbone, appréciation de la variabilité des dates absolues.

Key-words : Upper Palaeolithic, Eastern Europe, Kostenki-Borschevo area, radiocarbon chronology, application of the dates variability.

Kostenki-Borschevo area is the principal for the chronology of Upper Palaeolithic of the Eastern Europe. More than 25 sites are located on the territory of 20 sq. km about, along the right bank of the Don. Taking into account that more than 10 sites are multi-layers ones, remains of more than 50 settlements of palaeolithic times are represented here.

The stratigraphy of the second terrace above the floodplain of the Don and of the large ravins was the basis for relative chronology that was established by A.N. Rogachev in the middle 60th in cooperation with the geologists M.N. Grishchenko, G.I. Lazukov, A.A. Velichko (Rogachev, 1957 ; Velichko, Rogachev, 1969). The sequence of deposits from the top up to bottom represents by following sucession : chernoziem, followed by loess-like loams, and two humic beds, separayed by non-humic loams with lenses of volcanic ash.

Modern chronological scheme for the area consists of three chronological groups. The first (ancient) group included sites with cultural layers in the lower humic bed ; the second conasisted by sites in the upper humic bed ; and the third included sites in the overlaying loess loams which constitute a colluvial deposit on the first and second terraces above the floodplain.

The background for the division of lower and upper humic beds is the horizon of the sterile loam containing lenses of volcanic ash. According to analytical investigations, the age of the volcanic ash can be regarded at 38-33 kyr, and can be attributed to one of the eruptions of Campi Flegrei in Italy (Melekestsev *et al.*, 1984 ; also Lefevre, Gillot, 1994 ; Sorokin, Schervakova, 1995).

These dates appear to be an upper limit of the *first chronological group*, (fig. 1, I) (table I, n. 151-168) which framework is define at 33-36 kyr with the very probable

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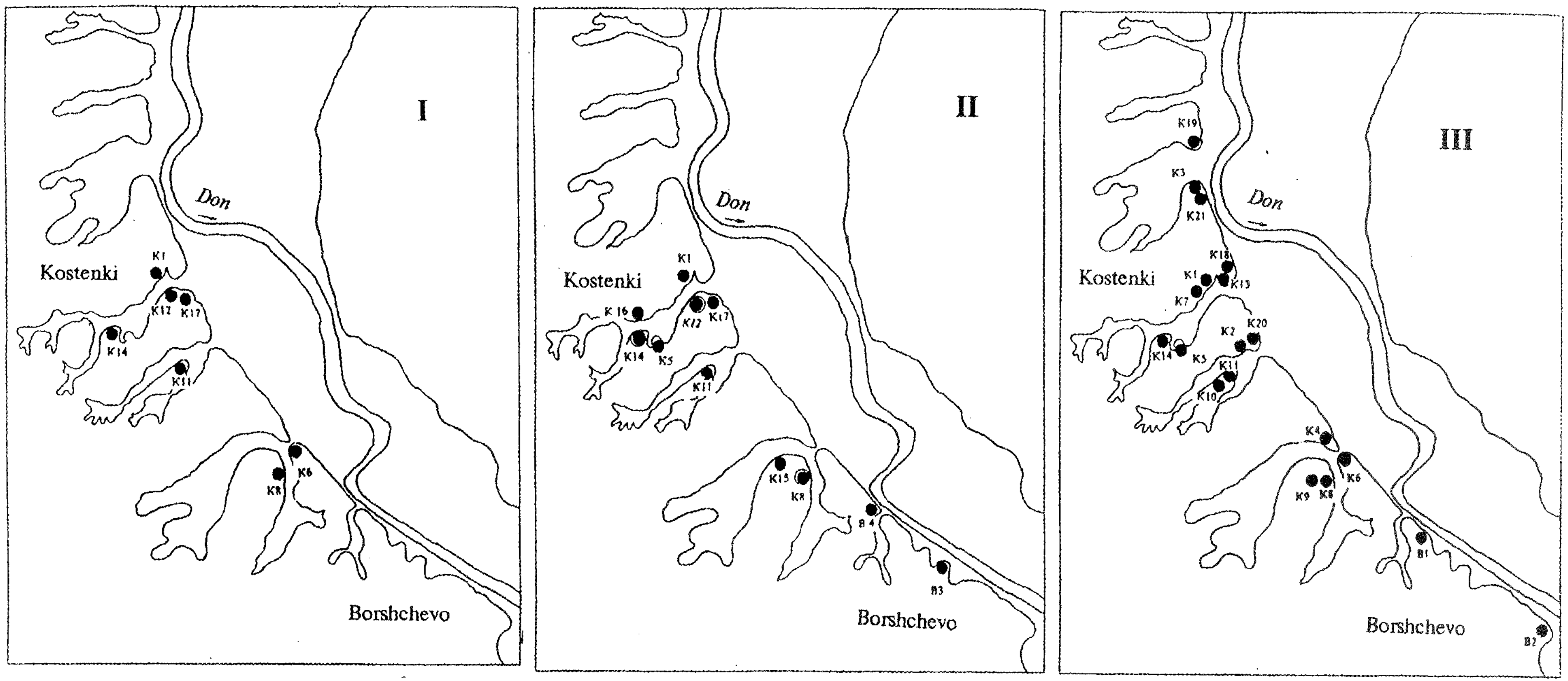

Fig. 1 : Kostenki-Borshchevo area. Distribution of upper palaeolithic sites.

I - First (ancient) chronological group (36-33 kyr).
II - Second (middle) chronological group (32-27 kyr).
III - Third (recent) chronological group (26-20 kyr).

Table I : Radiocarbon dates for sites of the Kostenki-Borshchevo area (Sinitsyn *et al.*, 1997). (Index of site is marked by Arabic ; index of cultural layers by Latin in parentheses also as a local and memorial names of sites ; cultural affiliation of sites is designed in parentheses ; Cyrillic alphabet is used for the designation sq.m network).

	Index	Material, context	^{14}C date
		Recent cronological group	
		Kostenki 1 (Poliakov site) (I) (East Gravettian, Kostenki-Avdeevo culture)	
1.	LE-3280	Burned bone	18 230 ± 620
2.	LE-4351	Mammouth tooth, sq. П-70	18 400 ± 3300
3.	LE-2950	Mammouth tooth, storage-pit, sq. ПР-72	19 010 ± 120
4.	LE-3292	Burned bone, pit, sq. H-76	19 540 ± 580
5.	LE-3281	Burned bone, sq. O-78	19 620 ± 460
6.	LE-2949	Mammouth tooth	19 860 ± 200
7.	LE-3277	Burned bone	20 100 ± 680
8.	AA-4800	Burned bone	20 315 ± 200
9.	AA-4799	Burned bone	20 855 ± 260
10.	GIN- 4851	Burned bone, pit, sq. O-73,74	20 800 ± 300
11.	GrN-17120	Burned bone, sq. P-78	20 950 ± 100
12.	GIN-4231	Burned bone, pit, sq. P-73	21 150 ± 200
13.	GrN-17119	Burned bone, heatrth sq. H-79	21 180 ± 100
14.	GIN-2534	Burned bone, dugout "A", northern chamber, floor	21 300 ± 400
15.	LE-3279	Mammouth tooth, sq. Л-77	21 680 ± 700
16.	LE-2802	Mammouth tooth, object "with a wall"	21 800 ± 200
17.	GIN-4230	Burned bone, hearth, sq. H,O-72,73	21 800 ± 300
18.	GIN-8041	Mammouth tooth, cultural layer	21 950 ± 250
19.	LE-3282	Mammouth tooth, storage-pit, sq. K-78	22 020 ± 310
20.	LE-3290	Bone, sq. П-76	22 060 ± 500
21.	GIN-3634	Burned bone, pit В,Г,Д-65-67	22 200 ± 300
22.	GIN-4903	Burned bone, dugout Т,У,Ф,Х-72-75	22 200 ± 500
23.	GIN-2533	Burned bone, dugout "A", central chamber	22 300 ± 200
24.	GIN-1870	Burned bone, sq. И-М-5-6	22 300 ± 230
25.	GrN-17118	Charcoal, heatrth, sq.H-79	22 330 ± 150
26.	GIN-6249	Mammouth tooth, sq. П-69	22 600 ± 300
27.	GIN-3633	Burned bone, heatrth, sq. H-62	22 600 ± 300
28.	LE-2969	Mammouth tooth, cultural layer	22 700 ± 250
29.	LE-2800	Mammouth tooth, sq. Ж-70	22 760 ± 250
30.	GIN-2530	Burned bone, dugout "Ж"	22 800 ± 200
31.	GIN-3632	Burned bone, dugout "A"	22 800 ± 300
32.	GIN-2528	Burned bone, dugout "A", central chamber	23 000 ± 500
33.	LE-3276	Mammouth tooth, sq. Л-78,	23 010 ± 300
34.	LE-3289	Mammouth tooth, dugout "T-X-72 -75"	23 260 ± 680
35.	LE-3286	Burned bone, dugout " T-X -72 -75"	23 490 ± 420
36.	GIN-2527	Burned bone, dugout "A", central chamber	23 500 ± 200
37.	GrA-5244	Charcoal, dugout E-3-72-74, floor	23 600 ± 410/400
38.	LE-3283	Mammouth tusk, pit, sq. K-78	23 640 ± 320
39.	LE -2951	Mammouth tooth, dugout "T-X -72-75".	23 770 ± 200
40.	GrA-5243	Charcoal, pit, sq. П-74	24 030 ± 440/410
41.	GIN-2529	Burned bone, dugout "3"	24 100 ± 500
42.	LE-4352	Mammouth tooth fragments, dugout "И"	24 570 ± 3 930

43.	LE-2801	Mammouth tooth, object "with a wall"	25 600 ± 2 810
		Kostenki 2 (Zamiatnin site) (Magdalenian)	
44.	GIN-93	Bone	11 000 ± 200
45.	LE-1599	Bone	16 190 ± 150
46.	GIN-8570	Mammouth bone	17 300 ± 160
47.	GIN-7992	Mammouth pelvis	23 800 ± 150
48.	GIN-7993	Mammouth bone	37 900 ± 900
		Kostenki 3 (Glinishche) (Magdalenian)	
49.	GIN-8022	Mammouth bone	19 800 ± 210
		Kostenki 4 (Alexandrovskaia site) (Gravvettian)	
50.	GIN-7995	Mammouth rib. 1937.	22 800 ± 120
51.	GIN-7994	Horse phalanx. 1927-28.	23 000 ± 300
		Kostenki 5 (Sviatoi log) (II) (Gravettian)	
52.	GIN-7996	Mammouth rib	20 600 ± 140
53.	GIN-8029	Mammouth bone	20 900 ± 100
54.	GIN-8571	Horse bone	22 920 ± 140
		Kostenki 8 (Telmanskaia site) (I) (Jerzmanowicko-telmanskaia culture)	
55.	GIN-7998	Mammouth rib, sq. Д-44	22 000 ± 160
56.	GIN-7997	Tooth, mammouth rib, sq.Г-45	22 900 ± 120
		Kostenki 10 (Anosovka 1) (Magdalenian ?)	
57.	GIN-8573	Mammouth bone of bad preservaion and bison bone	22 600 ± 1 000
58.	GIN-8027	Mammouth bone	28 250 ± 300
		Kostenki 11 (Anosovka 2) (Ia) (Magdalenian ?)	
59.	LE -1403	Mammouth bone	12 000 ± 100
60.	LE-1637	Mammouth bone	14 610 ± 120
61.	LE-1704a	Bone	16 040 ± 120
62.	LE-17046	Bone	17 310 ± 280
63.	GIN-8079	Mammouth bone	18 700 ± 80
64.	GIN-2532	Burned bone	19 900 ± 350
		Kostenki 11 (Anosovka 2)(II) (Gravettian, Pushkari culture, Gmelinskaia culture ?)	
65.	GIN-2531	Burned bone	21 800 ± 200
66.	TA-34	Bone	15 200 ± 300
		Kostenki 11 (Anosovka 2)(III) (Aurignacian, Stretsko-sungirskaia cultutre)	
67.	LE-1638a	Bone	16 040 ± 120
68.	LE-16386	Bone	22 760 ± 340
69.	GIN-8080	Mammouth bone	20 500 ± 300
		Kostenki 14 (Markina gora)(I) (East gravettian, Kostenki-avdeevo culture)	
70.	GIN-8024	Mammouth rib (1987)	19 900 ± 850
71.	LE-5269	Bone (1982)	20 100 ± 1500
72.	LE--5274	Bone (1994)	22 500 ± 1000

73.	OxA-4114	Bone (1987)	22 780 ± 250

Kostenki 18 (Khvoikovskaia site)
(East gravettian, Kostenki-avdeevo culture)

74.	GIN-8028	Mammouth bone. Overhead cover of the burial pit	17 900 ± 300
75.	GIN-8576	Mammouth bone. Overhead cover of the burial pit	19 300 ± 200
76.	GIN-8032	Mammouth bone. Overhead cover of the burial pit	20 600 ± 140
77.	OxA-7128	Human bone (vertebra). Burial.	21 020 ± 180

Kostenki 19 (Valukinskogo site) (Magdalenian?)

78.	GIN-107	Bone	11 800 ± 500
79.	LE-1705a	Bone	17 420 ± 150
80.	LE-1705b	Bone	18 900 ± 300
81.	GIN-8577	Mammouth bone	18 700 ± 600

Kostenki 21 (Gmielin site) (II) (Magdalenian ?)

82.	LE-1437a	Bone (Longine method)	19 100 ± 150
83.	LE-1437b	Bone (Arslanov method)	20 250 ± 100
84.	LE-1437c	Bone (complex method)	22 900 ± 150

Kostenki 21 (Gmielin site) (III)
(Gravettian, Gmelin culture)

85.	LE-1043	Charcoal	16 960 ± 300
86.	GrN-7363	Charcoal (the same sample)	22 270 ± 150
87.	GrN-10513	Charcoal	21 260 ± 340
88.	TA TL	Burned clay on the bottom of heatrth	26 765 ± 2 000

Borshchevo 1 (Magdalenian ?)

89.	GIN-8085	Mammouth bone, 1923	15 600 ± 70
90.	LE-3727	Mammouth bone, 1980	17 200 ± 150

Borshchevo 2 (Magdalenian ?)

91.	GIN-88	Soil, upper cultural layer	12 300 ± 100
92.	GIN-3261	Gyttja, lower horizon	12 550 ± 200
93.	GIN-8084	Horse burned bones (1925)	10 400 ± 200
94.	GIN-8415	Horse burned bones (1925)	10 900 ± 300
95.	LU-742	Charcoal, upper cultural layer	13 210 ± 270
96.	Mo-636	Humus, upper cultural layer	11 760 ± 240
97.	LE-4865	Humus, upper cultural layer, I horizon	9 520 ± 300
98.	LE-4866	Humus, upper cultural layer, I horizon	9 330 ± 390
99.	LE-4867	Humus, II horizon	14 030 ± 200
100.	LE-4837	Charcoal, I cultural layer	13 480 ± 720
101.	LE-4834	Charcoal, III cultural layer	13 540 ± 300

Middle chronological group

Kostenki 1 (III) (Aurignacian)

102.	GIN-4848	Charcoal, sq. Ж-72	20 900 ± 1 600
103.	GIN-2942	Mammouth tusk, sq. Ж-72	> 22 000
104.	GIN-4850	Charcoal, sq. Д-72	24 500 ± 1 300
105.	GIN-6248	Charcoal, sq. Д-72	25 400 ± 400
106.	GIN-4852	Burned bone, sq. Д-72	25 600 ± 100
107.	GIN-4902	Burned bone, sq. Д-72	25 700 ± 600
108.	LE-3541	Charcoal	25 730 ± 1 800
109.	GIN-4849	Charcoal, sq. Ж-72	25 900 ± 2 200
110.	GrN-22276	Charcoal	25 820 ± 400

111.	GIN-4885	Charcoal, sq. Д-74	26 200 ± 1 500
112.	GrN-17117	Charcoal	32 600 ± 400
113.	OxA-7073	Human bone	32 600 ± 1100
114.	AA-5590	Charcoal	38 080 ± 5 460 3 200
		Kostenki 8 (Telmanskaia site) (II) (Gravettian)	
115.	OxA-7109	Burned fragments of human skull	23 020 ± 320
116.	GIN-7999	Horsee bone (1959)	24 500 ± 450
117.	GrN-10509	Charcoal	27 700 ± 750
		Kostenki 12 (Volkov site) (I-Ia) (Gorodtsovskaia culture, Streletskaia culture)	
118.	TA-154	Bone	20 900 ± 390
119.	LU-1749	Humus, 2-nd horizon	24 420 ± 310
120.	LU-1821	Humus, 3-d horizon	29 030 ± 560
		Kostenki 12 (Volkov site) (I) (Gorodtsovskaia culture)	
121.	GIN-89	Humus	23 600 ± 300
122.	GIN-8019	Mammouth pelvis bone	24 000 ± 800
123.	GIN-8574	Bison bone	26 300 ± 300
		Kostenki 12 (Volkov site) (Ia) (Streletskaia culture)	
124.	GrA-5552	Charcoal	28 500 ± 140
125.	LE-1428a	Bone	28 700 ± 400
126.	LE-1428б	Bone	30 240 ± 400
127.	LE-1428в	Mammouth tooth (collagene)	31 150 ± 150
128.	LE-1428г	Mammouth tooth (DTA)	31 900 ± 200
129.	GrN-7758	Charcoal	32 700 ± 700
		Kostenki 14 (Markina gora) (II) (Gorodtsovskaia culture ?)	
130.	LE-1400	Bone	19 300 ± 200
131.		The same sample, lab. LU	25 090 ± 310
132.	GIN-8030	Bone	25 600 ± 400
133.	LU-59a	Bone (fr.A)	26 400 ± 660
134.	LU-59b	Bone (fr.B)	28 200 ± 700
135.	GrN-12598	Charcoal	28 380 ± 220
136.	OxA-4115	Bone	28 580 ± 420
		Kostenki 14 (Markina gora) (II-III)	
137.	AA-4798	Charcoal, lower horizon of the upper humic bed	14 355 ± 120
138.	GrN-10510	Charcoal, upper humic bed	15 260 ± 260
		Kostenki 14 (Markina gora) (III) (Gorodtsovskaia culture)	
139.	GIN-79	Bone	14 300 ± 460
140.	GrN-21802	Charcoal	30 080 ± 590/550
		Kostenki 15 (Gorodzovskaia site) (Gorodtsovskaia culture)	
141.	LE-1430	Bone	21 720 ± 570
142.	GIN-8020	Bison bone, dwelling onstruction	25 700 ± 250
		Kostenki 16 (Uglianka) (Gorodtsovskaia culture?)	
143.	LE-1431	Bone	25 100 ± 150

144.	LE-5270	Bone	27 400 ± 100
145.	GIN-8033	Horse bone (upper horizon)	26 800 ± 600
146.	GIN-8031	Horse bone (lower horizon)	28 200 ± 500

Kostenki 17 (Spitzyn site) (I)
(Gorodtsovskaia culture ?)

147.	GIN-8076	Mammouth bone, sq. $Ж_1$-2 (1980 г.)	21 100 ± 600
148.	GIN-8074	Mammouth bone, sq. E_1-2 (1980)	23 000 ± 800
149.	GIN-8075	Mammouth bone, sq. $Ж_1$-3 (1980)	24 300 ± 500
150.	GrN-10511	Charcoal	26 750 ± 700

Ancient chronological group

Kostenki 1 (Poliakiv site) (V)
(Streletskaia culture)

151.	GIN-6247	Charcoal	> 18 800
152.	LE-2030	Mammouth tooth	27 390 ± 300
153.	LE-3542	Charcoal	30 170 ± 570
154.	GrA- 5557	Charcoal	32 300 ± 220
155.	GrA-5245	Charcoal	34 900 ± 350
156.	GrA-5245	Charcoal	37 900 ± 2800 2100

Kostenki 6 (Streletskaia 2) (Streletskaia culture)

157.	GIN-8023	Mammouth bone	21 100 ± 200
158.	GIN-8572	Horse bone (1952 г.)	31 200 ± 500

Kostenki 12 (Volkov site) (III)
(Streletskaia culture)

159.	GIN-8021	Mammouth bone	> 31 000
160.	GrA-5551	Charcoal	36 280 ± 360/350

Kostenki 14 (Markina gora) (IV)
(Magdalenian ?)

161.	OxA-4116	Horse bone	27 460 ± 390
162.	OxA-4117	Horse bone	27 710 ± 410

Kostenki 14 (Markina gora) (IVa) (?)

163.	LE-5271	Horse bone	27 400 ± 5500
164.	GIN-8025	Horse bone	29 700 ± 400
165.	GrN-22277	Charcoal	33 280 ± 650/600

Kostenki 17 (Spitsyn site) (II)
(Spitsynskaia culture)

166.	LE-1436	Bone	32 780 ± 300
167.	GrN-10512	Charcoal	32 200 ± 2 000 1 600
168.	GrN-12596	Charcoal	36 780 ± 1 700 1 400

more ancient lower limit back to 40 kyr. Among the serie of 17 ^{14}C dates for 6 site of this group the most important are dates of 34-37 kyr for Kostenki 1 (V)[1], 36 kyr for Kostenki 12 (III) and Kostenki 17 (II), and 33 kyr for Kostenki 14 (IVa). Pollen records indicate an evolution of the vegetation from pine forest conditions to forest with the dominant of spruce (Picea) of tiaga type and to the meadow-steppe associations. The climat change from cold to temperate, relatively warm and humid corresponded to the interglacial environment in the lower part and to the beginning of glaciation in the upper part of the deposits of the lower humic bed (Spiridonova, 1989, 1991). Paleomagnetic digression correlated with Lashamp excursus (41-43 kyr) was identified inside this deposits (Zubakov, 1986, 100). Times and conditions of the accumulation of lower humic bed are comparable with the Hengelo interglaciation of Western Europe.

(1) Index of the site is marked by arabic numerals ; index of cultural layers by roman numerals in parenthesis.

Remains of 14 settlements, 10 of which have a radiocarbon dates, compose the *second chronological group* (fig. 1, II) (table I, n. 101-150) which cultural lyers lie in the deposits of the upper humic bed above the horizon of volcanic ash. According to series of ^{14}C dates for Kostenki 1 (III), Kostenki 12 (Ia), Kostenki 14 (II) the age of the sites and the times of the accumulation of upper humic bed are defined in the frameworks of 32-27 kyr. Pollen records are the evidence for the very complicated processes of climat fluctuation during this period. From 7 up to 4 vegetation cycles are identified on Kostenki 1, 14, 17 (Fedorova, 1963 ; Levkovskaya, 1977 ; Maliasova, Spiridonova, 1982, 1991). In general the climat and environment indicate the replacement of the warm humid interglacial conditions by cold and dry environment of the glaciation. The most probable equivalent seems to be Arcy-Denecamp-Kesselt period of Western scheme.

Chronology of sites of the *third (recent) group* (fig. 1, III) (table 1, n. 1-101) is the most complicated problem. Remains of 25 palaeolithic settlements of different cultural affiliation are connected with the deposits of loess loams of colluvial train of the first and the second terraces. From two up to four horizons of initial soil formations are identified in loams bed on Kostenki 11, 14, 17, 21 but its correlation remains debatable. More than 100 radiocarbon dates for the sites of this group have a very wide range of variability, sometimes of more than 10 kyr for one cultural layer.

The most important are : the unique serie of 43 dates for Kostenki 1 (I) in the framework of 19-24 kyr ; dates of 22-23 kyr for Kostenki 4 ; Kostenki 8 (I) ; Kostenki 14 (I) ; Kostenki 21 (III). With the exception of Borshchevo 2 the age of which is the special problem, the chronological framework of the recent group of the area is defined by the period of 26-20 kyr. According to pollen evidences the evolution of climat in direction form temperate to cold arid conditions with the increasing role of herbaceous associations is reconstructed (Spiridonova, 1991). Accumulation of overlying loams is connected with the period before the maximum of the last glaciation because the extremely cold conditions known, for example, in the Middle Dnieper basin, was not identified in Kostenki-Borshchevo area. Both sediments of the maximum of last glaciation and any evidences of human activity are absent here.

The paleomagnetic digression under the level of Gmielin fossil soil on Kostenki 21 is correlated with the excursus Mono dated back to 22-24 kyr.

Trinominal periodization of the Palaeolithic of Kostenki-Borshchevo area appears to be a good background for the estimation for the possibilities and degree of exactness of the radiocarbon method. Inside a serie of 17 dates for the sites of the first chronolocal group which age is defined by the framework of 36-40 - 32 kyr, only 9 dates or 53 % are in correspondence with the complex of evidences. This index is 43 % for the middle chronological group in the limits of 32-27 kyr ; and 72 % for the sites of the recent group in the framework of 26-20 kyr.

It is natural that increasing of the degree of exactness of the method is in direct connection with the decreasing of the real age of archaeological sites. The principal problem is the 50 % level of exactness and trustwortiness of the radiocarbon method for the more ancient than 25 kyr times.

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Index of laboratories

AA - NSF-Arizona AMS Laboratory, The University of Arizona (Tucson, USA).
GIN - Geological Institute RAS (Moscow, Russia).
GrN, GrA - Centre for Isotope Research, University of Groningen (The Netherlands).
LE - Institute of the History of Material Culture RAS (St-Peterburg, Russia).
LU - Geographical Research Institute, St-Petersburg State University (St-Petersburg), Russia).
Mo - Vernadski Institute of Geochemistry and Analytic Chemistry RAS (Moscow, Russia).
TA - Institute of Zoology and Botany, Estonian AS (Tartu, Estonia).
OxA - Oxford Radiocarbon Accelerator Unit. Research Laboratory for Archaeology and the History of Art (Oxford, UK).

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PROPOSITION DE RÉVISION DES STADES TECHNO-TYPOLOGIQUES DU GRAVETTIEN ORIENTAL

Pierre NOIRET, Karl ENGESSER* et Marcel OTTE**

Résumé : La définition de stades pour le Gravettien d'Europe centrale et orientale, réalisée sur la base des «armatures», permet de constater l'existence d'un rythme évolutif des industries lithiques, commun à différentes régions. Ce rythme n'implique pas une nécessaire succession chronologique des industries, qui montrent toujours des tendances régionales marquées.

Abstract : The definition of stages for the Gravettian of Central and Eastern Europe, based on «armatures», permits the observation of an evolutionary rhythm in lithic industries, common across different regions. The rhythm does not necessarily imply a chronological succession of industries, which still demonstrate marked regional tendencies.

Mots-clés : Gravettien, Europe centrale, Europe Orientale.

Key-words : Gravettian, Central Europe, Eastern Europe.

Jadis, des «impressions» ont été publiées quant à l'évolution des «faciès» ou «stades» du Gravettien d'Europe centrale (Otte, 1981 ; 1985). Des recherches menées récemment en Europe de l'est, appuyées par de nombreuses analyses radiométriques, permettent d'étendre ce canevas (Borziak, 1991, 1993 ; Chirica, 1989 ; Damblon *et al.*, 1996 ; Otte et Chirica, 1993 ; Otte *et al.*, 1996a). Encore provisoire, ce nouveau schéma permet de placer les observations réalisées en Moldavie (aire récemment étudiée) dans les schémas autrichien et russe.

Ces stades sont essentiellement définis sur base des «armatures» (au sens large) et n'implique pas une nécessaire succession chronologique. Toutefois, on y constate ainsi un «rythme» apparemment commun à ces différentes régions, dont l'interprétation reste ouverte. Mis en évidence à travers différentes zones très dispersées dans l'Europe orientale, et participant à la genèse du Gravettien, ce rythme n'exclut pas l'existence de tendances régionales correspondant aux «faciès» définit par ailleurs (Otte, 1981, 1985, 1991 ; Otte *et al.*, 1996b).

Les traits principaux peuvent être résumés, tout en ouvrant la possibilité d'y inclure d'autres stades ou ensembles non cités ici.

Stade I : de 30.500 à 27.000 ans B.P.

Ce stade montre des industries lamellaires, comprenant microlithes, fléchettes et microgravettes (par exemple à Kostenki 8/2, Willendorf 2/5-6).

Stade II : de 28 à 25.000 B.P.

Ce stade présente un débitage plus large, avec lames apppointées, lames retouchées, pointes de la Gravette et pointes à retouches bifaces (Willendorf 2/7-8 ; Mitoc M.G. cycles 6 et 7 ; Molodova 5/9-10, Kostenki 8/1).

Stade III : de 25 à 23.000 B.P.

Ce stade livre des pièces à cran, burins sur troncature, éléments tronqués, microgravettes et statuettes féminines (Willendorf 2/9, Mitoc M.G. cycles 4 et 5, Molodova 5/7-8 ; Kostenki 1/1).

Stade IV : de 23 à 19.000 B.P. (non représenté ici).

De très rares ensembles sont à peine connus pour cette phase rigoureuse où les éléments tronqués et lamelles à dos sont présents (Kostenki 7/2 et peut-être Mézine).

Stade V : de 19 à 17.000 ans B.P.

Eléments tronqués, pointes à dos et troncature, figurines, pendeloques sont caractéristiques (Molodova 5/4-5-6, Cosaoutsi c. 1-6).

Stade VI : de 17 à 14.000 B.P. (non représenté ici).

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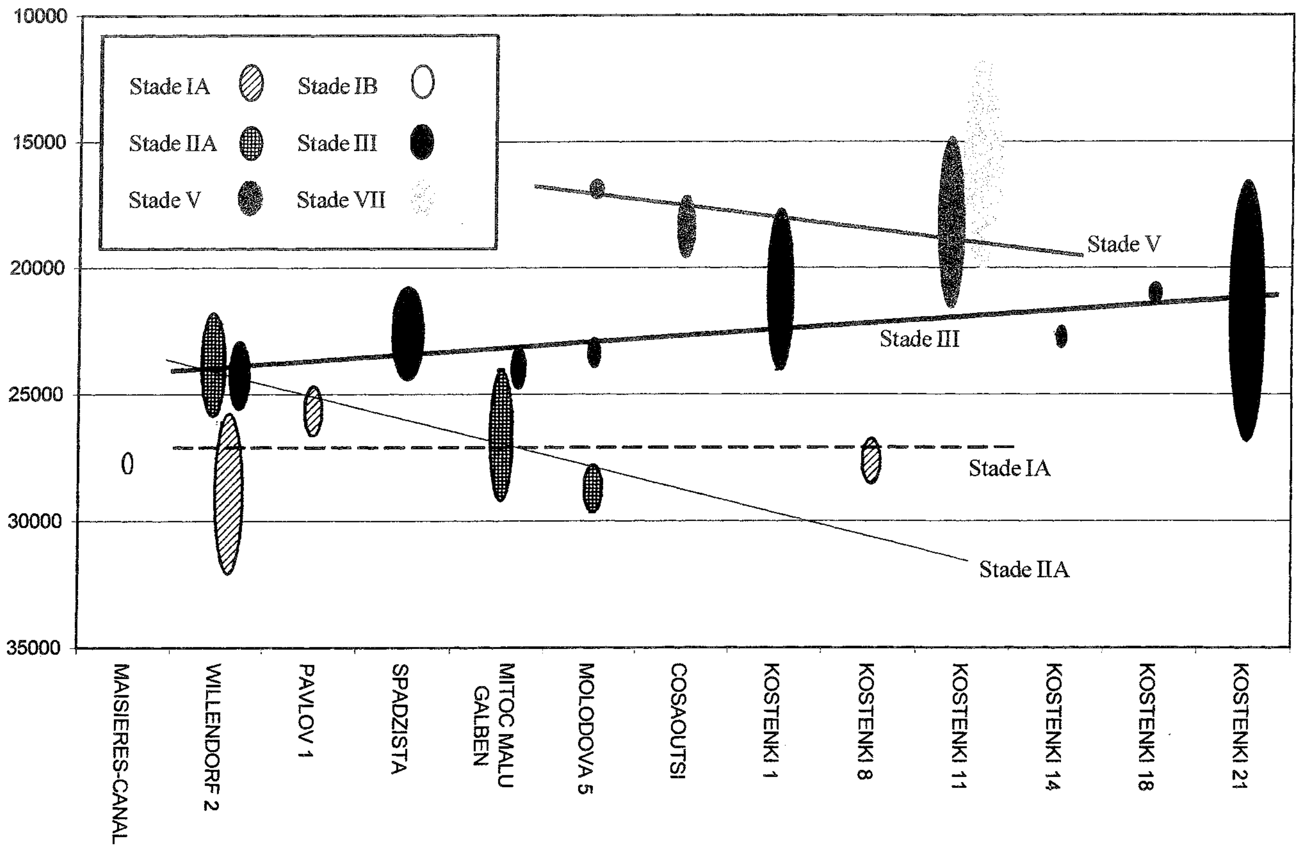

Stades du Gravettien oriental.

Ce stade est représenté à Mézerich (Soffer, 1985).

Stade VII : de 14 à 11.000 B.P.

Lamelles à dos, pointes microlithiques sont caractéristiques (Kostenki 11/1a).

Le **Graphique** montre la répartition chronologique de ces stades pour quelques sites importants d'Europe centrale et orientale, sur base de 134 dates C14 pour 14 sites.

Chaque stade est représenté par un symbole propre. Les sites de Willendorf 2 (Autriche), Mitoc-Malu Galben (Roumanie), Molodova 5 (Ukraine) et Kostenki 11 (Russie) montre une superposition stratigraphique de deux stades différents au moins.

Sauf pour le groupe des gisements de Kostenki considérés dans leur entièreté, les différents stades ne sont pas représentés ensemble au sein d'une même séquence. Ceci est peut-être dû au piégeage, limité dans le temps, de la formation sédimentaire durant laquelle une courte phase seulement a pu être enregistrée.

Ceci n'explique pas toutefois le hiatus existant apparemment au centre de la séquence, au stade IV. Pour le reste, cette zone orientale semble constamment peuplée et en perpétuelle évolution. Les traditions locales n'empêchent pas d'y distinguer des innovations reconnaissables de l'Oural au Bassin de Vienne, et parfois même jusqu'en Occident (statuettes féminines, fléchettes).

Les moyennes linéaires des 4 principaux stades ont été ajoutées. Elles montrent l'ancienneté des stades IA et III dans le bassin de Vienne et la Moravie, par rapport aux autres régions. Le stade II A ne semble pas suivre cette tendance, mais cela est sans doute dû ici à l'existence de dates relativement récentes pour la couche 8 de Willendorf 2 par rapport à la couche 9 du même site.

Le stade V quant à lui semble montrer une plus grande ancienneté dans la zone moldave, ce qui confirmerait l'existence d'un faciès propre, dénommé «Molodovien» (au sens de J.K. Kozlowski, 1986).

REMERCIEMENTS

Les travaux qui sont à la base de cette étude (à Mitoc et Cosaoutsi) ont pu être réalisés grâce à l'appui financier d'un programme de recherches émanant du Ministère Belge de la Politique Scientifique (Contrats SSTC SC-004 et SC/09/001) et grâce à un budget INTAS accordé par les Communautés Européennes (Contrats 93-20 et 93-203-ext).

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Tableau des dates du Gravettien oriental

SITE	NIVEAU	DATE B.P.	SIGMA	LAB. CODE	LAB. NUM.	STADES
MAISIERES-CANAL		27965	± 260	GRN	5523	IB
WILLENDORF 2	6	26150	± 110	GrA	1016	IA
WILLENDORF 2	6	26500	± 480	GrN	20768	IA
WILLENDORF 2	5	27270	± 290	GrA	218	IA
WILLENDORF 2	6	27600	± 480	GrN	17803	IA
WILLENDORF 2	6	27620	± 230	GrA	895	IA
WILLENDORF 2	5	30500	± 850	GRN	11193	IA
WILLENDORF 2	5	32000	± 3000	H	246-131	IA
WILLENDORF 2	8	22180	± 190	GrA	917	IIA
WILLENDORF 2	8	24710	± 180	GrA	894	IIA
WILLENDORF 2	8	25230	± 320	GrN	17801	IIA
WILLENDORF 2	8	25400	± 170	GrN	21690	IIA
WILLENDORF 2	8	25440	± 170	GrN	20767	IIA
WILLENDORF 2	8	25660	± 350	GrN	17802	IIA
WILLENDORF 2	9	23180	± 120	GrA	5005	III
WILLENDORF 2	9	23860	± 270	GrN	21898	III
WILLENDORF 2	9	24370	± 290	GrN	22208	III
WILLENDORF 2	9	24910	± 150	GrA	5006	III
WILLENDORF 2	9	25800	± 800	GRN	11191	III
PAVLOV 1		25020	± 150	GRN	1325	IA
PAVLOV 1		26000	± 350	GIN	104	IA
PAVLOV 1		26620	± 230	GRN	1272	IA
PAVLOV 1		26730	± 250	GRN	4812	IA
SPADZISTA		21000	± 300	Ly	2544	III
SPADZISTA		23040	± 170	GrN	6636	III
SPADZISTA		24380	± 180	GRN	11006	III
MITOC MALU GALBEN	cycle 6b	24070	± 180	GrA	1020	IIA
MITOC MALU GALBEN	cycle 7b	24800	± 430	OxA	2033	IIA
MITOC MALU GALBEN	cycle 7b	25080	± 500	GrN	18882	IIA
MITOC MALU GALBEN	cycle 6b	25140	± 210	GRN	14036	IIA
MITOC MALU GALBEN	cycle 6b	25140	± 210	GrN	14036	IIA
MITOC MALU GALBEN	cycle 6b	25160	± 220	GrN	15450	IIA
MITOC MALU GALBEN	cycle 7b	25330	± 420	GrN	14913	IIA
MITOC MALU GALBEN	cycle 6b	25610	± 500	GrN	20440	IIA
MITOC MALU GALBEN	cycle 7a	25840	± 90	GrN	15808	IIA
MITOC MALU GALBEN	cycle 7b	26020	± 650	GrN	18880	IIA
MITOC MALU GALBEN	cycle 6b	26100	± 800	GrN	15449	IIA
MITOC MALU GALBEN	cycle 7b	26110	± 1050	GrN	18883	IIA
MITOC MALU GALBEN	cycle 6b	26180	± 290	GrN	18811	IIA
MITOC MALU GALBEN	cycle 7b	26300	± 450	GrN	18879	IIA
MITOC MALU GALBEN	cycle 7b	26380	± 600	GrN	18881	IIA
MITOC MALU GALBEN	cycle 6b	26450	± 130	GrA	1354	IIA
MITOC MALU GALBEN	cycle 7b	26500	± 460	GrN	18815	IIA
MITOC MALU GALBEN	cycle 6b	26750	± 600	GRN	14035	IIA
MITOC MALU GALBEN	cycle 7b	27500	± 600	OxA	1778	IIA
MITOC MALU GALBEN	cyle 7b	28910	± 480	GN	12636	IIA
MITOC MALU GALBEN	cycle 5a	23390	± 280	GrN	20438	III
MITOC MALU GALBEN	cycle 5a	23490	± 280	GrN	15805	III
MITOC MALU GALBEN	cycle 4a	23650	± 400	OxA	1779	III
MITOC MALU GALBEN	cycle 5a	23830	± 330	GRN	14034	III
MITOC MALU GALBEN	cycle 4a	23850	± 100	GrA	1353	III

Tableau des dates du Gravettien oriental

SITE	NIVEAU	DATE B.P.	SIGMA	LAB. CODE	LAB. NUM.	STADES
MITOC MALU GALBEN	cycle 5b	23990	± 250	GrN	20439	III
MITOC MALU GALBEN	cycle 5a	24650	± 450	OxA	1780	III
MOLODOVA 5	9	28100	± 1000	LG	15a	IIA
MOLODOVA 5	9	29650	± 1320	LG	15a	IIA
MOLODOVA 5	7	23000	± 800	Mo	11	III
MOLODOVA 5	7	23700	± 320	GiN	10	III
MOLODOVA 5	1a		± 230	GIN	7	V
MOLODOVA 5	2		± 230	GIN	8	V
MOLODOVA 5	2		± 140	GIN	56	V
MOLODOVA 5	3		± 540	GIN	9	V
MOLODOVA 5	6	16750	± 250	GIN	105	V
MOLODOVA 5	4	17000	± 1400	GIN	147	V
MOLODOVA 5	5	17100	± 180	GIN	52	V
COSAOUTSI	2 A	17230	± 140	GrN	21792	V
COSAOUTSI	2 C	17620	± 210	GrN	21793	V
COSAOUTSI	4	17840	± 180	OxA	5257	V
COSAOUTSI	3	17840	± 180	OxA	5236	V
COSAOUTSI	2 C	17900	± 200	OxA	5233	V
COSAOUTSI	3 B	17900	± 180	OxA	5234	V
COSAOUTSI	3 B	17910	± 80	GrN	21360	V
COSAOUTSI	4	17950	± 100	GrN	21794	V
COSAOUTSI	3 A	18000	± 180	OxA	5237	V
COSAOUTSI	3 B	18000	± 180	OxA	5235	V
COSAOUTSI	3	18030	± 150	GrN	21359	V
COSAOUTSI	5	18060	± 180	OxA	5238	V
COSAOUTSI	5	18140	± 200	OxA	5247	V
COSAOUTSI	6 B	18560	± 200	OxA	5256	V
COSAOUTSI	6 A	18780	± 200	OxA	5248	V
COSAOUTSI	6 C	18860	± 200	OxA	5255	V
COSAOUTSI	6 B	18940	± 220	OxA	5249	V
COSAOUTSI	7	18980	± 220	OxA	5250	V
COSAOUTSI	10	18980	± 200	OxA	5254	V
COSAOUTSI	9 B	19060	± 200	OxA	5252	V
COSAOUTSI	9 A	19060	± 200	OxA	5251	V
COSAOUTSI	9 ?	19080	± 220	OxA	5253	V
COSAOUTSI	6 B	19200	± 130	GrN	21361	V
COSAOUTSI	9	19410	± 100	GrN	21795	V
KOSTENKI 1	1	18230	± 620	LE	3280	III
KOSTENKI 1	1	19010	± 120	LE	2950	III
KOSTENKI 1	1	19540	± 580	LE	3292	III
KOSTENKI 1	1	19620	± 460	LE	3281	III
KOSTENKI 1	1	19860	± 200	LE	2949	III
KOSTENKI 1	1	20100	± 680	LE	3277	III
KOSTENKI 1	1	20315	± 200	AA	4800	III
KOSTENKI 1	1	20800	± 300	GIN	4851	III
KOSTENKI 1	1	20855	± 260	AA	4799	III
KOSTENKI 1	1	21300	± 400	GIN	2534	III
KOSTENKI 1	1	21680	± 700	LE	3279	III
KOSTENKI 1	1	21800	± 200	LE	2801	III
KOSTENKI 1	1	22020	± 310	LE	3282	III
KOSTENKI 1	1	22060	± 500	LE	3290	III

Tableau des dates du Gravettien oriental

SITE	NIVEAU	DATE B.P.	SIGMA	LAB. CODE	LAB. NUM.	STADES
KOSTENKI 1	1	22300	± 200	GIN	2533	III
KOSTENKI 1	1	22300	± 230	GIN	1870	III
KOSTENKI 1	1	22700	± 250	LE	2969	III
KOSTENKI 1	1	22760	± 250	LE	2800	III
KOSTENKI 1	1	22800	± 200	GIN	2530	III
KOSTENKI 1	1	22800	± 200	GIN	2530	III
KOSTENKI 1	1	23000	± 500	GIN	2528	III
KOSTENKI 1	1	23010	± 300	LE	3276	III
KOSTENKI 1	1	23260	± 680	LE	3287	III
KOSTENKI 1	1	23490	± 420	LE	3286	III
KOSTENKI 1	1	23500	± 200	GIN	2527	III
KOSTENKI 1	1	23640	± 320	LE	3283	III
KOSTENKI 1	1	23770	± 200	LE	2951	III
KOSTENKI 1	1	24100	± 500	GIN	2529	III
KOSTENKI 8	2	27700	± 750	GrN	10509	IA
KOSTENKI 11	2	15200	± 300	TA	34	V
KOSTENKI 11	2	21800	± 200	GIN	2531	V
KOSTENKI 11	1a	12000	± 100	LE	1403	VII
KOSTENKI 11	1a	14610	± 120	LE	1637	VII
KOSTENKI 11	1a	16040	± 120	LE	1704a	VII
KOSTENKI 11	1a	17310	± 280	LE	1704b	VII
KOSTENKI 11	1a	19900	± 350	GIN	2532	VII
KOSTENKI 14	1	22780	± 250	OxA	4114	III
KOSTENKI 18		21020	± 180	Oxa	7128	III
KOSTENKI 21	3	16960	± 300	LE	1043	III
KOSTENKI 21	3	19100	± 150	LE	1437A	III
KOSTENKI 21	3	21260	± 340	GrN	10513	III
KOSTENKI 21	3	22270	± 150	GrN	7363	III
KOSTENKI 21	3	26765	± 2000	TA&TL		III
BORSHEVO 2	1	11760	± 240	Mo	6366	V
BORSHEVO 2	1	12300	± 100	GIN	88	V
BORSHEVO 2	1	13210	± 270	IU	742	V

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THE RELATIONSHIP OF EARLY METALLURGY IN ANATOLIA AND SOUTHEASTERN EUROPE BASED ON THE PRESENT RADIOCARBON EVIDENCE

Martin BARTELHEIM and Ernst PERNICKA**

Abstract : With the publication of a large number of radiocarbon dates in the Near East and southeastern Europe throughout the last decades chronological systems changed significantly and safer datation was possible for far earlier times than before. First signs of treating metals (copper) are known from the Early Neolithic in the Near East and date back to the 9th millennium BC. During the following millennia metallurgy slowly becomes more and more complex until the working of copper and its alloys, gold, silver and iron became highly sophisticated in the 3rd millennium BC. Concerning metallurgy, agriculture and sedentary life, southeastern Europe had generally been several centuries behind the Near East.

Résumé : Grâce à la publication au cours des dernières décennies d'un grand nombre de dates radiocarbone au Proche-Orient et en Europe du sud-est, l'échelle chronologique a bien évolué et les datations sont devenues plus sûres pour des époques bien plus lointaines. Les premiers signes d'apparition de métal travaillé (cuivre) sont connus dès le début du Néolithique dans le Proche-Orient et remontent au 9ème millénaire avant J.-C. Au cours du millénaire suivant, la métallurgie devient petit à petit de plus en plus complexe jusqu'au travail du cuivre ; ses alliages (or, argent et fer) devinrent très sophistiqués au cours du 3 ème millénaire avant J.-C. En ce qui concerne la métallurgie, l'agriculture et la vie sédentaire, l'Europe du sud-est a généralement eu plusieurs siècles de retard sur le Proche-Orient.

Key-words : Radiocarbon dates, chronology, metallurgy, Near East, southeastern Europe.

Mots-clés : Dates radiocarbone, chronologie, métallurgie, Proche-Orient, Europe du sud-est.

The traditional chronologies of the Near East and southeastern Europe, which were based on historical dates and typological comparisons of archaeological artefacts, have changed significantly due to the introduction or radiocarbon dating since the 1960s. It was mainly C. Renfrew, who compared traditional chronologies with the growing number of ^{14}C dates and pointed out that many relations between Europe and the eastern Mediterranean, which were thought to be reliable, turned out to be historically impossible. He showed among other things, that the parallelisation between the Early Vinca-culture and Troia I, which was based on typological arguments, could not be sustained any longer (Renfrew, 1969, fig. 2), because the former turned out to be about 2000 years older than the latter. Entire chronological systems had to be shifted, comparable with a geological folding zone, which Renfrew called «fault line» (Renfrew, 1970, fig. 2-3).

At that time ^{14}C dates for the Near East were scarce and due to the possibility of dating by historical events the chronological system was believed to be reliable. Before the beginning of the third millenium BC absolute dates were often estimated. Nowadays more than 600 ^{14}C dates are available (Pernicka, 1990, tab. 5). The chronology seems to be fairly reliable due to the calibration with the central and northern European curve. By these dates the chronology has been considerably prolongued in that the beginning of the pre-pottery Neolithic must be dated to the 10th millenium BC. In southeastern Europe the Neolithic begins with a retardation of more than three millennia and with the earliest known tell settlements in the 6th millenium BC.

The first indications of metal working are known from the 9th millenium BC (fig. 1). The oldest and most important are the ones from Cayönü, other sites follow soon. The earliest European metal finds are a copper awl from Balomir and a piece of copper from Iernut (both in Romania). Both finds originate from layers of the Early Neolithic Cris culture (middle of the 6th millenium BC).

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Site	Finds	Context	Datation (BC)	Literature
Çayönü Tepesi	more than 100 beads, borers and amorph pieces	all aceramic phases	8400-7500	Özdoğan 1990
Nevalı Çori	1 bead	aceramic	ca. 8000	Hauptmann 1993
Aşıklı Hüyük	39 beads	Schicht 2, 2 graves Schnitt 4-L und 4-M	7600	Esin et al. 1991
Tell Mağzaliya	1 borer	Mureybet IV	7500-8000	Bader et al. 1981
Ali Koš	1 bead	Zone B_2, Ali Koš Phase	7500	Hole et al. 1969, 427
Tepe Zageh	several awls	Level II, Cheshmeh Ali Phase	5500	Shahmirzadi 1977
Čoga Sefid	1 borer 1 ring and 1 amorph piece	beneath a wall of the late Sefid Phase Sefid or Surkh Phase	6000 ca. 6000	Hole 1977, 245
Tell es-Sawwan	beads and 1 amorph piece (knive?)	Schicht I	7200	El-Wailly und es-Souf 1965, 2
Tell Ramad	pendants	Schicht I	7200	France-Lanord und De Contenson 1973, 107-115
Çatal Hüyük	lead and copper beads lead and copper beads, rolls, pendants, finger rings	Schicht IX-VII Schicht VI	7200-6500 6500	Mellaart 1967
Tell Sotto	rolls	Schicht 1-7, grave	7200	Bader 1989
Yarim Tepe I	sheets ring pendant lead bracelet	Schicht 7 Schicht 10 Schicht 11 Schicht 11	6500-7000	Merpert und Munčaev 1987, 1-36
Kul-Tepe	several objects		6500-7000	Merpert et al. 1977, 82, Taf. 12, 2
Tellul et-Thalathat	2 amorph fragments	Schicht XV	6700	Fukai 1977, 54
Amuq	amorph piece	Schicht B	6400	Braidwood und Braidwood 1960
Yarim Tepe II	pendant (seal?)	earliest Halaf	ca. 6000	Merpert und Munçaev 1987
Tepe Sialk	awls, borers	Schicht I-3 or I-4	5900-6200	Ghirshman 1939
Hacilar	beads	Schicht Ia-IIa	ca. 6000	Mellaart 1960, 87
Mersin	2 pins	Schicht XXII	ca. 6000	Garstang 1953
Can Hasan III	bracelet, mace head	Schicht 2b	ca. 6000	French 1962

Fig. 1 : Earliest metal finds in the Near East (cal C-14 dates).

There are still more finds known from not so well dated contexts in southeastern Europe.

In the 5th millenium BC a larger number of copper objects appears on the Balkan peninsula. They are mostly heavy and were cast. Until a few years ago no parallels were known in the Near East. This was important, because the synchronism between the Chalcolithic cultures in southeastern Europe and Troia, in which metal objects were present, could not be longer sustained. This and the finds of early metallurgy (5th millenium BC) on the Balkans (Ai Bunar, Rudna Glava), which until some few years ago had no parallels in the Near East either, lead Renfrew to the conclusion, that metallurgy was independently discovered and developed in southeastern Europe. It was thought to have happened on the cultural basis of the Early Neolithic, which had been adopted from the Near East.

Besides that no earlier metal finds than those from the end of the 4th millenium BC were known from Northwest Anatolia – the region which links both areas geographically.

Meanwhile this gap has been successfully closed at least for the 4th millenium BC and it seems only a question of time until finds from the 5th millenium appear. Also Chalcolithic copper mines are now known in the Near East. At least the one in Kozlu dates back to the middle of the 5th millenium BC and is therefore contemporaneous with Rudna Glava. With finds of cast heavy tools like those from Susa dating to the 5th millenium BC even in this respect the find deficit is compensated in the Near East.

The distribution of the earliest metal finds in the Near East is identical with the so-called « fertile crescent», the region, in which the first important steps towards agriculture and sedentary living were made. Furthermore, this is connected with the development of elaborate technologies, like the production of pottery or mortar (Pernicka, 1990, Abb. 5-7). The earliest finds of both technologies were made in this area and with some delay an adoption can be observed in the surrounding regions like southeastern Europe.

It would, therefore, be most surprising if metallurgy as the most elaborate of the new technologies developed in the Near East should have been discovered independently in southeastern Europe. A decoupling of southeastern European metallurgy fom the Near East at the end of the 5th millenium BC is possible. The large number of heavy tools in this region seems to suggest such a development. However for the assumption of a totally independent development the general tendencies concerning technology and style development are too similar. Also similar interactions with the evolution of society can be observed. The emergence of a more complex metallurgy – such as alloying or smelting – is contemporaneous with the first social differenciation in both areas – so in the 'Obed culture (6th and 5th millennia BC) in the Near East and in the Varna culture (5th millennium BC) in Bulgaria.

According to the present chronology the development of metallurgy in the Near East and in southeastern Europe is as shown on fig. 2. After an initial phase between the 9th and the 7th millennium BC, in which in the Near East native copper is cold worked and annealed, copper metallurgy becomes more and more complex until alloying and casting of elaborate objects takes place in the 3rd millennium BC. In southeastern Europe the first steps of copper metallurgy are made in the 6th millennium. The use of other metals begins several millennia later. The latest important prehistoric metal is terrestrial iron, which is used in the Near East already in the 3rd millennium and in Europe mostly not until 2000 BC.

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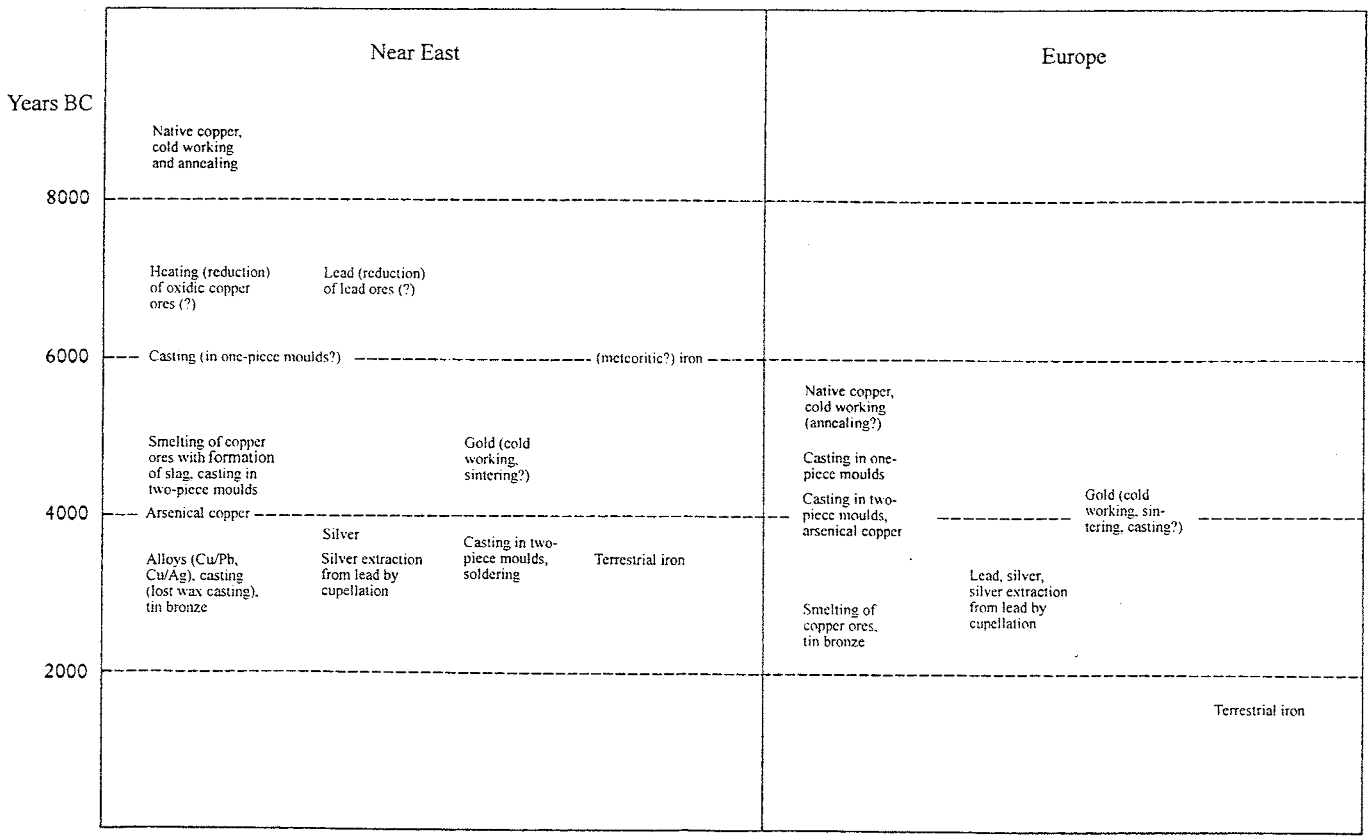

Fig. 2 : Comparison of the development of metallurgy in the Near East and in Europe.

Actes du colloque « C14 Archéologie », 1998, p. 161-164.

PROBLÈMES DE CHRONOMÉTRIE DE LA SUCCESSION RUBANÉ
Culture de Blicquy - Villeneuve-Saint-Germain

*Claude CONSTANTIN**

Résumé : A partir de 1982, l'interprétation d'une série de datations radiocarbone remettait en cause le modèle chronologique alors proposé : l'antériorité du Rubané par rapport aux Groupes de Blicquy - Villeneuve-Saint-Germain. Il devait s'en suivre un débat fort et nourri, né précisément de cette lecture des datations et qui dura une quinzaine d'années. En 1998 alors que le problème chronologique a été réglé par les méthodes classiques de l'archéologie, l'augmentation importante du nombre des datations ne permet toujours pas de trancher par la méthode du radiocarbone. On examine les causes de ces insuffisances, sans doute plurielles et en partie spécifiques à cette période.

Abstract : From 1982 onwards, the chronological model of the anteriority of the Bandkeramik in relation to the Blicquy and Villeneuve-Saint-Germain groups was called into question by the interpretation of a series of radiocarbon dates. As a direct result of this reading of the dates, there was a lively and prolonged debate which lasted for fifteen years. While the chronological problem has been solved by classic archaeological methods, it is still not possible in 1998 to settle the question with the radiocarbon method, despite a considerable increase in numbers of dates. The causes of these inadequacies, which are certainly multiple and partly specific to this period, are examined.

Mots-clés : Chronologie du Néolithique Ancien, Belgique, Nord de la France, datation radiocarbone.

Key-words : Earlier Neolithic chronology, Belgium, north France, radiocarbone dating.

1 - DÉBAT SUR L'ORIGINE DU NÉOLITHIQUE DU BASSIN PARISIEN

A la fin des années soixante-dix deux groupes néolithiques nouveaux étaient discernés, l'un en Belgique, le Groupe de Blicquy (Demarez *et al.*, 1977 ; Cahen *et al.*, 1978), l'autre en Bassin Parisien, le Groupe de Villeneuve-Saint-Germain (Constantin et Demoule, 1982 ; Constantin, 1985). Le premier groupe occupait une aire où était déjà connu le Rubané de Belgique tandis que le second recouvrait et étendait vers l'ouest l'aire occupée par le Rubané Récent du Bassin Parisien. Rubané belge et Rubané Récent du Bassin Parisien sont deux faciès régionalisés du Rubané qui est responsable de la néolithisation de l'Europe, de la Hongrie à la Belgique, tandis que les Groupes de Blicquy et de Villeneuve-Saint-Germain s'avèrent, au fur et à mesure que la documentation s'enrichit, constituer une même et unique culture possédant une unité territoriale sans discontinuité.

Dès 1977 (Demarez *et al.*, 1977) puis d'une façon plus détaillée plus tard (Constantin, 1985) nous avons souligné l'enracinement des deux nouveaux groupes dans le Rubané qui leur est donc, selon nous, antérieur, ceci à partir de multiples observations sur l'évolution de la culture matérielle, des types d'installation, etc...

Bien qu'il ne fut pas opposé d'arguments du même type à cette conception chronologique jusqu'en 1982, celle-ci était remise en cause cette année-là au colloque de Gand (Cahen et Gilot, 1983) à partir d'une série de cinquante-six dates radiocarbone. Il s'agissait de quarante-quatre dates du Rubané Belge et du Rubané Récent du Bassin Parisien, de deux dates du Groupe de Villeneuve-Saint-Germain et de douze dates du Groupe de Blicquy dont la dispersion étonnante aurait sans doute dû conduire à une interprétation plus prudente.

A partir de ces datations (fig. 1) était proposée la coexistence des Groupes de Blicquy et de Villeneuve-Saint-Germain avec le Rubané ou même leur antériorité.

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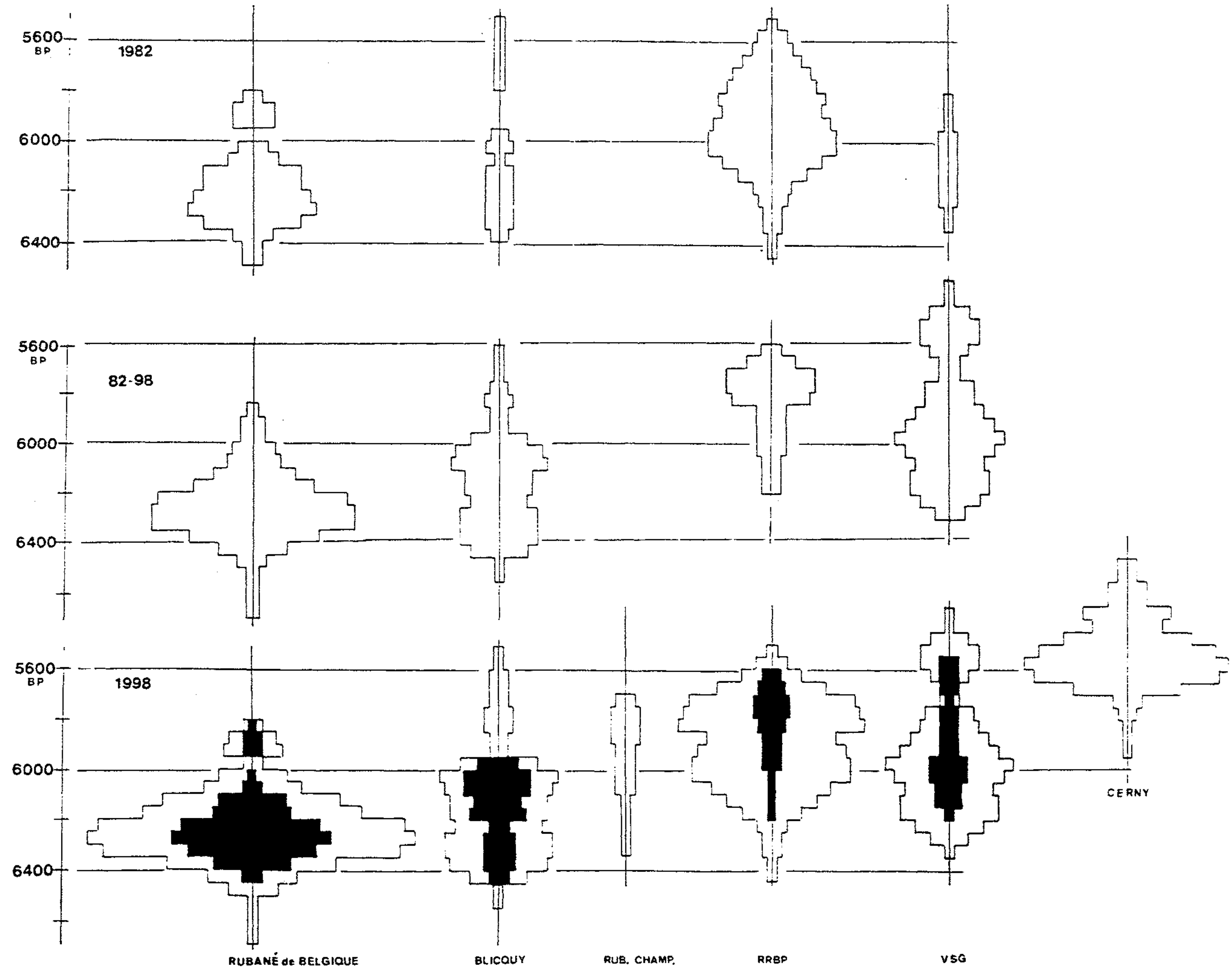

Fig. 1 : En haut : datations disponibles en 1982. Au milieu : datations effectuées en 1982 et 1998. En bas : ensemble des datations disponibles en 1998. En noir : datations dont l'écart-type est inférieur à 100 ans.
Fig. 1 : Top : dates available in 1982. Middle : dates produced between 1982 an 1998. Bottom : all the dates available in 1998. In black : dates with a standard deviation of less than 100 years.

Pour notre part, il ne pouvait être question de nier la réalité des datations mais notre conviction, basée sur un ensemble d'arguments de types évolutionnistes, nous conduisait à remettre en cause leur validité (Constantin et Lassere, 1983 ; Constantin, 1985). Les partisans de la thèse opposée à la nôtre étaient amenés quant à eux, et en tout logique, à développer un certain nombre d'arguments à partir des données archéologiques pour aller dans le sens des datations radiocarbone mais une difficulté subsistait : le Rubané étant admis par tous comme étant la plus ancienne culture néolithique originaire du Danube il fallait expliquer, en Belgique et en Bassin Parisien, l'origine d'un double groupe culturel qui leur aurait été contemporain ou antérieur. Ce pas fut franchi en 1987 (Roussot-Larroque *et al.*, 1987) lorsque quelques tessons de la Vallée de la Loire furent déclarés apparentés à la Céramique Cardiale. Ainsi l'arrivée en Bassin Parisien d'une culture antérieure au Rubané était assurée. On voit donc qu'à cette date, et à la suite de la prise en compte non critique des cinquante-six datations disponibles en 1982, ce sont deux conceptions fondamentalement différentes de la néolithisation du Bassin Parisien qui s'opposent. Au congrès de Liège consacré en 1982 au thème « Rubané et Cardial » de multiples néolithiciens soutiennent la postériorité du Rubané (Cahen et Otte, 1990 ; Roussot-Larroque, 1990 ; Schoenstein et Villes, 1990).

2 - LES DATATIONS RADIOCARBONE EN 1998

Cent quarante dates radiocarbone sont aujourd'hui disponibles pour les mêmes ensembles archéologiques effectuées sur charbons de bois ou sur os.

Nous avons réalisé un diagramme cumulatif de ces dates selon la méthode proposée par Gasco (Gasco, 1985) (fig. 1). Toutefois, pour ne pas étendre démesurément dans la durée ces diagrammes sont rejetées *a priori* et non prises en compte toutes les dates (trente-quatre au total) extérieures à l'intervalle 6400-5500 B.P. qui sont invraisemblables pour l'ensemble des archéologues quelque soit par ailleurs leur position dans le débat. La proportion des dates rejetées, 18 % pour le Rubané et 30 % pour les Groupes de Blicquy et Villeneuve-Saint-Germain indique des difficultés de datation plus grandes pour le second ensemble.

Au cours des années quatre-vingt-dix et progressivement, comme on le verra au paragraphe trois, notre position initiale, sur l'antériorité du Rubané semble de plus en plus assurée. C'est donc en référence à cette réalité que nous examinerons les diagrammes.

2.1 - DIAGRAMMES CUMULATIFS QUELQUE SOIT LA VALEUR DES ÉCARTS-TYPES

L'examen des diagrammes (fig. 1) donnent les résultats suivants :

- En Belgique le Groupe de Blicquy apparaît contemporain du Rubané,
- En Bassin Parisien le Groupe de Villeneuve-Saint-Germain apparaît contemporain du Rubané Récent du Bassin Parisien ou même partiellement antérieur.

Si on compare Belgique et Bassin Parisien on constate les décalages suivants :

- le Rubané Récent du Bassin Parisien apparaît comme postérieur au Rubané de Belgique. Si un décalage est acceptable pour l'apparition de ces cultures, le Rubané belge se mettant en place plus anciennement, il est largement inacceptable (200 à 300 ans) pour leur terminaison qui est synchrone à peu de temps près pour l'ensemble des chercheurs.
- le Groupe de Villeneuve-Saint-Germain apparaît, de même, comme postérieur de près de 200 ans au Groupe de Blicquy alors qu'ils forment une même culture.

Si on place sur la même figure l'ensemble des datations disponibles en 1998, pour la culture de Cerny, que les chercheurs jugent satisfaisantes dans le cadre de la chronologie radiocarbone du Bassin Parisien, celles-ci devraient constituer un terminus pour le Groupe de Villeneuve-Saint-Germain et *a fortiori* pour le Rubané Récent du Bassin Parisien (fig. 1).

Bien que minimisé par la non prise en compte de trente-quatre datations l'étalement temporel des datations reste tout à fait excessif. De plus, si notre conception de la succession chronologique est la bonne, alors l'intervalle de temps disponible pour placer l'un après l'autre Rubané et culture de Blicquy - Villeneuve-Saint-Germain est encore réduit et cela devrait conduire au rejet d'un nombre bien supérieur de datations, probablement plus que la moitié.

La dispersion anormale des datations est d'ailleurs illustrée concrètement par les écarts entre les datations effectuées dans une même fosse ou dans les fosses d'un même bâtiment.

C'est la culture de Blicquy - Villeneuve-Saint-Germain qui présente les dispersions les plus larges. Ecarts pour une même fosse : 815 ans à Bucy-le-Long (fosse 162) et compris entre 400 et 850 ans à Blicquy (fosses 1, 2, 3 et 4). Ecarts pour un même bâtiment : 430 ans à Echilleuses (maison 1) et 1110 ans à Blicquy (maison correspondant aux fosses énumérées ci-dessus).

2.2 - DIAGRAMMES CUMULATIFS POUR LES DATATIONS DONT LES ÉCARTS-TYPES SONT INFÉRIEURS A 100 ANS

Il reste quarante-neuf datations remplissant cette condition. Les résultats sont les suivants (fig. 1, en bas, en noir) : le décalage entre les datations de Belgique et celles du Bassin Parisien reste inchangé et inacceptable de même que le Rubané Récent du Bassin Parisien et le Groupe de Villeneuve-Saint-Germain apparaissent encore contemporains. Cependant la situation s'éclaire pour le Rubané de Belgique et le Groupe de Blicquy qui apparaissent alors un peu décalés dans le temps avec une transition qu'on pourrait peut-être se situer aux alentours de 6150 B.P. soit 5000 B.C. Cal. qui se trouve tout à fait en accord avec les dates proposées pour la fin du Rubané en Allemagne et en Autriche par différents auteurs (Lüning, 1982 ; Lanting et Van der Plicht, 1995 ; Weiner, 1995 ; Lenneis et Stadler, 1997) qui la situent entre 4950 et 5050 B.C. Cal.

3 - LA SOLUTION ARCHÉOLOGIQUE DE LA QUESTION

A partir du début des années quatre vingt-dix, et plus intensivement dans les années récentes, les données de terrain nouvelles et les études archéologiques portant sur le matériel ou les structures (bâtiments, tombes) ont permis de conforter la position des tenants de l'antériorité du Rubané. Nous ne pouvons donner ici qu'une revue rapide de ces travaux.

Sur le terrain de nouvelles découvertes ont montré l'existence sur les mêmes sites, d'habitats Rubané et d'habitats Villeneuve-Saint-Germain avec des mélanges de matériaux, entre des bâtiments proches de quelques dizaines de mètres, si minimes, qu'il fallait conclure au diachronisme et non à la coexistence (Caspar *et al.*, 1989 ; Ilett *et al.*, 1995). La mise en évidence d'échanges et de parallèles typologiques ont permis l'établissement de parallèles chronologiques entre la séquence du Bassin Parisien et de Belgique et celle de la Vallée du Rhin qui dans cette région ne prête pas à contestation. Ces parallèles assurent l'antériorité du Rubané. D'autre part, les données importantes acquises sur la culture de Villeneuve-Saint-Germain permettaient la réalisation d'études focalisées sur des types de matériels ou de structures qui établissaient l'antériorité du Rubané par des méthodes de chronologie relative. Parmi ces méthodes, on peut distinguer des sériations proprement dites et des études sur de plus longs termes qui mettent à jour des tendances évolutives fortes, qui toutes deux ont permis de remédier à l'absence de stratigraphie.

Utilisant les méthodes de sériation, D. Simonin (Simonin, 1994 et 1996) montre que les bâtiments Blicquy - Villeneuve-Saint-Germain sont le terme d'une évolution déjà en cours dans le Rubané, C. Jeunesse (Jeunesse, 1995) fait la même démonstration pour le rituel funéraire du Groupe de Villeneuve-Saint-Germain et C. Constantin et M. Ilett (Constantin et Ilett, 1997) établissent une sériation des décors céramique entre les étapes du Rubané Récent du Bassin Parisien puis celles du Groupe de Villeneuve-Saint-Germain.

Etudiant l'outillage lithique et l'outillage osseux du Néolithique ancien et moyen du Bassin Parisien, A. Augereau (Augereau, 1993) et I. Sidéra (Sidéra, 1993) montrent que l'évolution sur le moyen terme (on citera entre autres exemples la diminution de la composante laminaire dans l'outillage lithique ou l'augmentation de la place du cerf pour la réalisation des outils sur os) ne permet qu'une seule séquence chronologique : Rubané, puis Villeneuve-Saint-Germain puis Cerny.

Au total le débat déclenché par la prise en compte des datations disponibles en 1982 a donné lieu à des dizaines d'articles. Il est clair que ce fut aussi un avantage car certaines recherches qui ont été approfondies pour établir la séquence réelle qui ne l'auraient peut être pas été à ce point si la question chronologique ne s'était pas posée.

4 - LES CAUSES DES DÉFICIENCES DES DATATIONS RADIOCARBONE

Nous croyons devoir préciser que cet article n'a pas pour objectif de rejeter la méthode de datation radiocarbone. Comme on l'a vu les datations sont tout à fait satisfaisantes pour la culture de Cerny qui succède à la période qui nous intéresse ici. Il semble plutôt que de réelles difficultés de datation soient spécifiques à cette période. On envisagera ici quelques causes possibles pour ces difficultés en soulignant, d'une part que ces causes peuvent être multiples et se conjuguer, et, d'autre part que l'effort fait pour les élucider par la coopération chronologistes-archéologues reste insuffisant.

4.1 - Les fosses latérales des bâtiments des cultures qui nous intéressent ici et d'où proviennent les matériaux datés sont de grande surface, souvent quelques dizaines de mètres carrés, et sont en contact avec la couche de terre arable cultivée qui les recouvre, ce qui est éminemment favorable à leur pollution par les bioperturbations végétales et animales.

4.2 - Ces fosses sont creusées et remplies par un sédiment loessique en Belgique et par une nappe alluviale calcaire de sable et de gravier en Bassin Parisien.

4.3 - Du fait de la disparition des ossements en contexte loessique, la totalité des datations belges est effectuée sur charbon de bois. Ce dernier est par contre très fragmenté en contexte alluvial (probablement finement divisé par les bioperturbations) si bien que 90 % des datations du Rubané Récent du Bassin Parisien et 60 % des datations du Groupe de Villeneuve-Saint-Germain sont effectuées sur des ossements.

4.4. - Les datations des sites belges ont été effectuées à 80 % par les laboratoires de Louvain et de Hanovre tandis que 75 % de celles du Bassin Parisien l'ont été par Lyon. Même s'ils ne sont pas importants, on ne peut exclure des décalages systématiques entre laboratoire comme l'ont montré, précisément sur le Rubané, Lenneis et Stadler (Lenneis et Stadler, 1997) qui comparent les datations de 23 laboratoires.

Si les raisons précédents peuvent contribuer à expliquer les décalages entre les datations de Belgique et celles du Bassin Parisien une difficulté supplémentaire se présente pour la période qui nous intéresse :

4.5 - La courbe de calibration est affectée entre 6200 et 5750 B.P. de quelques oscillations qui couvrent au total 300 années radiocarbone (Stuiver et Becker, 1993). Selon l'oscillation considérée, des dates en années réelles séparées de 100 à 180 ans peuvent donner la même datation radiocarbone. Lanting et Van der Plicht (Lanting et Van der Plicht, 1995) ont bien montré la difficulté à rendre cohérentes les datations radiocarbone et la succession des étapes céramique du Rubané d'Allemagne du fait de ces oscillations.

Il est évidemment souhaitable que l'examen détaillé de ces difficultés conduise à augmenter la fiabilité dans les choix des matériaux datés et permette un tri plus efficace entre résultats fiables et douteux.

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NEANDERTHAL EXTINCTION : RADIOCARBON CHRONOLOGY, PROBLEMS, PROSPECTS AND AN INTERPRETATION OF THE EXISTING DATA

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Abstract : The extinction of the Neanderthals falls into the earlier age range of radiocarbon dating. This paper is concerned with the statistical precision of radiocarbon dating in this period, i.e. 30-40 ka BP/five to seven half lives of radiocarbon. The paper discusses the problems of sedimentary deposition and absolute chronologies and how these affect our understanding of complex processes such as extinctions and colonisations. These problems aside, a coarse and necessarily provisional attempt to interpret the existing archaeological database is made, with the assumption that Late Middle Palaeolithic and «transitional» industries are proxy indicators of Neanderthal presence in region. From this, it is suggested that the processes of Neanderthal extinction began by c. 40 ka BP in the Balkans and Central Europe, radiating out from there, leaving Neanderthal on the periphery of their old distribution as late as c. 29 ka BP.

Résumé : L'extinction des Néanderthaliens tombe dans la plage de temps couverte par la méthode de datation par le radiocarbone. Ce papier prend en compte la précision statistique de cette méthode pendant cette période, c'est-à-dire vers 40 ka BP (soit sept demi-vies du radiocarbone). Il discute des problèmes de dépôts sédimentaires et de chronologies absolues et comment ceux-ci affectent notre compréhension de processus aussi complexes que les extinctions et les colonisations. Ces problèmes mis à part, on fait un rapide, et nécessairement provisoire, essai d'interprétation des données existant pour l'archéologie, en supposant que les industries de la fin du Paléolithique Moyen et les industries dites «de transition» sont des bons indicateurs de la présence des Néanderthaliens dans une région. A partir de là, il est prouvé que le processus d'extinction des Néanderthaliens a commencé vers environ 40 000 BP dans les Balkans et dans l'Europe centrale, et a rayonné à partir de là, les laissant à la périphérie de leur ancienne aire de distribution jusque vers 29 000 BP.

Key-words : Radiocarbon dating, Neanderthal extinction, Late Middle Palaeolithic.

Mots-clés : Datation radiocarbone, extinction des Néanderthaliens, fin du Paléolithique Moyen.

INTRODUCTION

The earlier age range of ^{14}C dating provides us with one of the most interesting possibilities in Palaeolithic archaeology – that of monitoring the disappearance of a human species from the face of the earth ; that is to say, the extinction of the Neanderthals. If we are to reconstruct such a complex process with any degree of precision then it must surely be with radiocarbon, given the generally coarser precision of other absolute dating techniques available at present. This paper is concerned solely with the *precision* of radiocarbon dating in the 40 – 30 kyr period, and its effects on reconstructing the extinction of the Neanderthals. As it ignores the many potential problems with accuracy in this period, the paper therefore, to a large extent represents an examination of the efficacy of the best possible scenario for our chronological understanding of such an important period of prehistory. In this sense it represents a critique of archaeological assumptions made in the study of the Middle to Upper Palaeolithic transition, and offers a preliminary interpretation of the nature of Neanderthal extinction.

SEDIMENTARY DEPOSITION, ABSOLUTE CHRONOLOGY, AND TRANSITIONAL INDUSTRIES

There is a hierarchy of resolution on any Palaeolithic site, which must be understood if we are to understand the limitations of absolute chronology. Three time-series are in operation at any given Palaeolithic site, the nature of each and, most importantly, the interaction between which needs to be understood before we can confidently address such questions of the contemporaneity of

**Radiocarbon Accelerator Unit, University of Oxford, 6 Keble Road, OXFORD OX1 3QJ and Keble College, OXFORD OX1 3PG.*

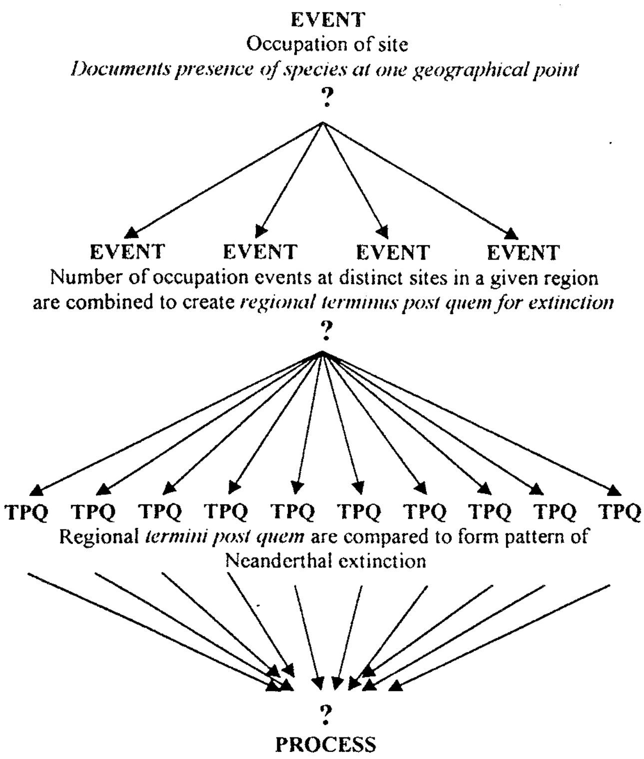

Fig. 1 : Inferring extinction processes from archaeological data. Argument begins with the observation and dating of *event* and progresses to *process*. *Question marks denote stages in which assumptions are made.*

Neanderthals and modern humans and the nature of archaeological industries "transitional" between the Middle and Upper Palaeolithic. This hierarchy of three time-series is expressed in figure 2. First, there is the problem of archaeological palimpsest ; that is, that it is generally impossible to determine exactly how many occupations of a given site have resulted in a particular archaeological level. In archaeological nomenclature, this might be referred to as the *level specific time-series*. The effects of this unknown palimpsest will be felt most clearly when seeking to address questions as to behavioural issues in the immediate environment, such as how long a site was used, what its nature was, etc. To some extent, the problems of the level specific time-series do not affect the issues at hand here, but feed into the problem as a whole. The archaeological level in turn is deposited as a series of palimpsests within the context of sedimentary deposition, which of course can vary from site to site and within sites over time. Changes in rates of sedimentary deposition may affect how one views archaeological palimpsests : for example, distinct occupation events close in time – perhaps seasonal, are more likely to be stratigraphically identifiable under high rates of deposition, whereas lower rates are more likely to mask such differences. Rates of deflation will obviously confuse matters further. This second hierarchy may be termed the *bed specific time series*. The first ambiguity regarding precise dating of archaeological horizons pertains to the relationship of the level specific time-series to the bed specific time-series that contains it. In addition to the time represented by the archaeology - i.e. the human phenomena that are of interest – the geological sediments will have accumulated over a certain, often inestimable, period of time. Usually, the archaeological palimpsest can be placed only relatively within the geological matrix, i.e. one may tell that it formed early on or late in the period in which the relevant sediment was accumulating, but given the processes of deflation even this may be unclear. The situation then, is that one has an archaeological palimpsest reflecting activity of often unknown duration, contained *somewhere* in a geological matrix of unknown formation time. This is expressed in figure 1 by the dotted lines of the

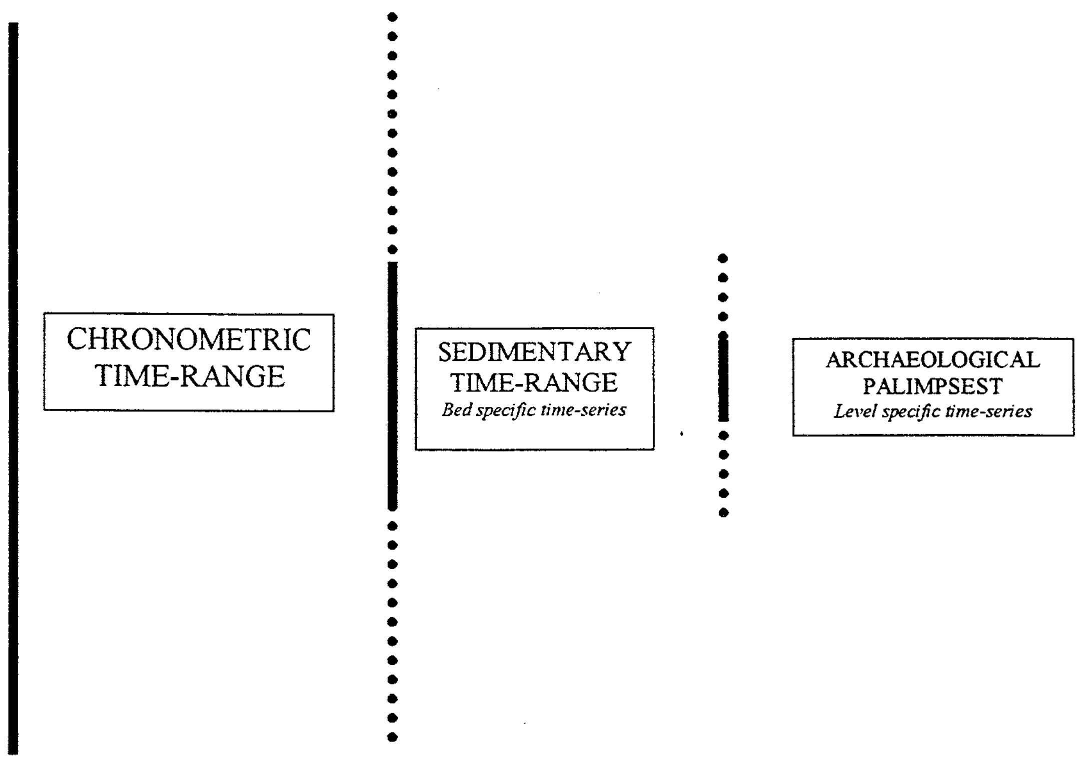

Fig. 2 : Hierarchy of resolution.

archaeological palimpsest, which relate to the solid line of the sedimentary time range. Within this, one has selected materials to date using radiocarbon or other methods. The resulting ages, which taken at two standard deviations, ironically reflect absolute age ranges that are probably greater than the period of geological deposition in question, even though they come from archaeological palimpsests that must inevitably have been of (often considerably) shorter duration than the sedimentary accumulation. This is the fundamental problem of applying absolute dating methods to archaeological materials, which will inevitably have is most profound effects when asking fine-grained questions of the data. This third hierarchical level may be referred to as the *chronological time-series*, within which the bed specific, and by extension the level specific time-series belong, again in a loose way. The Chatelperronian archaeological palimpsest at the Grotte du Renne, Arcy-Sur-Cure serves as an example as to how this affects reconstruction and interpretation.

The Châtelperronian assemblage from level X at the Grotte du Renne, Arcy-sur-Cure has played an important role in the discussion of the nature of "transitional" industries. The identification by CAT scans of a temporal bone from this layer as Neanderthal stimulated discussion as to potential contact between Neanderthal and anatomically modern human groups (Hublin *et al.*, 1996). The perceived importance of this discovery is clear from the fact that a picture of the bone and tooth pendants from this level made the cover of *Nature*, alongside the caption *Neanderthal fashion* ? It is interesting to examine the nature of layer X in the light of the problems discussed above.

Level X at the Grotte du Renne is a thick deposit that can be clearly distinguished from adjacent levels as it is red in colour (Farizy, 1990). The sequence represented by levels IX (also containing a Châtelperronian) and X probably represents *"a time span of hundreds of years...*[forming]... *a complex structure whose interpretation is made more difficult by gravity sorting and differential chemical action"* (Farizy, 1990, 307). By contrast, the formation of the overlying level XIII was rapid, and this yielded only a poor Châtelperronian industry and some evidence of bear and hyaena use of the cave. The one reliable radiocarbon date for level X (Oxa-3464 33820 ± 720 BP) has a chronological range of three millennia at 2 sigma. For the Châtelperronian at the Grotte du renne, therefore, one has an archaeological palimpsest that has accumulated over an inestimable number of visits to the site by one *or more* human species (see below), encompassed in a geological deposit that has formed over several centuries and perhaps more than a mellennium, one date for which indicates a period of some three millennia. In view of this, we cannot eliminate the possibility that *some* of the "Châtelperronian" material was deposited by Neanderthals up to *three millenia* before more of it was deposited by anatomically modern humans ! The lesson to be drawn from this is that only through a careful use of stratigraphic observation in conjunction with chronological data can we ever improve upon the picture of extinction and other phenomena in remote time, whether of ammonites, dinosaurs or sea urchins at the K/T boundary (the latter of which was seriously affected by such problems – Gould, 1996 ; Smith and Jeffery, 1998 ; Marshall, 1998) or of species much later in time such as those under discussion here.

CHRONOLOGICAL RESOLUTION AND NEANDERTHAL EXTINCTION

Nearly two decades ago, François Bordes noted that, if we do not get to grips with the problems of chronological precision, we remain in danger of putting Charlemagne on a motorbike (Bordes, 1981). How might the limitations of precision affect our reconstructions of Neanderthal extinction ? If one accepts the mathematical models of scholars such as Zubrow (1989), it seems possible that Neanderthal extinction could have occurred very rapidly in geological time, even with only a small change in either birth spacing or mortality :

"...a small demographic advantage [in this case of competitive anatomically modern humans] in the neighbourhood of a difference of two percent mortality will result in the rapid extinction of the Neanderthals. The time frame is approximately 30 generations..." (Zubrow, 1989, 229).

From what we do know about the chronology of the latest Neanderthals, one might hypothesise that the local extinction of Neanderthals had begun in some areas by 40 kyr BP, and by contrast did not begin in others until approaching 30 kyr BP, i.e. around the age of the youngest securely dated Middle Palaeolithic sites (see below). It is instructive to see how such a hypothesised pattern of what one might term *staggered local extinction* fits with the precision of radiocarbon chronology for this ten thousand (radiocarbon) year time block. Table 1 divides this time block into 2 kyr periods, for each of which the mean error for a number of samples measured at Oxford is presented at 1 and 2 standard deviations.

Two observations can be made from this table. First, it can be seen that, given that errors (and therefore precision) are a function of the mean age of a sample, the precision over this period is not homogeneous, but "improves" towards the younger end of the range. At 40 – 38 kyr then, resulting age ranges are over double those of samples dating to 32 – 30 kyr BP. This implication is that our chronological understanding of a localised extinction occurring at the beginning of this period will inevitably be coarser that of the last Neanderthals. Secondly, it can be seen that, even in the best situation (i.e. at 1 sigma in the 32 – 30 kyr age range) the chronometric age range obtained will vary nearly 700 radiocarbon years either side of the mean age, resulting in a total chronometric time series of one and a half millennia. This is the finest resolution available for studying Neanderthal extinction. In order to examine the effect of this resolution on addressing Neanderthal extinction, Table 2 presents the number of Neanderthal generations that fit into these errors within each time block, again at 1 and 2 standard deviations.

It can be seen that, even in the time range where precision is finest, 34 Neanderthal generations are being "sampled" by a radiocarbon date at 1 standard deviation. The implications this are clear : even with the best chronological precision, such a complicated process as Neanderthal extinction could have occurred within the error range of one radiocarbon date. If indications based on maturation of Neanderthal molars are correct, Neanderthals may have matured anatomically - and one might infer reproductively - quicker than anatomically modern humans (Trinkaus *pers. comm.*). If this were so, their generational durations would be even shorter. Thus, if one assumes, for the sake of argument, that a Neanderthal generation is 18 and not 20 years, then a

	40-38kyr	38-36kyr	36-34kyr	34-32kyr	32-30kyr
Mean error (1 sigma)	1573	1378	1187	875	679
Mean error (2 sigma)	3146	2756	2374	1745	1358
Number of measurements	31	25	29	34	30

Tab. 1 : Mean errors for the period 40 – 30 kyr BP by 2 kyr time blocks.

	40-38kyr	38-36kyr	36-34kyr	34-32kyr	32-30kyr
Number Generations (1 sigma)	79	69	59	44	34
Number Generations (2 sigma)	157	138	119	87	68

Tab. 2 : Number of Neanderthal generations sampled by mean errors in the time Range 40 – 30 kyr BP, by 2 kyr time blocks. Rounded to nearest whole.

radiocarbon date in the 32-30 kyr time block will be sampling 38 generations at 1 sigma, and at the other extreme, 175 generations at 2 sigma in the period 40-38 kyr BP.

The chronological reconstruction of Neanderthal extinction is inevitably coarse, and one is essentially restricted to viewing *termini post quem* against a geographic context. This is exactly what has been attempted by Hahn (1993), who, in noting that radiocarbon dates for the late Mousterian fall between 40 and 30 kyr BP, attempted to place the available dates on a map of Europe in the form of isochron contours suggestive of a later persistence of the Neanderthals in France south of the Loire. The following section presents a brief review of the chronological data available to the author to date. A major assumption here is that Mousterian and transitional industries are proxy indicators of neanderthal, as opposed to anatomically modern human, activity.

CHRONOLOGY OF THE LATEST NEANDERTHALS

In Siberia, Neanderthals seem to have persisted – at least in certain regions – as late as c. 30 kyr BP (Kuzmin *pers. comm.*), by which time anatomically modern humans had been in the area at least 10 kyr, e.g. such as at Kara Bom (Goebel and Aksenov, 1995). The Middle to Upper Palaeolithic transition on the Russian Plain is poorly dated (Soffer, 1989). Given this, and the geographical difference between the latest Neanderthal and earliest anatomically modern human sites, it is difficult to interpret the data that is available in the light of Neanderthal extinction, although a relatively late date of c. 36 kyr for the latest Middle Palaeolithic of Betovo makes it broadly "contemporary" with the Early Upper Palaeolithic in more south-easterly areas of the Plain, e.g. Kostenki XVII, layer 2 (GrN-12596 36400 ± 1400) (ibid. 723-725). Given that, according to Soffer, there is a more restricted occupation of the Russian Plain in the later Middle Palaeolithic as opposed to the earlier, it might be reasonable to assume that, by the time anatomically modern humans had moved into the region, Neanderthals were already restricted to limited areas of the landscape, a process which might have considerable antiquity and need not have had anything to do with the arrival of modern humans. As this is the case, one might interpret the chronological pattern of the Russian Plain in terms of a process of Neanderthal extinction independent of the arrival of anatomically modern humans in the region, a process which may have been stimulated or even facilitated by the opening up of a vacant niche space – i.e. that of a human top carnivore beginning around 36 kyr BP.

The radiocarbon evidence for the Middle Palaeolithic of the Crimea has been discussed by Pettitt (forthcoming). One might tentatively conclude that the Middle Palaeolithic of the Crimea persists down to c. 33 kyr at Starosel'e, c. 31 kyr at Kabazi II and c. 29 kyr or even later at Buran-Kaya III. In all, one might tentatively conclude that the *terminus ante quem* for the Middle Palaeolithic of Crimea is c. 29 kyr or even a little later, i.e. a relatively late persistence of the Middle Palaeolithic, and by which time the Upper Palaeolithic and "transitional" industries seem to have existed in the region for over 2 kyr.

The chronology of the Middle to Upper Palaeolithic transition in the Balkans has been summarised by Kozlowski (1988), where it seems the Upper Palaeolithic appears as an intrusive phenomenon, not a local development (Kozlowski, 1992). At Temnata Cave, Bulgaria, anatomically modern humans, as represented by the Aurignacian, were present before 40 kyr BP, a date at which a Late Middle Palaeolithic with leaf points the Levallois technique is present, e.g. as at Ripiceni-Izvor (Kozlowski, 1988, 1992). At Bacho Kiro, The transitional Bachokirian of level 11 dates to between c. 38 and 35 kyr BP (Hedges *et al.*, 1994 ; Kozlowski, 1988). In the Middle Danube Basin, the earliest Aurignacian is contemporary with the Szeletian and Bohunician, suggesting some degree of overlap between the latest Neanderthals and the earliest antomically modern humans, and in the Upper Danube Basin the latest Middle Palaeolithic has been dated to c. 37 kyr BP at Sessefelsgrotte (Kozlowski, 1988).

In Central Europe generally, the Szeletian and Jerzmanowician date to between c. 43 – 32 kyr BP, with a median age of c. 40 kyr BP (Allsworth-Jones, 1986, 1990), and dates for the Bohunician, at Bohunice and Stranska Skala (Moravia) date to between 42 – 36 kyr BP (Damblon *et al.*, 1996 ; Hahn, 1993). This suggests that the process of Neanderthal extinction, as in France, had begun earlier on in the 40 – 30 kyr time range, although, given that the Bohunician appears to have no relationship to the Middle Palaeolithic (Kozlowski, 1992, 10) it may represent anatomically modern humans, suggesting that extinction of Neanderthals in Moravia occurred by this time. The incursion of anatomically modern humans into Central Europe in general is noticeable around 34 kyr BP, but begins as early as 40 kyr BP at Willendorf and Schwallenbach, Austria (Damblon *et al.*, 1996 ; Haesaerts and Otte, 1987 ; Allsworth-Jones, 1986, 1990). In Romania, a minimum age of 29700 + 1700 – 1400 for Neanderthal occupation at Gura Chei Risnov has been provided ar the interface of the uppermost Mosterian horizon and a sterile level above, but Mousterian horizons and other sites generally date to older than c. 37 kyr BP (Allsworth-Jones, 1990).

The contemporaneity of Châtelperronian and Aurignacian industries in France around 33 – 34 kyr BP is well known (e.g. Harrold, 1988 ; Mellars, 1989). A late persistence of Neanderthals can be seen in Iberia (e.g. Strauss and Heller, 1988 ; Zilhão, 1988). A Late Mousterian horizon at Ermitons, Catalonia, had been dated to 33190 ± 660 (OxA-3725, Hedges *et al.*, 1994), some 7 kyr or so after the arrival of anatomically modern humans north of the Ebro by 40 kyr, e.g. at El Castillo (Hedges *et al.*, 1994). The concept of an "Ebro frontier" has been discussed by Zilhão (1995), and the notion that Neanderthals persist relatively late south of this has been supported by a seemingly late date for the Neanderthal occupation of Zafarraya Cave, southern Spain, although this is open to doubt given the possibility that dated samples have been subject to stratigraphic mobility (*pers. obs.*). A radiocarbon dating programme at Gorham's Cave, Gibraltar, has so far pinned down the transition only to between 45 – 30 kyr BP, although the picture is likely to improve considerably as further results emerge (Stringer *et al.*, forthcoming).

In Britain, the latest dates for the Middle Palaeolithic come from a cutmarked red deer incisor associated with Neanderthal activity at the Hyaena Den, Wookey (c. 40 kyr BP) and a date of c. 38 kyr BP from a reindeer antler at Coygan Cave, Wales, which is best regarded as a minimum age (Aldhouse-Green *et al.*, 1995). Anatomically modern humans appear to have been present by at least 30 kyr BP, on the basis of the Kent's Cavern 4 human maxilla which is anatomically modern and is associated with a small, undiagnostic, but nevertheless Upper Palaeolithic industry (Stringer in Hedges *et al.*, 1989). The Aurignacian at Paviland Cave, Gower, Wales also appears to be present by 30 kyr BP (Aldhouse-Green and Pettitt, forthcoming). The gap of some 8 kyr or more between the latest dated Neanderthals and earliest dated anatomically modern humans if filled to some extend by the enigmatic leaf-point industries, which, however have an overall chronological range of some 10 kyr, i.e. from 38 to 28 kyr BP, although with over 50 % of the determinations in the range 30 – 27 kyr. As earlier occurrences are sporadic, assuming all leaf point assemblages ere made by Neanderthals is perhaps not justified. At present, therefore, one can only conclude that the terminus post quem for Neanderthal extinction in Britain was c. 38 kyr BP.

So where are the youngest dates for Neanderthal occupations in Eurasia ? As Hahn (1993, 71) has noted, it is difficult to establish the "real" end of the Mousterian, and results will therefore allways be to some extent provisional. Assuming that all Mousterian and "transitional" industries are reliable reflections of Neanderthal activities, then, from the admittedly cursory examination of the data above it would appear that the youngest dates come from sites in Siberia, Crimea, and potentially southern Iberia. Interpreted in a general sense, the picture supports a process of extinction which begins in Central Europe and radiates outwards from there, leaving isolated, regional pockets of Neanderthals at the periphery of their range. There may, of course, be some reality in this general picture – it is simply too early to say – but it is probable that more complex processes occurred within this and that the "retreat" to each peripheral area was not synchronous. How can one potentially examine further ?

Figure 3 plots the latest dates for Neanderthal occupations against apparent degree of chronological overlap with anatomically modern humans by regions for which information was available. The data is, needless to say, "fuzzy" and provisional at best. As the degree of overlap with modern humans appears to vary irrespective of the last date of Neanderthals in any given region, it cannot be assumed that anatomically modern humans always played the major role in Neanderthal extinction. On the contrary, in regions such as Siberia, where Neanderthals persisted latest despite an apparent overlap with modern humans of up to 10 kyr, it would be surprising if modern humans played a major role at all. By contrast, in regions such as Central Europe, the Balkans, the Russian Plain, France and Crimea, the relatively brief periods of overlap may be indicative of more of an active role by modern humans in the extinction process. Overall, I interpret the varied

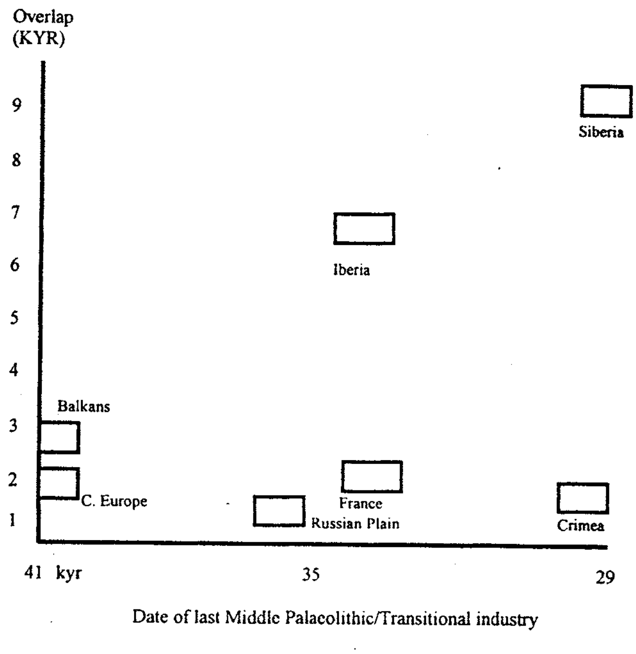

Fig. 3 : Neanderthal extinction, timing and degree of overlap with modern humans.

picture of chronological persistence of Neanderthals and degree of overlap as indicating a complex process of extinction that cannot have had one major cause. The (multiple) caused of Neanderthal extinction, be they competition from modern humans, or other factors perhaps archaeologically invisible, may be expected to vary from region to region. In view of this, we must now begin to question the colonial assumption that it was the spread of modern humans that brought about the demise of the Neanderthals.

PROSPECTS

What we have to do, of course, is to generate hypotheses from which come predictions that are answerable at the level of precision we are able to get for this period. Bordes on Charlemagne repeat. To date, we have generated discussion that invokes a degree of precision far finer that we are able to get in actuality, and the obvious problem here is that our hypotheses – most notably about contact and acculturation between Neanderthal and anatomically modern humans groups – are impossible to test. Even a period of 10 000 years over which space of time both species are found in the same geographical areas is not enough to convince us that the two ever met, and given the apparently low population densities for both species in the period, the areas of Europe which appear to be human deserts at this time, and a hypothesised variation in human distribution over such a long period of time – it may actually be relatively unlikely that the two ever met. In any case, the problem is academic, as it cannot be tested, short of finding the two in association at the same site in the context of rapid sedimentation.

The process of Neanderthal extinction must have been complex, and it has been argued above that there was no one cause for this and that modern humans may only have played a role in this in certain regions, e.g. where overlap between the two was minimal. We are unlikely ever to establish the real causes of Neanderthal extinction, but one thing we can say with a good degree of certainty, in the words of Stringer and Gamble (1993, 194) is that *for whatever reasons* "...the days of the Neanderthal era in Europe were numbered when the Cro-Magnons first arrived."

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DATATIONS ^{14}C DU PALÉOLITHIQUE SUPÉRIEUR EUROPÉEN : BILAN ET PERSPECTIVES

*François DJINDJIAN**

Résumé : Après avoir apporté un cadre chronologique inespéré à la datation des peuplements du Paléolithique supérieur européen, la méthode radiométrique du ^{14}C a progressivement déçu les archéologues devant les incohérences observées entre les séries de dates et les chronologies relatives obtenues par ailleurs, jusqu'à l'arrivée de la méthode AMS. La présente communication essaie de tracer un bilan de l'application du ^{14}C au Paléolithique supérieur, sur un plan méthodologique tout d'abord, puis en approfondissant quelques exemples d'application, entre 40 000 B.P. et 20 000 B.P., pour la transition Paléolithique moyen-Paléolithique supérieur, et les origines de l'Aurignacien en Europe, puis le Gravettien et le Solutréen en France. Les conclusions mettent en évidence les capacités du ^{14}C AMS à dater avec une précision globale du même ordre de grandeur de 1000 ans que les autres méthodes de chronologie relative (stratigraphie, typologie, paléoclimatologie). En corollaire, près de 70 % à 80 % des datations ^{14}C déjà publiées présentent des écarts de plus de 1000 ans par rapport à la date attendue, et sont donc à considérer avec prudence, confirmant le danger de pratiquer des statistiques sur les banques de datations ^{14}C. Enfin, la nécessité de réaliser de nouvelles campagnes systématiques de datations sur des sites déjà fouillés par des procédures d'échantillonnage adaptées, dans le cadre d'un grand programme multiannuel, s'impose pour construire une première carte chronologique et régionale fiable des peuplements européens entre 45 000 B.P. et 10 000 B.P. avec une précision inférieure à 1000 ans.

Abstract : After having given an inexpected absolute chronological frame to the european upper palaeolithic peopling, the ^{14}C radiometric method has progressively disappointed archaeologists because of incoherence observed between series of ^{14}C dates and relative chronology obtained by other methods, until the recent progress of AMS method. The paper try to deliver the results of ^{14}C application to upper Palaeolithic, first on a methodological point of view concerning inexpected errors, and secondly by focusing on several examples between 40 000 B.P. and 20 000 B.P. for middle to upper palaeolithic transition and origins of aurignacian peopling in Europe, and then for Gravettian and Solutrean in France. Conclusions are showing ability of ^{14}C AMS method to date with a global accuracy of 1000 years, with the same scale than other relative chronology (stratigraphy, typology, paleoclimatology). It means also that about 70 % to 80 % of ^{14}C dates actually published have more than 1000 years of difference with expected dates, and then have to be considered carefully, confirming the danger to make statistics on ^{14}C data banks. Finally, the necessity to realise new systematic ^{14}C dates strategies on already excavated sites by adapted dating sampling procedures, with a multiannual large programm, is pointed out to build the first chronological and regional map of european peopling between 45 000 B.P. and 10 000 B.P. with an accuracy of less than 1000 years.

Mots-clés : Datation ^{14}C, Paléolithique supérieur, Europe.

Key-words : Carbon ^{14}C, upper Palaeolithic, Europe.

1 - INTRODUCTION

La méthode radiométrique de datation par le ^{14}C a représenté dans les années 50 et 60 une contribution fondamentale à la chronologie absolue du Paléolithique supérieur. Pour la première fois, une méthode fournissait un ordre de grandeur d'une date absolue, de façon répétitive et universelle, permettant ainsi de situer dans le temps les grandes étapes de l'évolution des peuplements au Paléolithique supérieur, jusqu'au delà de 30 000 ans. La confiance d'alors des archéologues dans les méthodes scientifiques (Géologie et Physique) les avait amenés à considérer comme sûres les dates fournies par les différents laboratoires, ainsi que le fameux écart-type («sigma») associé. L'accumulation des datations ^{14}C dans les années 70 et 80 a permis d'obtenir progressivement des séries statistiques importantes, exploitées pour la construction de synthèses chronologiques et régionales basées prioritairement sur ces données de chronologie absolue. Par ailleurs, l'évolution parallèle des méthodes de reconstitution paléoenvironnementale, et les corrélations typologiques et stratigraphiques des séquences

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loessiques et des remplissages d'abris, ont parallèlement permis de bâtir également une chronologie relative à mille ans près pour le Paléolithique supérieur européen. Confrontées à cette échelle de chronologie relative, les datations ^{14}C classiques montraient à la fois des rajeunissements systématiques de plusieurs milliers d'années, de près de 6 000 ans pour le Paléolithique supérieur ancien à 1000 ans pour le Paléolithique supérieur récent. La mise au point des techniques de comptage AMS à la fin des années 80 a alors profondément changé l'attitude de certains paléolithiciens, plus critiques ou plus curieux, sur la validité des datations ^{14}C. Ces datations AMS se sont révélées rapidement plus fiables, c'est-à-dire plus répétitives (sur un même ensemble clos) et plus cohérentes (sur des séries stratigraphiques ou des séries spatiales de dates), permettant de resynchroniser les cultures du Paléolithique supérieur dans une chronologie vieillie, avec des durées plus courtes dans le temps, contribuant à une modification significative de la vision actuelle du peuplement de l'Europe au Paléolithique supérieur.

2 - LA PRÉCISION DES DATATIONS ^{14}C

L'archéologue a pris l'habitude de considérer l'écart-type associé à la datation fournie par le laboratoire comme un intervalle de précision. Or cet écart-type ne traduit que la précision du comptage effectué par les appareillages physiques. Il ne traduit en aucune façon un intervalle de précision «de bout en bout» de la datation. Plusieurs autres types d'erreurs peuvent en effet affecter une datation, dans le processus pré- et post-dépositionnel, dans le processus archéologique et dans le processus de traitement en laboratoire. Ces erreurs ne sont pas prises en compte pour la simple raison qu'elles ne sont pas pour la plupart d'entre elles quantitativement estimables.

* processus pré- et post-dépositionnel :

- l'échantillon choisi n'est pas contemporain de l'occupation humaine, (ramassage d'ossements et de coquilles fossiles),
- le niveau archéologique a subi des remaniement postérieurs (géologiques, biologiques),
- les échantillons ont subi des pollutions chimiques (dues à des infiltrations ou des percolations de composants carbonatés : $CACO_3$, H_2CO_3, etc..).

* processus archéologique :

- erreur d'attribution stratigraphique,
- pollution chimique involontaire après découverte,
- erreur d'identification,
- mauvaise conservation.

* processus de traitement en laboratoire :

- extraction de la matière à dater dans le ou leséchantillons,
- traitement chimique de préparation laissant passer d'éventuelles pollutions,

(Faut-il par exemple continuer à dater des échantillons pour le Paléolithique supérieur sans sélection par chromatographie des chaînes longues d'acides aminés ?)

- pollution accidentelle des appareillages de lachaîne de préparation chimique,
- pesages imprécis,
- mauvais étalonnage des appareils de comptage.
- influence du bruit de fond.

L'intervalle de précision réel d'une date est la somme de toutes ces erreurs potentielles, dont la plupart ne sont pas estimables statistiquement, et qui peuvent altérer de quelques centaines d'années à quelques milliers d'années la datation.

La pollution potentielle d'un échantillon a des conséquences plus graves pour une datation classique que pour une datation AMS. En effet, l'obligation de prendre plus de matière sur l'échantillon (ou parfois plusieurs échantillons) augmente le risque de prendre des parties plus ou moins polluées ou plus ou moins mélangées, ce qui entraîne par lissage un rajeunissement de la datation. Au contraire, un prélèvement ponctuel pour être traité en AMS s'effectuera sur une zone plus homogène de l'échantillon, polluée ou non, et de ce fait fournira des résultats contrastés, plus facilement détectables.

Giot et Langouët (1984) ont analysé les conséquences d'une pollution dans un échantillon paléolithique et calculé les rajeunissements important induits :

	10 000 BP	20 000 BP	30 000 BP
1%	170 ans	860 ans	2 800 ans
5%	950 ans	3 600 ans	9 200 ans

En conclusion, la recherche méthodologique dans les datations par radiocarbone ne doit pas être considérée par les laboratoires de service comme définitivement achevée, notamment dans le domaine des pollutions naturelles, et des traitements chimiques de préparation, adaptés à l'élimination de ces pollutions.

3 - POUR UNE PROCÉDURE DE DATATION EN ARCHÉOLOGIE

L'archéologue ne peut être que désorienté devant une série de datations présentant une forte variabilité et censée dater une même occupation. Une des raisons possibles de cette variabilité est que ces datations n'ont pas en réalité été effectuées dans les mêmes conditions expérimentales : date de prélèvement archéologique différente (années, fouilleur, archives), matériau différent (charbon de bois, os brûlé, os, ivoire, bois, coquille, humus, etc...), procédure de préparation chimique différente, technique de comptage différente (classique, AMS), laboratoire différent. Croyant vérifier ses datations, l'archéologue multiplie au contraire les sources d'incertitude et augmente sans le savoir son écart-type global. Il est alors tenté d'effectuer des statistiques sur les séries de datations à sa disposition. Si les datations n'étaient entachées que de l'erreur de comptage, la date suivrait une loi normale avec sa moyenne, et son écart-type (sigma). En théorie, la moyenne de deux lois normales n'est pas une loi normale. En conséquence, la date moyenne n'est pas la moyenne des dates, et son calcul est interdit, tout comme celui d'un écart-type moyen. En outre, d'autres erreurs, comme nous l'avons vu précédemment, non estimables en termes statistiques, se rajoutent. Les histogrammes des valeurs de dates d'un même ensemble clos traduisent une distribution asymétrique vers le rajeunissement de nature log-normale. Les moyennes calculées sur ce type de distribution ne fournissent donc en fait qu'une moyenne *a priori* inconnue plus des erreurs additionnelles (au pire située entre la date la plus ancienne (prééminence donnée à la pollution) et la date médiane (compromis). C'est pourquoi, même l'utilisation d'une technique de représentation robuste comme la courbe logistique devrait être limitée, puisque sa pente est également induite par les erreurs additionnelles. En conclusion, puisqu'il n'est pas possible de valider statistiquement une date, on ne peut donc la valider qu'individuellement.

Comment en conséquence réduire les imprécisions par la mise en oeuvre d'une procédure de datation d'un site ? La réduction des imprécisions commence par la définition d'un plan d'échantillonnage formalisé sur le site archéologique, basée sur une série stratigraphique (site stratifié) ou une série spatiale (site à structure d'habitat), ou les deux simultanément si nécessaire, tout en respectant les règles suivantes :
- choix d'un seul laboratoire ^{14}C,
- choix d'un seul matériau (charbon de bois ou os non brûlé en AMS),
- choix d'une seule technique de préparation chimique de l'échantillon,
- choix d'une seule méthode de comptage (AMS pour le Paléolithique supérieur).

4 - LA VALIDATION D'UNE DATATION

La validation d'une datation s'effectue soit au niveau du site, soit par corrélation sur un ensemble de sites.

Au niveau du site, la validation s'effectue par contrôle de cohérence sur la série stratigraphique ou sur la série spatiale des datations. En cas d'incohérences, le contrôle par répétition à l'intérieur d'une sous-structure de l'habitat, ou d'un niveau stratigraphique peut être nécessaire.

Au niveau d'un ensemble de sites, la validation est opérée par corrélation stratigraphique, paléoclimatique, typotechnologique, et régionale, ce qui permet de détecter les dates anormales ou aberrantes par rapport à un schéma général cohérent.

L'élimination d'une date incohérente ne peut être réalisée sans une explication des raisons de cette incohérence, la proposition de la bonne date supposée, et une action débouchant le plus souvent sur une nouvelle procédure de datation.

5 - LES DATATIONS DES DÉBUTS DU PALÉOLITHIQUE SUPÉRIEUR

Il n'est guère surprenant de constater que la transition entre Paléolithique moyen et Paléolithique supérieur entre 45 000 B.P. et 35 000 B.P., et les débuts du Paléolithique supérieur entre 40 000 B.P. et 35 000 B.P. sont particulièrement mal datés, puisque nous sommes ici aux limites de validité de la datation ^{14}C.

Les datations trop jeunes sont légions pour le Moustérien. Encore aujourd'hui nous ne possédons qu'une connaissance très insuffisante de la chronologie absolue de ces cultures et de leur éventuelle contemporanéité (Djindjian, 1993b). Les recherches les plus récentes semblent néanmoins avoir démontré l'existence d'un Moustérien tardif, ou présumé tardif, dans la Péninsule ibérique et en Crimée. Dans un futur proche, il est probable que notre connaissance de ces moustériens tardifs s'enrichisse encore, notamment dans les régions les plus méridionales de l'Europe. Il est cependant encore trop tôt pour valider définitivement les datations de ces industries, en particulier les plus tardives d'entre elles entre 40 000 B.P. et 30 000 B.P.

À partir de 40 000 B.P., d'autres industries, considérées comme des industries du Paléolithique supérieur ayant évolué à partir d'industries moustériennes, sont connues dans différentes régions d'Europe :
- le Jerzmanowicien (Ranisien, Lincombien) à pointes foliacées, dans les grandes plaines du Nord de l'Europe, d'Angleterre en Pologne,
- le Szelétien, à pointes foliacées, en Europe centrale (Hongrie, Moravie, Slovaquie),
- le Strélétien à pointes foliacées à base concave, en Europe du nord-est jusqu'à l'Oural,
- le Castelperronien à couteau à dos abrupt, en Europe franco-cantabrique,
- l'Uluzzien à couteau à dos (demi-lune), dans la péninsule italienne.

Ces industries sont datées par des datations encore trop rares autour de 38 000 B.P. (fig. 1). La question de leur perduration au delà de l'interstade würmien jusque dans le premier épisode froid du Würm récent, et de leur disparition vers 32 000 B.P. demande à être vérifié sur la base de nouvelles datations AMS (Castelperronien dans le Centre-Ouest et le Bassin parisien de la France, Széletien supérieur, Strélétien, Uluzzien).

Le nombre de datations validant cette chronologie sont faibles en regard de l'ensemble des datations disponibles pour ces industries. Ainsi près de 80 % des datations sont à rejeter. La figure 2 montre pour l'exemple les 22 dates connues du Castelperronien, dont seulement quatre dates AMS, comparé à sa chronologie supposée. L'ensemble du Castelperronien est donc à redater.

6 - L'AURIGNACIEN

Les récentes datations AMS effectuées sur plusieurs sites aurignaciens européens ont significativement vieilli l'apparition du premier aurignacien de près de 5 000 ans.

Dans la péninsule ibérique, en Catalogne (L'Arbreda, Mollet, Reclau-Viver), la chronologie de l'Aurignacien est la suivante :

Aurignacien 0	interstade würmien	vers 38 000 B.P.
Aurignacien 1	1° épisode froid	vers 33-34 000 B.P.
Aurignacien 2	Arcy	mal daté

Les dispersions des datations de l'Aurignacien 0 entre 35 000 et 41 000 B.P., aux limites de la méthode ^{14}C, doivent être considérées avec prudence, et ne pas servir d'argument pour une quelconque antériorité entre l'ouest et l'est de l'Europe sur la naissance et la diffusion de l'Aurignacien. Bien dater les séquences cantabriques de référence (Cueva Morin, Pendo, Castillo, Vina) et l'Aurignacien évolué et final de la côte levantine permettrait d'achever la reconstruction chronologique de l'Aurignacien ibérique (fig. 3a).

Sur la côte méditerranéenne française, si l'Aurignacien 0 est connu depuis les années 70, les datations de ces sites (L'Esquicho-Grapaou, La Laouza), trop jeunes, sont à refaire en AMS.

En Italie, les nouvelles datations AMS ont confirmé l'existence d'un Aurignacien 0 en Ligurie (abri Mocchi) et en Vénétie (abri Fumane, Paina), daté autour de 35-38 000 B.P.. Les données actuelles sont cependant insuffisantes pour reconstruire la chronologie du peuplement aurignacien, qui, malgré les désignations typologiques maintenant obsolètes de Protoaurignacien, devraient plutôt se situer de 34 000 à 29 000 B.P. dans la péninsule jusqu'en Sicile.

Aurignacien 0	interstade würmien	40 000 à 34 000 B.P.
Aurignacien 1/2		insuffisamment daté

En Europe centrale, les récentes datations AMS dans la haute-vallée du Danube, principalement en Basse-Autriche, mais également en Moravie et Pologne, mettent en évidence un peuplement dont la présence est liée aux fluctuations climatiques des débuts du Würm récent (fig. 3b).

Aurignacien 0	interstade würmien	41 000 à 36 000 B.P.
Aurignacien 2	Oscil. d'Arcy	32 000 à 30 000 B.P.

Un Gravettien ancien lui succède dès l'oscillation de Maisières vers 29 000 B.P.

STRÉLETIEN							
- SUNGIR (Vladimir, Russie)							
		ch	25 500	±	200	BP	GrN 5425
- KOSTIENKI I (Poliakov site, Voronej, Russie)							
	V	ch	34 900	±	350	BP	GrA 5245
- KOSTIENKI 6 (Streletskaia 2 site, Voronej, Russie)							
		os	31 200	±	500	BP	GIN 8572
- KOSTIENKI 12 (Volkov site, Voronej, Russie)							
	III	ch	36 280	±	360	BP	GrA 5551
PALEO SUP INDÉTERMINÉ							
- KOSTIENKI 14 (Markina Gora, Voronej, Russie)							
	IVa	ch	33 280	±	650	BP	GrN 22277
SPITSYNIEN							
- KOSTIENKI 17 (Spitzyn site, Voronej, Russie)							
	II	ch	36 400	±	1 700/1400	BP	GrN 12596
GOROTSOVIEN							
- KOSTIENKI 12 (Volkov site, Voronej, Russie)							
	Ia	ch	32 700	±	700	BP	GrN 7758
- KOSTIENKI 14 (Markina Gora, Voronej, Russie)							
	II	os	28 580	±	420	BP	OxA 4115
- KOSTIENKI 16 (Uglianka site, Voronej)							
	cinf	os	28 200	±	500	BP	GIN 8031
JERZMANOWICIEN / LINCOMBIEN							
- NIETOPERZOWA (Jerzmanowice, Cracovie, Pologne)							
	6		38 500	±	1 240	BP	GrN 2181
- KENT'S CAVERN (Lincombe, Devonshire, Angleterre)							
			38 270	±	1470/1240	BP	GrN 6324
PALÉO.SUP.INDÉTERMINÉ							
- WILLENDORF II (Basse-Autriche)							
	2-D1 som		39 500	±	1 500/1200	BP	GrN 11190
BOHUNICIEN							
- BRNO-BOHUNICE (Moravie)							
			36 000	±	1 100	BP	GrN 16920
- STRANSKA SKALA IIIa (Moravie)							
	5		38 200	±	1 100	BP	GrN 12297
SZELETIEN							
- VEDROVICE V (Moravie)							
			37 600	±	800	BP	GrN 15514
- SZELETA (Borsod, Montagnes de Bukk, Hongrie)							
	inf		43 000	±	1 100	BP	GrN 6058
	sup		32 620	±	400	BP	GrN 5130
ULUZZIEN							
- GROTTE CASTELCIVITA (Salerne, Campanie, Italie)							
	12		33 300	±	430	BP	GrN 13985
CASTELPERRONIEN							
- GROTTE DU RENNE (Arcy-Sur-Cure, Yonne, France)							
	Xb		33 820	±	720	BP	OxA 3464
- GROTTE DES COTTES (Saint-Pierre De Maillé, Vienne, France)							
	G1		33 300	±	500	BP	GrN 4333
- ABRI DE ROC DE COMBE (Payrignac, Lot, France)							
	10		38 000	±	2 000	BP	OxA 1443

Fig. 1 : Une sélection de datations pour les débuts du Paléolithique supérieur.

En France, en Aquitaine et en Charentes, les anciennes datations classiques mettent en évidence un peuplement aurignacien entre 34 000 et 23 000 B.P. Peu de datations ^{14}C AMS ont été réalisées (Djindjian, 1993a). La chronologie est toujours basée sur la séquence de dates de l'abri Pataud en Périgord réalisée par le laboratoire de Groningen qui montre l'absence d'un Aurignacien 0 et la présence d'un Aurignacien 1 à 4 daté de 34 000 à 28 500 B.P., confirmée par quelques datations AMS récentes pour l'Aurignacien le plus ancien (I) situé dans le premier épisode froid du Würm récent (fig. 3c).

Aurignacien 1	1° épisode froid	34 000 à 31 500 B.P.
Aurignacien 2	Oscil. d'Arcy	31 500 à 30 500 B.P.
Aurignacien 3	2° épisode froid	30 500 à 29 500 B.P.
Aurignacien 4	Oscil. de Maisières	29 500 à 28 500 B.P.

En Europe nord-occidentale, dans le nord de la France, l'Angleterre, la Belgique, la Rhénanie, les datations AMS mettent en évidence un peuplement encore plus tardif, seulement à partir de l'oscillation tempérée d'Arcy, vers 31 000 B.P. (fig. 3d).

Aurignacien 2	Oscil. d'Arcy	31 500 à 30 500 B.P.

En Europe orientale, l'Aurignacien 0 est connu en Bulgarie (Bacho Kiro). Pendant le premier épisode froid et l'oscillation d'Arcy, il est présent également en Roumanie, sur le bassin du Dniestr (Mitoc), et en Russie dans la vallée du Don (Kostienki I,3).

Aurignacien 0	Interstade würmien	38 500 à 34 800 B.P.
Aurignacien 1/2		33 700 à 32 200 B.P.

En Crimée, l'occupation aurignacienne serait plus récente encore (28 500 à 29 500 B.P.).

La figure 4 donne une sélection de datations ^{14}C considérée comme valides.

7 - LE GRAVETTIEN EN FRANCE

En Europe centrale, les datations du Gravettien sont essentiellement basées sur la séquence de la haute-vallée du Danube, et notamment de Willendorf II, et sur la série stratigraphique et spatiale du Pavlovien de Moravie. En Europe orientale, les datations du Gravettien sont connues par les anciennes datations de Molodova V, sur le Dniestr et celles récentes de Mitoc, sur le Prut, et par les séries spatiales du Gravettien récent (Kostienkien) à Kostienki, Avdeevo, etc... Sur l'ensemble des sites concernés, les datations ^{14}C AMS ont considérablement renouvelées et précisées le cadre chronologique connu (*cf.* Damblon et Haesarts, ce volume, et Iakovleva, ce volume).

Le Gravettien en France a fait l'objet d'environ 130 datations depuis 28 500 B.P. jusqu'au delà de 20 000 B.P., situant principalement cette culture entre 26 000 B.P. et 20 000 B.P., avant les premières datations AMS qui ont vieilli globalement ce Gravettien de plus de 2000 ans de 28 500 B.P. à 22 000 B.P. Cette forte variabilité des datations ^{14}C classiques rendait difficile les corrélations entre stratigraphie, environnement, typologie et chronologie absolue. Les premières datations AMS en Périgord ont permis de réviser la structuration chronostratigraphique du Gravettien français (Djindjian et Bosselin, 1994), issu du Périgordien de D. Peyrony, et de valider la chronologie des différents faciès (fig. 5). Il en résulte que 75 % environ des dates publiées sont à rejeter (fig. 6). En outre, si la chronologie du sud-ouest français est maintenant mieux connue, il reste à redater les sites du centre et de l'est de la France (La Vigne-Brun, Solutré, Arcy, etc...).

8 - LE SOLUTRÉEN EN FRANCE

Les datations ^{14}C classiques laissent penser à une existence longue du Solutréen de 21 000 B.P. à 16 000 B.P. Les datations AMS sont inexistantes ou contradictoires (Combe-Saunière). Les subdivisions inférieur/moyen/supérieur ne sont pas corrélées avec les datations ^{14}C,

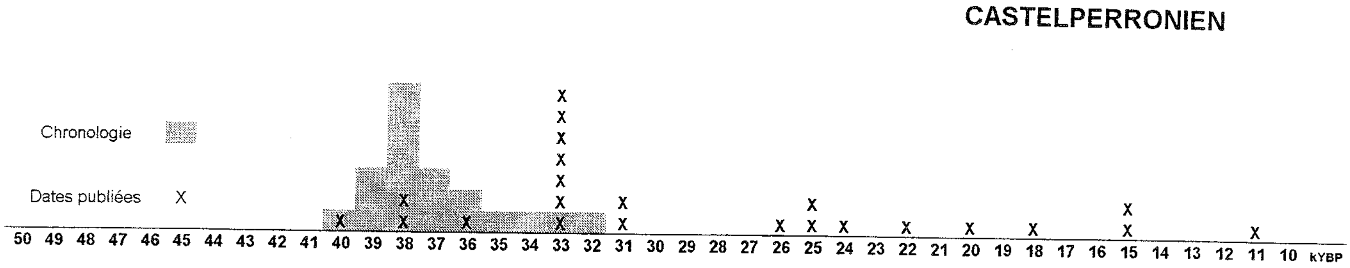

Fig. 2 : Histogramme des datations publiées du Castelperronien.

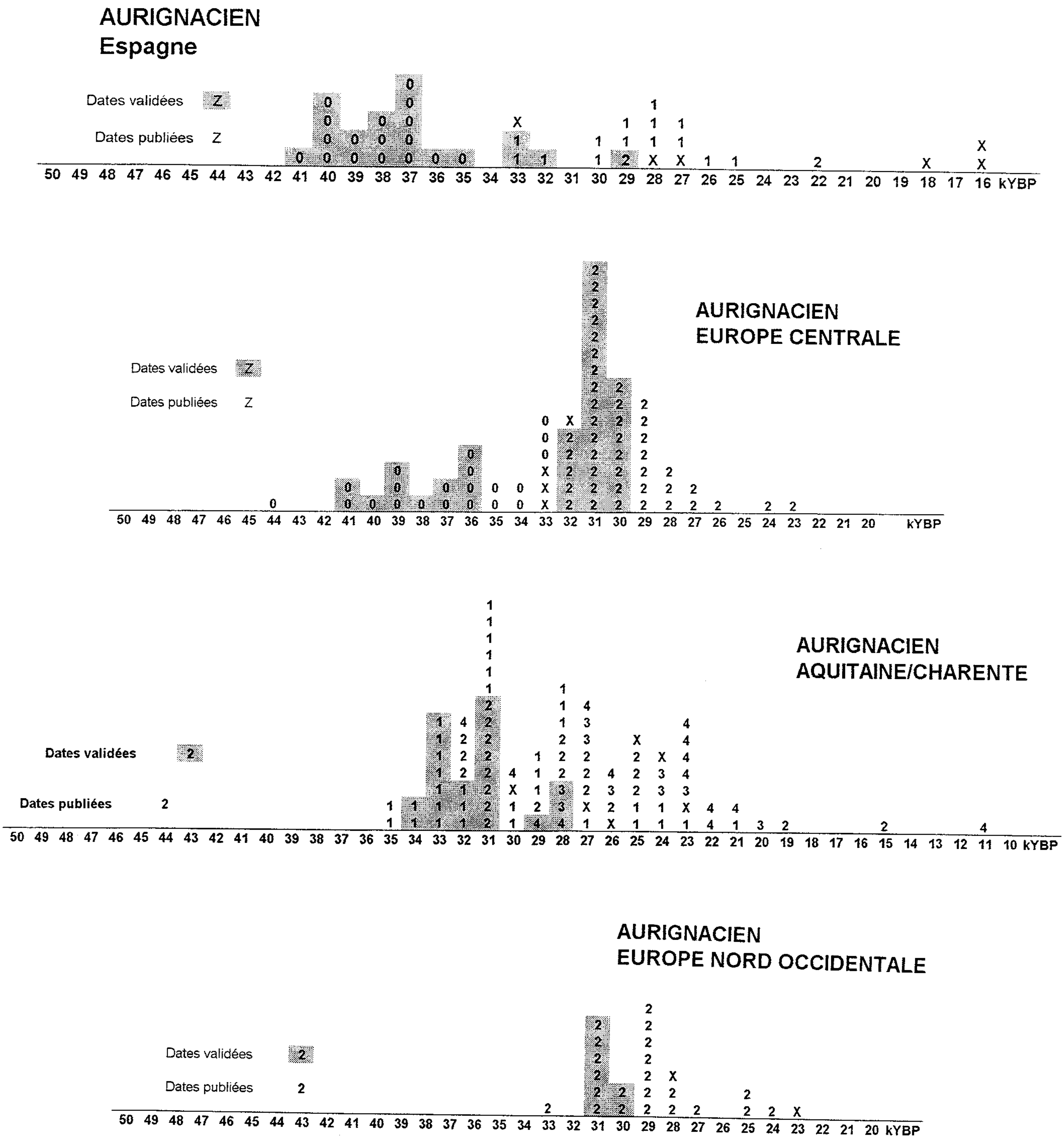

Fig. 3 : Histogramme des datations de l'Aurignacien : dates publiées et dates validées.
3a : Espagne. 3b : Europe centrale. 3c : France (Aquitaine et Charentes). 3d : Europe nord-occidentale.

FRANCE						
AURIGNACIEN I						
- ABRI DE LA FERRASSIE (Savignac-de-Miremont, Dordogne)						
	K6	33 220	±	570	BP	GrN 5751
- ABRI PATAUD (Les Eyzies-de-Tayac, Dordogne)						
	14	34 250	±	675	BP	GrN 4507
	11	32 600	±	550	BP	GrN 4309
- ABRI DU FLAGEOLET I (Bezenac, Dordogne)						
	11	33 800	±	1 800	BP	OxA 598
- ABRI DE LA QUINA (Gardes, Charente)						
		32 650	±	850	BP	OxA 6147
- ABRI DE ROC DE COMBE (Payrignac, Lot)						
	7c	34 800	±	1 200	BP	OxA 1263
AURIGNACIEN II ancien						
- ABRI PATAUD (Les Eyzies-de-Tayac, Dordogne)						
	8	31 800	±	280	BP	GrN 6163
- ABRI DE LA FERRASSIE (Savignac-de-Miremont, Dordogne)						
	K3b	31 300	±	300	BP	Gif 4277
- GROTTE DU RENNE (Arcy-sur-Cure, Yonne)						
	VII	30 800	±	250	BP	GrN 1717
- GROTTE DU PAPE ET GROTTE DES HYÈNES (Brassempouy, Landes)						
	2A	31 820	±	550	BP	Gif 8568
AURIGNACIEN II récent						
- ABRI PATAUD (Les Eyzies-de-Tayac, Dordogne)						
	7	31 800	±	310	BP	GrN 4531
AURIGNACIEN III						
- ABRI DE LA FERRASSIE (Savignac-de-Miremont, Dordogne)						
	I1	28 700	±	250	BP	GrN 4271
- ABRI PATAUD (Les Eyzies-de-Tayac, Dordogne)						
	6	28 510	±	280	BP	GrN 6273
AURIGNACIEN IV						
- ABRI DE ROC DE COMBE (Payrignac, Lot)						
	5	28 500	±	700	BP	OxA 1441
- ABRI DE LA FERRASSIE (Savignac-de-Miremont, Dordogne)						
	G1	29 000	±	850	BP	OxA 405
PÉNINSULE IBÉRIQUE						
Côte Cantabrique						
- CUEVA DEL CASTILLO (Santander, Cantabres)						
Au0 ?	18b2	38 500	±	1 300	BP	OxA 2474
Côte Méditerranéenne						
- ARBREDA (Gerona, Catalogne)						
Au0	E2BE111	37 700	±	1 000	BP	AA 3779
- BENEITO (Valence)						
Au1	C4	33 900	±	1 100	BP	AA 1388
CROATIE						
- VELIKA PECINA (Goranec, Croatie)						
Au2	h-j	33 850	±	520	BP	GrN 4979
ITALIE						
- ABRI MOCHI (Savona, Ligurie)						
Au0	59	35 700	±	850	BP	OxA 3591
- GROTTE CASTELCIVITA (Salerne, Campanie)						
Au2	6	32 390	±	490	BP	Beta 58184
- GROTTE DE FUMANE (Vérone, Vénétie)						
Au2	A1	31 900	±	500	BP	Utc 2049
Au0	A2 (S14)	36 800		+1200/-1400	BP	Utc 2688
- GROTTE AZZURA DI PAÏNA (Vérone, Vénétie)						
Au0	9	37 900	±	800	BP	Utc 2042
HONGRIE						
- ISTALLÖSKÖ (Svilvas Varad, Montagnes du Bukk)						
Au0	1	39 700	±	900	BP	GrN 4658
Au2	2	31 140	±	600	BP	GrN 1935

Fig. 4 : Une sélection de dates ^{14}C AMS pour l'Aurignacien.

POLOGNE						
- OBLAZOWA (Nowa Biala, Cracovie)						
Au2	VIII	32 400	±	650	BP	OxA 4584
AUTRICHE						
- WILLENDORF II (Niederoesterreich)						
Au0	3-C8	37 930	±	750	BP	GrA 896
Au2	4-C4	31 210	±	260	BP	GrA 501
- SENFTENBERG (Niederoesterreich)						
Au0		36 350	±	600	BP	GrN 16887
- GALGENBERG (Stratzing-Krems)						
Au2	cs	31 790	±	280	BP	GrN 16135
ALLEMAGNE DU SUD						
- HÖHLENSTEIN-STADEL						
Au2	IV	31 750	±	850	BP	H3800
- GEISSENKLOSTERLE						
Au 2	IIb	31 070	±	750	BP	Pta 2361
Au 0	IIIA	37 800	±	1050	BP	ETH 8267
GRANDE-BRETAGNE						
- KENT'S CAVERN (Angleterre)						
Au2		30 900	±	900	BP	OxA 1621-
(Mandibule humaine)						
BELGIQUE						
- GROTTE WALOU (Trooz, Liège, Belgique)						
Au2	7A	33 830	±	1 790	BP	LV 1641
RHÉNANIE						
- LOMMERSUM (Euskirchen, Nord-Westphalie, Allemagne)						
Au2	IIc-?	31 950	±	320	BP	GrN 6699
BULGARIE						
- BACHO-KIRO						
Au0	11	37 650	±	1 450	BP	OxA 3183
Au1	6b	33 300	±	820	BP	OxA 3182
ROUMANIE						
- MITOC-MALUL GALBEN (Botosani, Moldavie roumaine)						
Au2	12b	32 730	±	220	BP	GrA 1357
RUSSIE						
- KOSTIENKI I (Voronej, Russie)						
Au2	3	32 600	±	400	BP	GrN 17117
CRIMÉE						
- SIUREN I (Crimée)						
Au2	F	29 550	±	700	BP	OxA 5155

Fig. 4 (suite).

entraînant l'émergence d'autres hypothèses, soit de modèles régionaux différentiés, soit même de la mise en cause du modèle typologique classique basé sur la stratigraphie de Laugerie-haute (Djindjian, 1996 ; Bosselin et Djindjian, 1997).

Il n'est donc pas possible de valider les dates actuellement à notre disposition. Si l'on appliquait cependant au Solutréen, les mêmes règles qui ont été appliquées au Gravettien, la chronologie du Solutréen pourrait être considérablement raccourcie et s'établirait ainsi :

Protosolutréen	22 000 à 21 000 B.P.
Solutréen ancien	21 000 à 20 000 B.P.
Solutréen récent	20 000 à 19 000 B.P.
lacune ou Episolutréen	19 000 à 18 500 B.P.

Dans ce cas, près de 80 % des datations publiées seraient à rejeter. De nouvelles campagnes de datations sont donc nécessaires pour vérifier la validité d'une chronologie longue basée sur les dates actuelles, ou d'une chronologie courte suggérée par une synthèse critique de toutes les informations disponibles (fig. 7).

FRANCE
Gravettien ancien
À Fléchettes (Bayacien)(«Périgordien IV»)
- ABRI PATAUD (LES EYZIES-DE-TAYAC, DORDOGNE)
5 28 400 ± 1 100 BP OxA 169
À pointes de la Font-Robert («Périgordien Va»)
- ABRI DE LA FERRASSIE (SAVIGNAC-DE-MIREMONT, DORDOGNE)
D2X 27 900 ± 770 BP OxA 402
À pointes de la Gravette seules («Périgordien IV», «Périgordien Vb»)
- ABRI PATAUD (LES EYZIES-DE-TAYAC, DORDOGNE)
5 26 600 ± 200 BP GrN 4477
Gravettien Moyen
À burins de Noailles(«Périgordien Vc»)
- ABRI DU FACTEUR (TURSAC, DORDOGNE)
10/11 25 450 ± 650 BP OxA 594
- GROTTE D'ENLENE (MONTESQUIEU-AVANTÈS, ARIÈGE)
5 24 600 ± 350 BP Gif 6656
À burins du Raysse(«Périgordien Vc»)
- ABRI PATAUD (LES EYZIES-DE-TAYAC, DORDOGNE)
3-4 25 500 ± 700 BP OxA 687
Gravettien Récent (Périgordien VI»)
- ABRI PATAUD (LES EYZIES-DE-TAYAC, DORDOGNE)
3 23 180 ± 670 BP OxA 163
Gravettien Final (Protomagdalénien)
- ABRI PATAUD (LES EYZIES-DE-TAYAC, DORDOGNE)
2 22 000 ± 600 BP OxA 162
PENINSULE IBÉRIQUE
Gravettien Moyen à Burins de Noailles
Côte Cantabrique
- AITZBITARTE III (Landarbaso-Renteria, Guipuzcoa)
VI 24 545 ± 415 BP réf?
Gravettien Récent
Côte Cantabrique
FUENTE DEL SALIN (Cantabres)
1 22 340 ± 510 BP GrN 18574
GRÈCE
Gravettien ancien
- ASPROCHALIKO (Épire)
10 25 100 ± 700 BP OxA 777
Gravettien récent
- FRANCHTI (Argolide)
II 21 480 ± 350 BP P 2233
- KASTRITSA (Épire)
21 21 800 ± 470 BP I 2467
ITALIE
Gravettien ancien
- GROTTE PAGLICI (Foggia, Pouilles)
22 28 300 ± 400 BP réf?
- GROTTE DE LA CALA (Salerne, Campanie)
26 880 ± 320 BP OxA 5869
Gravettien moyen à burins de Noailles
- GROTTE DE LA CALA (Salerne, Campanie)
24 620 ± 220 BP OxA 6263
Gravettien récent
- GROTTE PAGLICI (Foggia, Pouilles)
21c 24 210 ± 410 BP F 54
20c 22 110 ± 330 BP F 49
19a 20 730 ± 290 BP F 46
18b2 20 200 ± 305 BP F 44
GROTTA DE S. MARIA DI AGNANO (Brindisi, Pouilles)
Squelette
1 24 410 ± 410 BP Gif 9247
- ARENE CANDIDE (Finale Ligurie, Ligurie)
P12 23 450 ± 220 BP Beta53983
P13b 25 620 ± 200 BP Beta53982
SLOVAQUIE
Gravettien ancien
- GROTTE SLANINOVA (Turnianske Podhradie-haj, Slovaquie Orientale)
27 950 ± 270 BP GrN 14832
Gravettien récent à pointes à cran
- NITRA I CERMAN (Nitra)
24 020 ± 400 BP GrN 2456
HONGRIE
Gravettien ancien
- PÜSPÖKHATVAN (Montagne Cserhat)
27 700 ± 300 BP Deb 1901
MORAVIE
Gravettien ancien
- PAVLOV I (Pavlov, Moravie)
26 650 ± 230 BP GrA 19539
- DOLNI VESTONICE II (Dolni Vestonice, Moravie)
- Etage inférieur de la nouvelle briquetterie
foyer (A-B-C) 27 660 ± 80 BP GrN 13962
- Etage supérieur de la nouvelle briquetterie
triple Sépult 26 640 ± 110 BP GrN 14831
foyer nord 26 550 ± 160 BP GrN 15325
Amas d'os de mammouth 26 100 ± 200 BP GrN 14830
- PREDMOSTI (Prerov, Moravie)
26 320 ± 240 BP GrN 6852
Gravettien récent
- DOLNI VESTONICE III (Dolni Vestonice, Moravie)
foyer 93 24 560 ± 660 BP GrN 20392
- PETRKOVICE
23 370 ± 160 BP GrA891
POLOGNE
Gravettien récent à pointes à cran
- KRAKOW-SPADZISTA C2
III 24 380 ± 180 BP GrN 11006
AUTRICHE
Gravettien ancien à fléchettes
- WILLENDORF II (Basse-Autriche)
??? 5-C2 30 500 ± 900 BP GrN 11193
6-C1 28 560 ± 520 BP GrN 17804
6-B4 27 620 ± 230 BP GrA 895
- KREMS-WATCHBERG (BASSE-AUTRICHE)
Gr 27 400 ± 300 BP GrN 3011
Gravettien récent à pointes à cran
- WILLENDORF II (Basse-Autriche)
8-B2 25 400 ± 170 BP GrN 21690
9-B1 24 910 ± 150 BP GrA 5006
ALLEMAGNE
Gravettien ancien
- GEISSENKLOSTERLE (Jura souabe)
Ia 29 200 ± 460 BP OxA 4592
GRANDE-BRETAGNE
- PAVILAND CAVE (Glamorganshire, Pays de Galles)
(sépulture de la dame rouge)
26350 ± 550 BP OxA 1815
BELGIQUE
Gravettien ancien à Font-Robert
- MAISIÈRES (Belgique)
Sol Maisières & Gr
27 965 ± 260 BP GrN 5523
Gravettien moyen/récent
- GOYET (Namur, Belgique)
24 440 ± 280 BP OxA 4926
ROUMANIE
- MITOC-MALUL GALBEN (Botosani, Moldavie roumaine)
7b 27 500 ± 600 BP OxA 1778
6b 26 450 ± 130 BP GrA 1354
5a 24 650 ± 450 BP OxA 1780
4b 23 650 ± 400 BP OxA 1779
UKRAINE
Gravettien ancien du Dniestr
- MOLODOVA V
9 28 100 ± 1 000 BP LG 15
Gravettien récent du Dniestr
- MOLODOVA V
7 23 700 ± 320 BP GIN 10
RUSSIE
Gravettien ancien du Don (Thalmanien)
- KOSTIENKI 8
2 27 700 ± 750 BP GrN 10509
Gravettien récent du Don à pointes à cran (Kostienkien)
- KOSTIENKI 1
1 23 500 ± 200 BP GIN 2527

Fig. 5 : Une sélection de dates ^{14}C AMS pour le Gravettien.

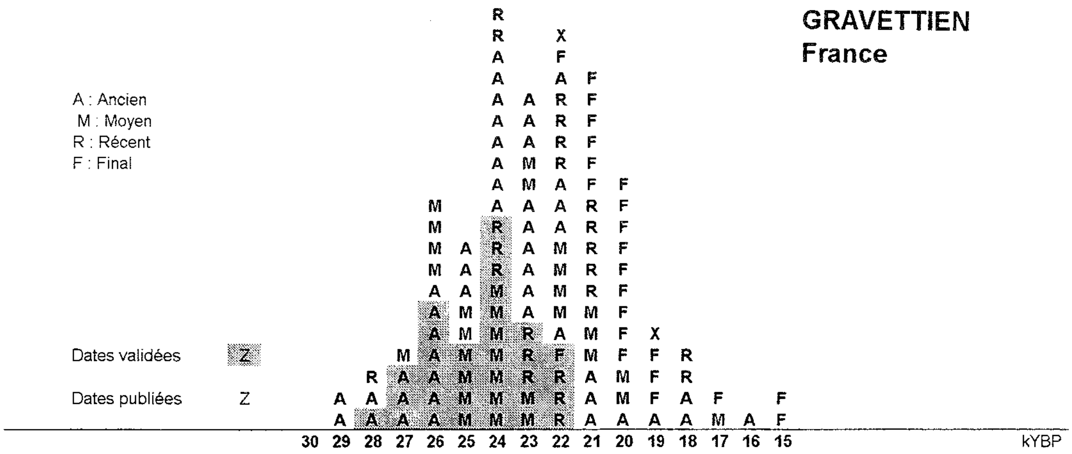

Fig. 6 : Histogramme des datations du Gravettien français : dates publiées et dates validées.

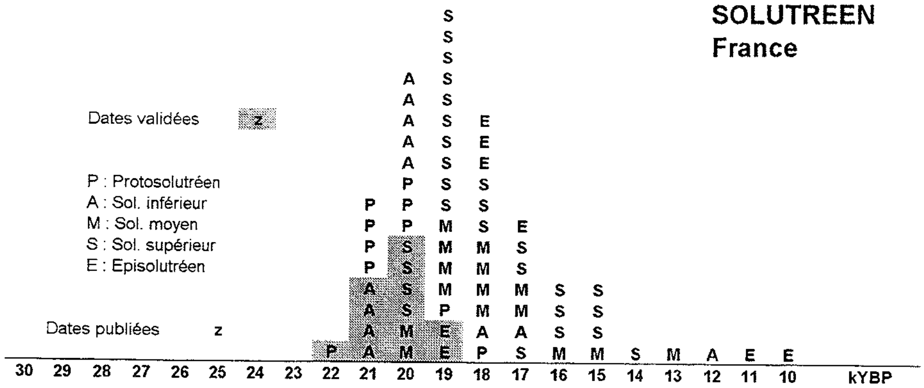

Fig. 7 : Histogramme des datations du Solutréen français : dates publiées et hypothèse de validation des dates.

9 - CONCLUSIONS

Les datations ^{14}C actuellement connues donnent une vision erronée de la chronologie du Paléolithique supérieur dans une proportion variable de 6 000 ans pour le Paléolithique supérieur ancien, jusqu'à 1000 ans pour le Paléolithique supérieur récent, due à des erreurs additionnelles non estimables qui rajeunissent systématiquement les datations classiques. Le pourcentage de dates à rejeter varie de 70 % à 80 % des dates actuellement recensées dans les banques de données.

Les datations effectuées avec la méthode de comptage AMS et des traitements de préparation chimique appropriés permettent d'obtenir des datations absolues qui corrélées avec la typologie, la paléoclimatologie, la stratigraphie et les dates ^{14}C fournissent des ordres de grandeur avec une marge d'incertitude de moins de 1000 ans.

Les matériaux archivés permettraient de redater un certain nombre de sites de référence et de reconstituer avec un pas de 1000 ans la cartographie et la chronologie des peuplements au Paléolithique supérieur en Europe, en utilisant des procédures formalisées de datations de séries stratigraphiques ou spatiales plutôt que par la datation de quelques échantillons isolés. De nouvelles campagnes de datations ^{14}C AMS dans le cadre d'un grand programme systématique de redatation du Paléolithique supérieur européen, sont indispensables pour atteindre ce but.

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PROTOSOLUTRÉEN
Région Languedoc
- GROTTE DE LA SALPÉTRIÈRE (RÉMOULINS, GARD)
30A 22 750 ± 410 BP Mc 2389
Côte cantabrique
- RIERA (Asturies)
1 20 860 ± 410 BP BM1739
Portugal
- LAPO DE ANECRIAL (Portugal)
21 560 ± 220 BP OxA
5526
SOLUTRÉEN ANCIEN
Région Languedoc
- GROTTE DE LA TÊTE DU LION (BIDON, GARD)
E/F 21 650 ± 800 BP Ly 847
- GROTTE DE LA SALPÉTRIÈRE (RÉMOULINS, GARD)
8 21 600 ± 700 BP Ly 2049
Région Aquitaine
- ABRI DE LAUGERIE-HAUTE EST (LES EYZIES-DE-TAYAC, DORDOGNE)
31h 20 890 ± 300 BP GrN
1888
Côte Méditerranéenne
- PARPALLO (Valence)
20 490 ± 900 BP BM859
SOLUTRÉEN RÉCENT
Région Languedoc
- GROTTE DE LA SALPÉTRIÈRE (RÉMOULINS, GARD)
Sol moy B 20 500 ± 300 BP MC 2085
Région Centre-Ouest
- ABRI FRITSCH (POULIGNY-SAINT-PIERRE, VIENNE)
Sol sup 8d 19 280 ± 230 BP GrN
5499
Région Centre-Est
- STATION DU CRÔT DU CHARNIER (SOLUTRÉ, SAÔNE-ET-LOIRE)
Sol moy -2,4m 19 590 ± 280 BP Ly 1533
Région Aquitaine
- ABRI DE LAUGERIE-HAUTE OUEST (LES EYZIES, DORDOGNE)
Sol sup 2 20 000 ± 240 BP GrN
4441
Région Pyrénées
- GROTTE DU PHARE (BIARRITZ, PYRÉNÉES-ATLANTIQUES)
Sol sup L 19 900 ± 350 BP Gif6777
Bassin de l'Ebre
- CHAVES (Bastaras, Huesca)
Sol sup 1 19 700 ± 310 BP GrN
12681
Côte Cantabrique
- CALDAS (Asturies)
Sol sup 16 19 510 ± 330 BP Ly 2428
Côte du Portugal
- GRUTA DO CALDEIRAO (Tomar, Portugal)
Sol sup H 20 530 ± 270 BP OxA
2511
ÉPISOLUTRÉEN
Région Languedoc
- GROTTE DE LA SALPÉTRIÈRE (RÉMOULINS, GARD)
Salp ancien 6b 18 800 ± 300 BP
MC 2083
Côte méditerranéenne
- PARPALLO (Valence)
Epi Sol s 17 900 ± 340 BP Birm 521

Fig. 8 : Une sélection de dates ^{14}C AMS pour le Solutréen.

Actes du colloque «C14 Archéologie», 1998, p. 181-182.

QUELQUES REMARQUES SUR L'ORIGINE DU PALÉOLITHIQUE SUPÉRIEUR ORIENTAL

Marcel OTTE et Karl ENGESSER**

Résumé : Les phénomènes de transition se manifestent sous une forme hétérogène et irrégulière, vers les aires orientales du continent. La superposition des datations, échelonnées dans le temps et dans l'espace, empêche une explication simple de tels phénomènes. Au contraire, les aspects abrupts de cette transition se retrouvent dans les extrémités territoriales, tel que l'ouest européen. Autant sur le plan chronologique, la diversité régionale des faciès représentés à l'est témoigne de différents mouvements, tendant vers l'ère nouvelle, mais ici de traditions régionales distinctes.

Abstract : The phenomena of transition appear under an heterogeneous and irregular pattern, in the direction of the Eastern areas of the continent. The superpositon of the datings, spread in time and in space, doesn't allow a simple explanation for such phenomena. On the contrary, «steep» aspects of this transition can be found in the territorial extremities, such as Western Europe. From a chronological point of view, the regional diversity of the «facies» present in the East testifies of different movements, in the direction of the new era, but - here - of distinct regional traditions.

Mots-clés : Datation radiocarbone, Paléolithique supérieur, région de l'Est.

Key-words : Radiocarbon dating, Late Paleolithic, Eastern areas.

Sur la base des datations ^{14}C récentes, combinées aux séquences stratigraphiques classiques, il est possible aujourd'hui de saisir le phénomène d'apparition du Paléolithique supérieur. Il s'y trouve en effet combiné à diverses tendances culturelles régionales distinctes, connaissant chacune une évolution propre.

La base de la séquence est formée d'une évolution des faciès moustériens, spécialement ceux aux pointes foliacées, de type Ak Kaya en Crimée.

Récemment fouillé, le site de Berioucha Balka en Russie méridionale a fourni la clef évolutive d'une forme archaïque de Paléolithique supérieur local, le Sungirien. Retrouvée à travers toute la plaine russe jusqu'au milieu de la période, cette industrie est inter-digitée avec l'Aurignacien, puis le Gravettien ancien.

Le Paléolithique moyen a donc livré un ensemble technique autonome, basé sur le façonnement bifacial, progressivement étendu aux supports laminaires. Les pointes triangulaires à base concave en sont l'élément le plus caractéristique qui, régulièrement, s'allègent à mesure de l'évolution technique (Matioukine, 1990).

D'autres faciès moustériens semblent subir la même transformation vers les supports laminaires et l'allégement de l'outillage, menant à Gorodtroskaia (Vadim Cohen, communication personnelle).

La base du Paléolithique supérieur paraît donc bien être d'origine locale, mais l'élément d'origine extérieure apparaît néanmoins sous la forme classique de l'Aurignacien traversant la séquence locale au tout début de la période. Par conséquent, il n'est pas possible, ici comme ailleurs, de faire la part des causes externes ou internes à ce mouvement, car elles coïncident dans une large mesure.

Quoiqu'il en soit, l'Aurignacien apparaît bien comme intrusif en de nombreux points d'Europe orientale (Russie, Moldavie, Crimée, Roumanie), mais spécialement à une phase ancienne en Bulgarie, vers 40.000 ans (Kozlowski, 1982).

Par contre, relativement récent, le Gravettien semble originaire de l'Europe centrale où il se trouve lié aux phases les plus récentes des «pointes foliacées». Les mouvements s'inversent donc à ce stade où le «Gravettien oriental» vient se superposer à l'Aurignacien et au Sungirien, interstratifiés à Kostenki 1 (Praslov et Rogachev, 1982).

Enfin, la base de Kostenki 17 contient une industrie d'aspect très évolué, déjà laminaire et avec pendeloques,

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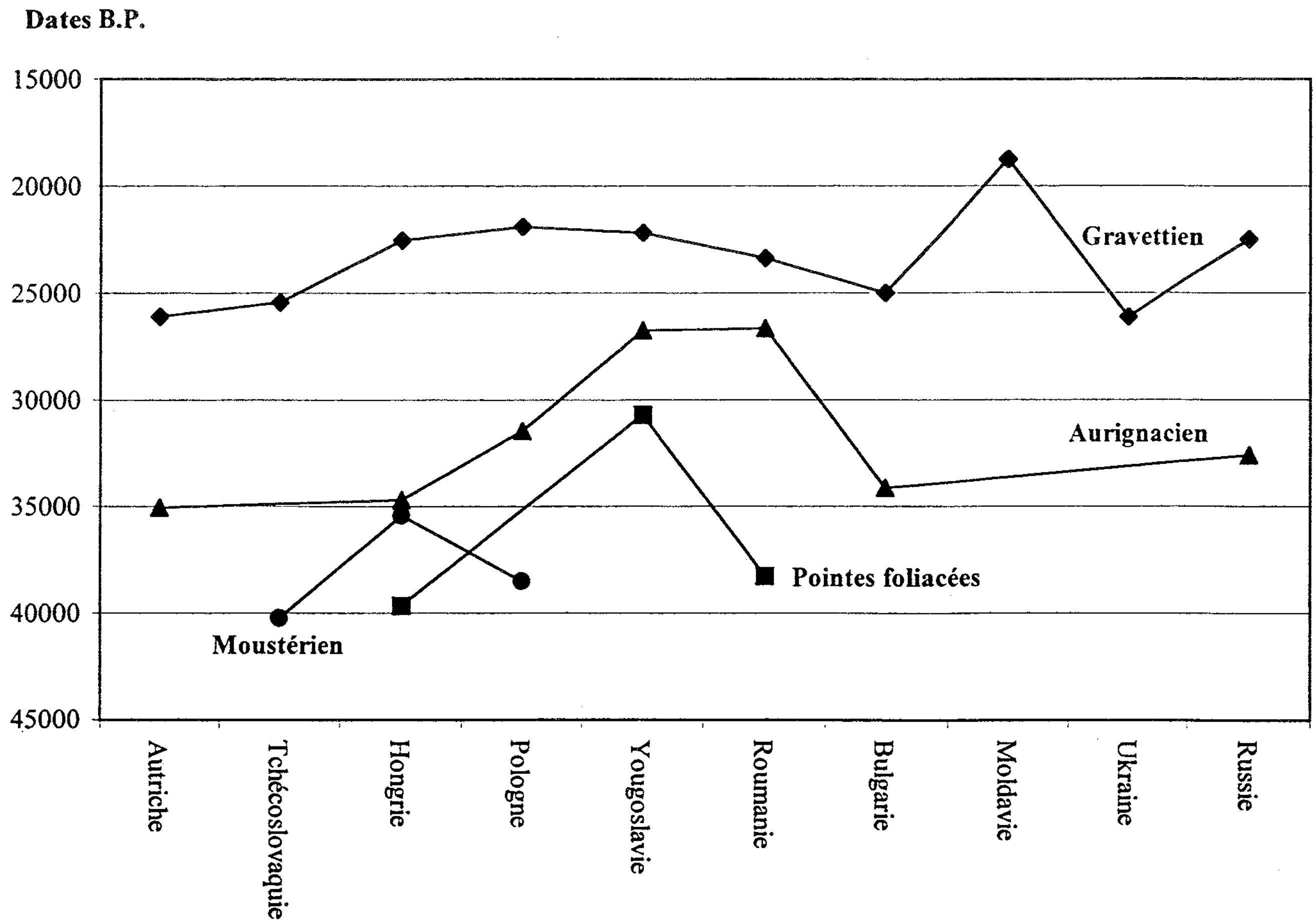

apparemment antérieure au Sungirien classique. De telle sorte qu'une composante locale, encore mal comprise, a pu en outre participer à cette formation déjà si complexe (Praslov et Rogachev, 1982). C'est sous ces différents aspects qu'il faut envisager à la fois la genèse du Paléolithique supérieur oriental et les influences qui se sont ensuite faites sentir sur le reste du continent. A nouveau, les «tendances évolutives» étaient présentes dans les ensembles précédents, mais on ne peut exclure l'effet d'un stimulus extérieur, portant sur les conceptions globales (technologie, art, pendeloques), apparemment apporté par l'Aurignacien.

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Actes du colloque «C14 Archéologie», 1998, p. 183-188.

EARLY BRONZE AGE METALLURGY IN THE NORTH ALPINE REGION AND ^{14}C-DATING (2300 - 1600 BC)

*Rüdiger KRAUSE**

Abstract : The main results of this study show that with the use of radiocarbon dates, we can demonstrate that the highly developed copper and tin metallurgy of the Únetice culture had already started in eastern Germany before 2000 BC. Further, we have convincing evidence, that the metallurgy of the Únetice culture began to influence local metal-working in the foothills of the Alps in southern Germany and in Switzerland shortly after 2000 BC. What could be termed the 'industrial phase' of metal-working in the Únetice culture already existed in the centuries around 2000 BC. In southern Germany and in Switzerland it is represented as the third step in the development of metallurgy during the advanced EBA, between c. 1700 and 1500 BC.

Résumé : Les principaux résultats de cette étude montre que l'utilisation de dates radiocarbone permet d'affirmer que la métallurgie du cuivre et du fer dans la culture Unetice existait déjà en Allemagne de l'est avant 2000 av. J.-C. D'autre part, nous avons des preuves convaincantes qui démontrent que la métallurgie de la culture Unetice a influencé la métallurgie locale dans les Alpes, en Allemagne du sud et en Suisse, peu après 2000 av. J.-C. Ce que l'on pourrait appeler la « phase industrielle » de la métallurgie dans la culture Unetice existait déjà vers 2000 av. J.-C. En Allemagne du sud et en Suisse, cette phase est représentée comme étant la troisième étape dans le développement de la métallurgie entre 1700 et 1500 av. J.-C.

Key-words : Early bronze age metallurgy, sheet-metal-work, casting, tin, Únetice culture, radicarbon dating.

Mots-clés : Métallurgie du Bronze ancien, tôlerie, fonderie, étain, culture de Unetice, datation radiocarbone.

Varied scientific investigations on culture groups of the Early Bronze Age in areas north of the Alps as well as the Únetice culture in eastern Germany have led to a better knowledge of the development of Early Bronze Age (EBA) metallurgy. Several new radiocarbon dates were made mainly by Bernd Kromer (Heidelberg) and Jochen Görsdorf (Berlin) on human bone material from major sites of that period in these areas (fig. 1, see also Rassmann, 1997, 201, map 1) : in Baden-Württemberg at Singen and in the Neckarland around Stuttgart (Krause, 1988a ; Becker *et al.*, 1989 ; Krause, 1997), in Sachen-Anhalt and Thüringen eastern Germany – the area of the northern Únetice culture – (Rassmann, 1997) and in Switzerland (Hafner and Suter, 1998). In addition important new data has been gained from the EBA cemetery of Jelšovce in western Slovakia (Görsdorf, in print). However, the statistical basis of radiocarbon dates for the EBA is still insufficient and there are many places from which only one or two dates are at our disposal (fig. 1). Nevertheless, the dates which are known now enable an initial reconstruction of the main steps in the formation of EBA metallurgy in Central Europe.

These important investigations on the chronological framework has been supplemented by c. 3000 new metal analyses made by Ernst Pernicka (formerly in Heidelberg, now in Freiberg/Sachsen) of metal objects from the eastern German Únetice culture within a project funded by the Volkswagen foundation in Germany (Krause, 1998, 174f.). Together with the large database of the 'Stuttgart Metall Analysis Project' (called SMAP, see Krause and Pernicka, 1996), we now are able to reconstruct the development of metallurgy from the Neolithic period to the Early Bronze Age, the use of tin, and the distribution of different copper-types in major EBA areas in Central Europe. Through metal analysis of copper artefacts and by radiocarbon dating of their find contexts (mainly

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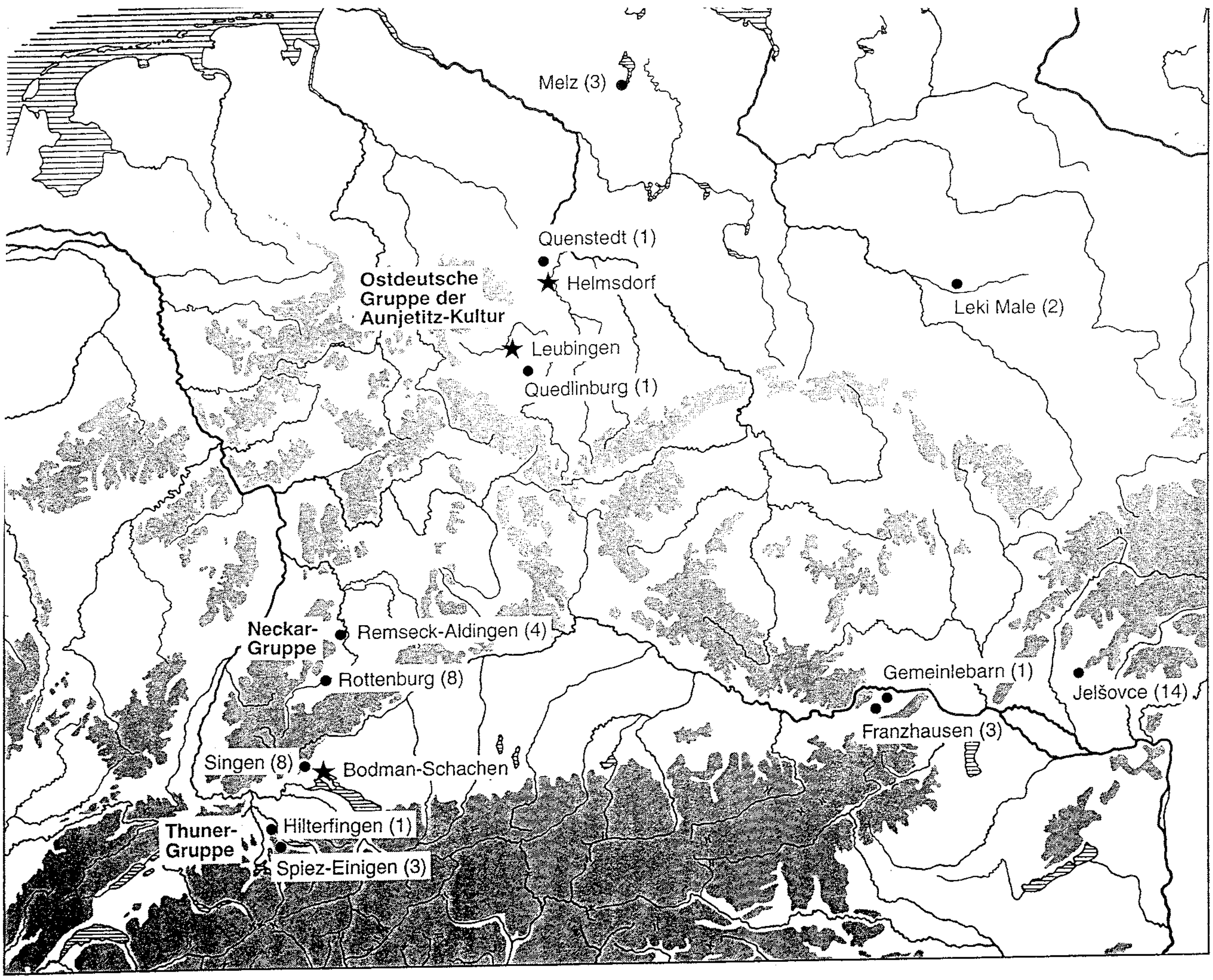

Fig. 1 : Major areas and important sites of Early Bronze Age cultures in Germany and Poland.

human bone material from graves) at least three major steps in the development of Early Bronze Age metallurgy north of the Alps can be discerned. They are closely related with the introduction and use of tin. In the following the main important sites with radiocarbon datings related to the development of EBA metallurgy will be characterised briefly.

SOUTH-WESTERN GERMANY (fig. 1)

Figure 2 shows the most important sites in south-western Germany along the Neckar River and at Lake Constance. The older phase of the EBA (beginning around 2200 BC) is represented in the cemeteries of Singen, Remseck-Aldingen and Rottenburg (fig. 2). Within the so-called sheet-metal-work (Blechkreis) of Danubian tradition, we find imported Armorico-British daggers at Singen cemetery and a cast 'three-armed pin' (Dreiarmnadel) at Rottenburg cemetery (Krause, 1997, 78, fig. 4), indicating the beginnings of Únetice influence in cast- and tin metallurgy (fig. 2). According to radiocarbon dates the pin was imported from the east or north-east between 2000 and 1800 BC. In these cemeteries artefacts are characteristically made of fahlerz copper with little or no tin content. At Bodmann-Schachen, a lakeside settlement in the west of Lake Constance (fig. 1), a pin with spherical, obliquely perforated head (Kugelkopfnadel), which had been hollow-cast with a clay core, and a flanged axe (Randleistenbeil) (Köninger, 1993, chap. 4.3, plate 11) were found within a settlement layer which can be dated by dendrochronology between 1630 and c. 1500 BC. Thus, the first results show that fahlerz metallurgy of the EBA in southern Germany (Krause and Pernicka, in print) started around 2200 BC. Tin was initially imported from the Atlantic facade, as is indicated by the Armorico-British daggers found in Singen (Krause, 1988a, 56ff.). Influence from the Únetice sphere on metallurgy in the North Alpine region commenced soon after 2000 BC.

WESTERN SWITZERLAND (fig. 1)

Recently new data was published from the area of Lake Thun in western Switzerland (Hafner and Suter, 1998). It indicates that the loop-headed pin (or 'Bohemian eyelet pin', Ösenkopfnadel), typical of Únetice cast-metallurgy, was present in the western Alpine area between c.1900 and 1700 BC (fig. 3). One date from a grave in Hilterfingen, which contained a metal-hilted dagger (Vollgriffdolch) of the Rhône type and a pin of local shape, leads us to presume, that highly developed metallurgy with complicated casting techniques was already present at that time : based on the calibrated range of the date either already around 2000 BC or shortly after. On the other hand, closely related daggers of the so-called Alpine type appear as imported objects in northern Únetice areas (Krause, 1988c, fig. 4). This is evidenced by their characteristic metal composition of West Alpine copper. Thus it seems that intensive contact between the northern Únetice areas and the West Alpine region was already in existence around or shortly after 2000 BC.

EASTERN GERMANY AND POLAND (fig. 1)

Figure 4 presents important radiocarbon and dendrochronological dates from northern Únetice areas in eastern Germany and in Poland with Leki Male (Becker *et al.*, 1989 ; Rassmann, 1997). Unfortunately the C14 dates from Leki Male and Melz are rather old with a wide range of possible calibrated, calender dates. Most important are the dates of the graves from Quedlinburg and Quenstedt, which are connected with cast 'Ösenkopfnadeln'. Calibrated dates range between 2300 and 2000 BC. Together with the dates from Melz and Leki Male they illustrate that casting and rather complicated casting-techniques as well as tin alloying might already been employed in northern Únetice areas during the last or even final two centuries of the 3rd millennium (Rassmann, 1997, 205).

Two dendrochronological dates from timbers of the principle graves chambers at Leubingen and Helmsdorf (Becker *et al.*, 1989), of the late 20th and 19th century, underline the fact that highly developed Únetice

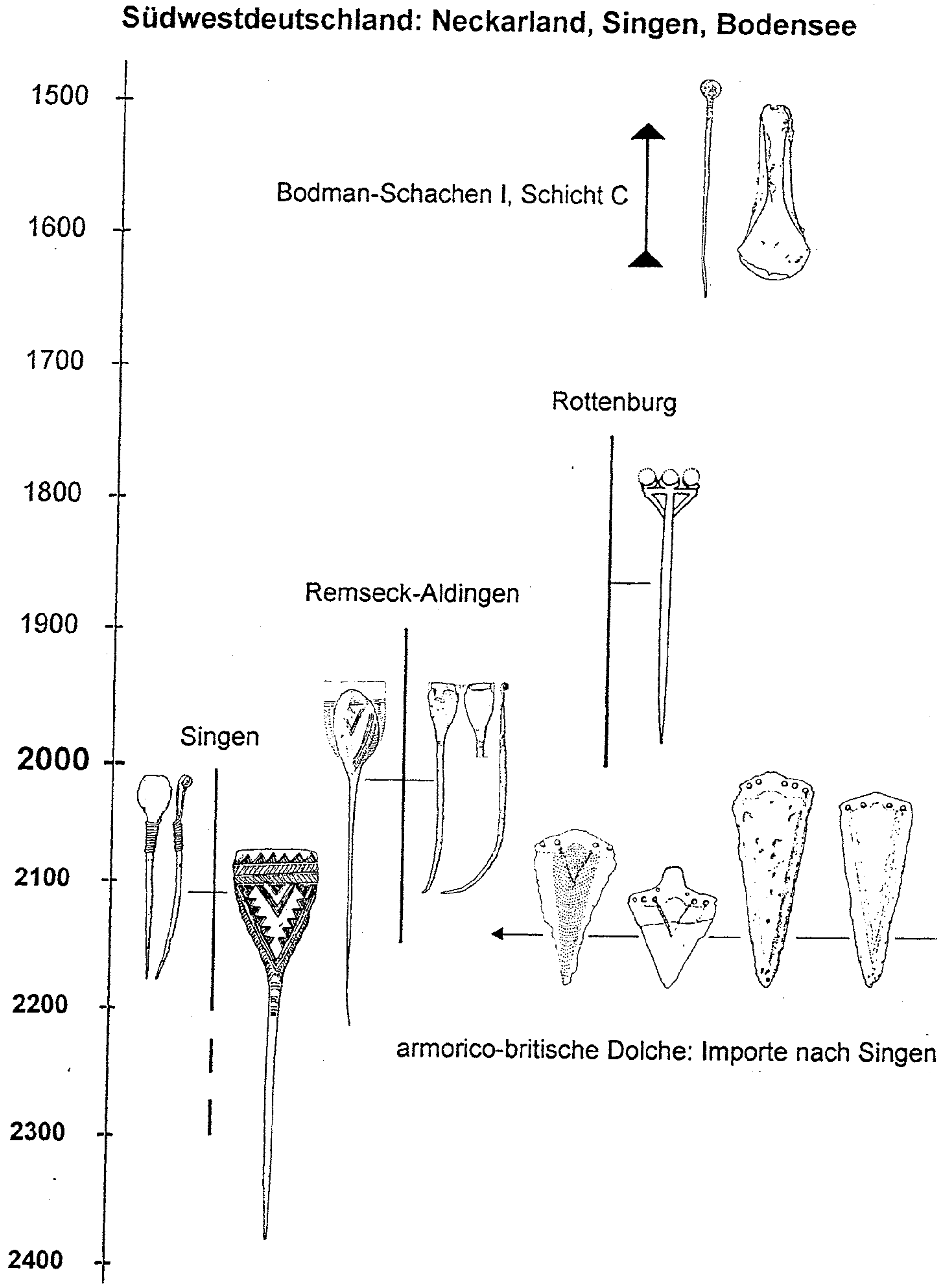

Fig. 2 : Examples of metalworking in south-west Germany : the Neckarland, Singen and Lake Contance.

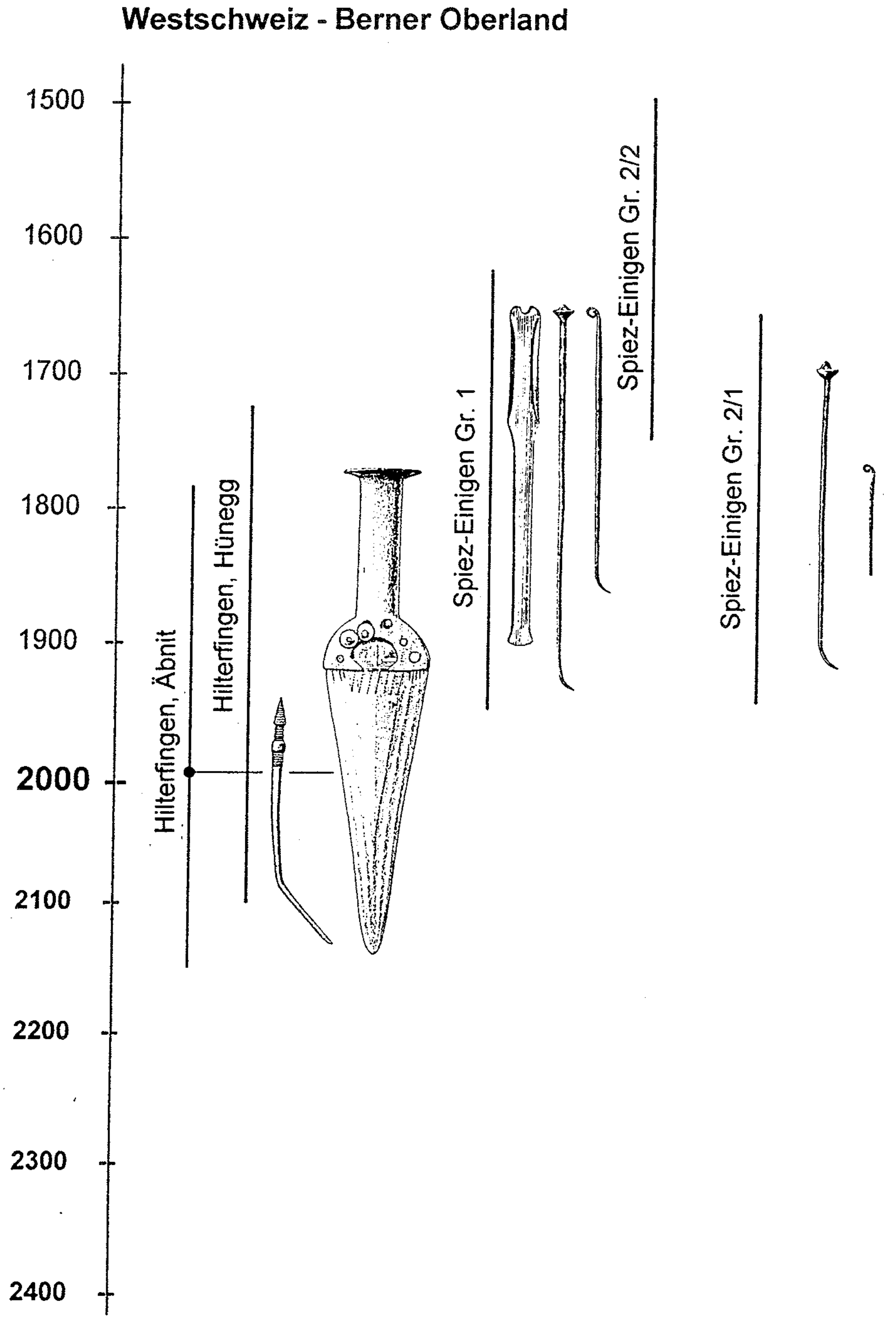

Fig. 3 : Examples of metalworking in western Switzerland.

metallurgy was quite early. In both cases, the bracelets and the 'Ösenkopfnadeln' were made of gold and emphasize that these were extraordinary burials.

AUSTRIA AND WESTERN SLOVAKIA (fig. 1)

Here one single data from the large cemetery of Gemeinlebarn in lower Austria can be contributed, while from the other even larger cemetery of Franzhausen no more than three C14 dates are at our disposal and these without a favourable archaeological context (Neugebauer, 1991, 59). Hopefully a large series of radiocarbon dates will be produced in the near future. The single date from grave 188 in Gemeinlebarn F is reliable and can be correlated with 'Kugelkopfnadeln' with twisted shaft and followingly with the developed EBA (see Neugebauer, 1991, plate 9). This type of pin is indicative of a younger phase within the EBA. The calibration of the single date from Gemeinlebarn lies between 1800 and 1600 and fits very well in the three major steps of EBA development north of the Alps.

A new series of 13 radiocarbon dates by Jochen Görsdorf (Görsdorf, in print) from the large cemetery in Jelšovce, western Slovakia (Batóra, 1986), show that the Nitra group of the early EBA as represented there can be placed roughly between 2150 and 1900/1800 BC. There is a wide overlap with the following Únetice culture, which after Görsdorf seems to be between 1930 and 1730 BC. Calibrated dates of the Únetice period cover the time-span between 1900 and 1730 BC. The final Mad'arovce period lasted from 1730 to the end of the 16th century. Characteristic of the Nitra group are, among others, rings of sheet copper with willow-leaf shaped end (Weidenblattringe), the Únetice period by cast 'Kugelkopfnadeln' with twisted shaft and the Mad'arovce period at the end of the EBA by short 'Kugelkopfnadeln' without shaft torsion.

CONCLUSIONS

We can conclude, that at the end of the 3rd millennium, the appearance of Armorico-British daggers within the context of the cemetery of Singen is of further significance due to their relatively high tin content of 5 - 9 %. Whereas tin as an alloying component is absent in artefacts from the oldest Singen graves, it is consistently present among those from younger graves. At other sites, such as the cemetery in Remseck-Aldingen (Krause, 1988b, analyses not published), only one or two low tin alloys were present. It seems that tin was used hesitantly at the beginning of the EBA and that the later and consistent presence of tin in Singen is directly related with the appearance of the Armorico-British daggers there. Therefore we propose that at the end of the 3rd millennium tin in southern Germany came from coastal areas of Brittany and/or Cornwall (see Krause, 1988a, fig. 21), where tin-ores were abundant.

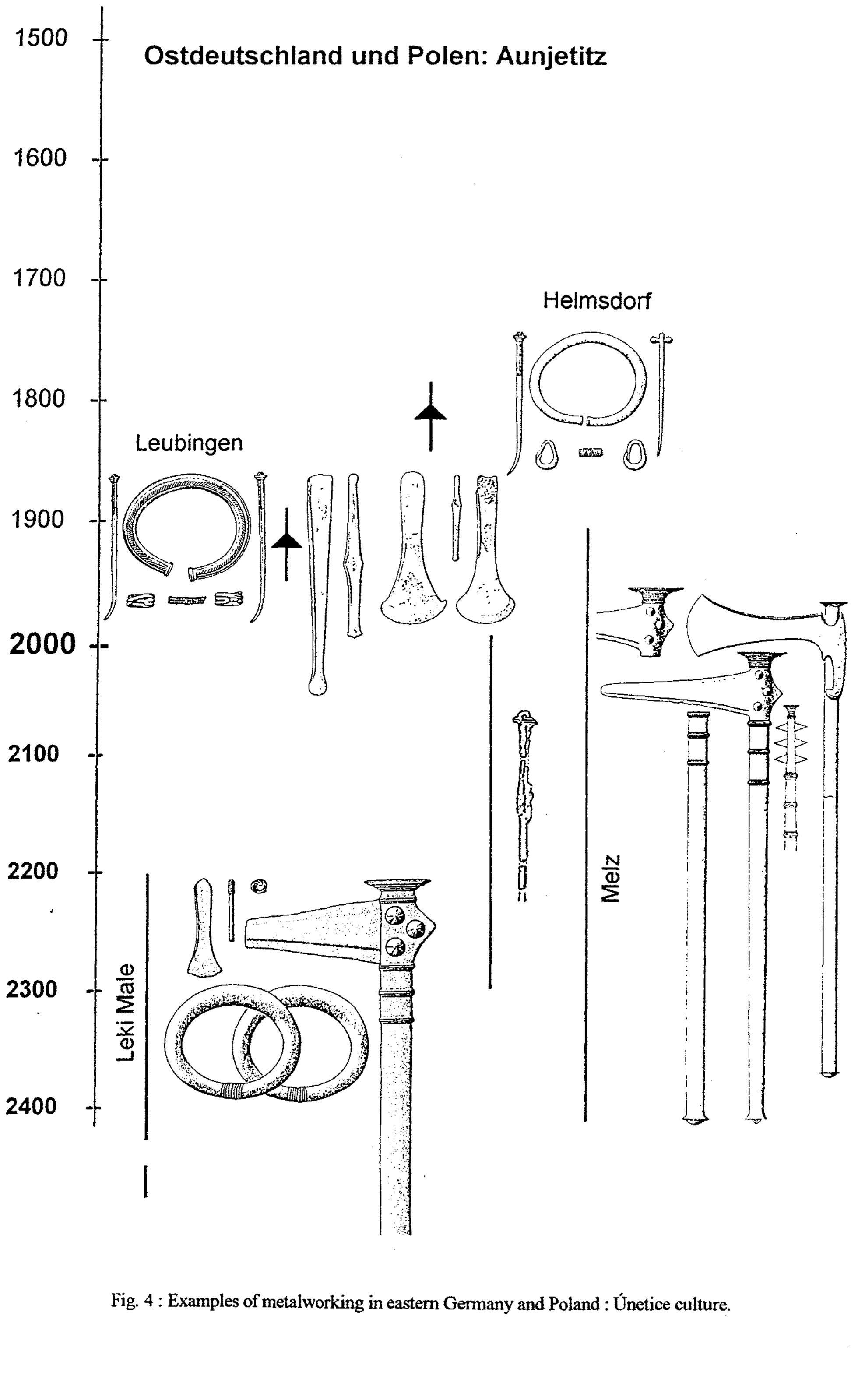

Fig. 4 : Examples of metalworking in eastern Germany and Poland : Únetice culture.

The sources of tin from the Atlantic facade seemed to have lost their importance for western central Europe quickly. I would designate the first step as the initial phase of tin metallurgy in southern Germany. At the same time (that is, at the end of the 3rd millennium) a developed form of metallurgy with complicated casting techniques as well as alloying with tin already existed in the Únetice areas of eastern Germany and Poland. In regard to the origin and development of the new techniques, it seems that they evolved within a rather short time without (?) any preceding steps or influences from outside areas.

The tradition of copper metallurgy in eastern Germany, as transmitted through the younger Neolithic periods (from Bernburg culture via the Corded Ware- and Bell-Beaker- groups) to the EBA may indicate, that the knowledge and tradition of copper working was already present in those areas (Strahm, 1994 ; Krause, 1998, 185ff.). In view of the proximity of rich copper and tin sources, above all in the Bohemian Ore Mountains and in the Harz, we can imagine that the EBA metallurgy of the Únetice culture grew very quickly. As yet we do not know the extent to which additional foreign influences coming from the eastern Mediterranean via the Carpathian Basin may have played a formative role. Indeed, there are a few objects from the Únetice area, which are imports or copies of foreign objects from the south-east (Krause, 1998, 180 p., fig. 18), evidence of foreign influence in the development of (tin)metallurgy in the northern Únetice area.

In eastern Germany as well as in the North Alpine region of southern Germany, tin and tin alloys seem to have appeared first during the Bell Beaker period. In my opinion, there is no satisfactory explanation yet, as to whether this was contemporary with the early EBA or whether tin metallurgy had already existed before the beginning of the EBA.

The main results of this study show that using radiocarbon dates we can prove that the highly developed copper and tin metallurgy of the Únetice culture had already started in eastern Germany before 2000 BC. Further, we have convincing evidence, that the metallurgy of the Únetice culture began to influence local metal-working in the foothills of the Alps in southern Germany and in Switzerland shortly after 2000 BC. What could be termed the 'industrial phase' of metal-working in the Únetice culture already existed in the centuries around 2000 BC. In southern Germany and in Switzerland it is represented as the third step in the development of metallurgy during the advanced EBA, between c. 1700 and 1500 BC.

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ON THE PROBLEM OF THE NEOLITHISATION OF EASTERN EUROPE AND THE POSITION OF THE SOUTH RUSSIAN AREA IN THIS PROCESS

V.I. TIMOFEEV and Ganna I. ZAITSEVA**

Abstract : The Radiocarbon datings of the sites from the Steppe and Forest Steppe zones of Southern Russia demonstrate a very early dating for the Neolithic in the area (the lower layers of Rakushechnyi Yar and the Elshan sites dated to about 8000 BP, uncal.). The numerous datings of Early Neolithic sites in the Eastern European Forest zone Early Neolithic sites are somewhat younger and represent different stages of the Neolithisation of the more Northern areas : in Central Russia pottery appears about 7100-7000 BP at the Early Neolithic sites of the Upper-Volga culture and in the north-western, Northern Russia as well as in the Eastern Baltic area the sites with the Early pottery are dated to about 6600-6500 BP. The ^{14}C chronology shows that the first pottery in Eastern Europe appeared independently from the influences of the more western centres of early agriculture and probably as the result of diffusion from the cultures of the Steppe and Forest/ Steppe zone.

Résumé : Les datations au ^{14}C des sites dans la zone steppique et steppique-forestique de la Russie du sud indiquent l'apparition précoce du Néolithique dans cette région : les couches inférieures du site du Rakushechny Yar sur le Don étant datées de 8000 ans BP non calibrées. Les dates des sites du Néolithique ancien dans les régions plus au nord sont plus récentes et correspondent aux étapes consécutives de la néolithisation de la zone forestière de l'Europe de l'Est : la culture de la Haute Volga dans la Russie du centre est datée de 7100-7000 BP et celles de la région Baltique de l'est de 6600-6500 BP. La chronologie au ^{14}C indique que la fabrication de la poterie de l'Europe de l'Est est survenue d'une façon indépendante des centres agricoles de l'Ouest, résultant vraisemblablement de la diffusion à partir des cultures dans la zone steppique et steppique-forestique.

Key-words : Radiocarbon chronology, Early Neolithic, pottery production, Steppe- and Forest-Steppe zones, Volga basin, Don basin, dispersion of Neolithic, diffusion.

Mots-clés : Datation radiocarbone, Néolithique ancien, poterie, zone steppique et steppique-forestique, la Haute Volga, le Don, néolithisation, diffusion.

The introduction of the Neolithic in Eastern Europe is in Russian archaeology traditionally connected with the appearance of the first pottery. Food-production appeared in the main part of the area much later than the ceramics. In many territories of the Forest zone this happened in the Bronze Age or even in the Iron Age.

The Radiocarbon chronology of the Eastern European Neolithic improved during last two decades. We have now more than 400 datings for the sites of European Russia (Timofeev, Zaitseva, 1996). The main part of them are from the Neolithic cultures of the Forest zone and the work for constructing the chronology of the more southern regions is very urgent.

The Neolithic assemblages in the Steppe and Forest/ Steppe zones of Russia were discovered through the field research of T.D. Belanovskaya, L.Ya. Krizhevskaya, V.Ya. Kiyashko and others close to the Azov sea and in the lower Don basin, by A.T. Sinyuk in the Middle river Don basin and by I.B. Vasilyev, A.A. Vybornov and others in Lower Volga basin. An important review of these materials was done by D.Ya. Telegin in the chapters of the newly published volume «The Neolithic of Northern Eurasia» (ed. by S.V. Oshibkina). The dating of the Neolithic in the area has become a topic of prime importance. In this connection must the ideas of the oustanding researcher of the Stone Age in the Steppe zone the late prof. V.N. Danilenko (1969) be mentioned. He considered the Neolithic of the area as very ancient and proposed also, that pottery dispersed from this area to the Early Neolithic cultures situated immediately to the West and to the North.

The last years a number of Radiocarbon datings of importance for the understanding of the Neolithisation in the area have been obtained from the Forest-Steppe area of the Volga basin. The Early Neolithic sites were discovered there in 1970's (Vasilyev, Penin, 1977). These

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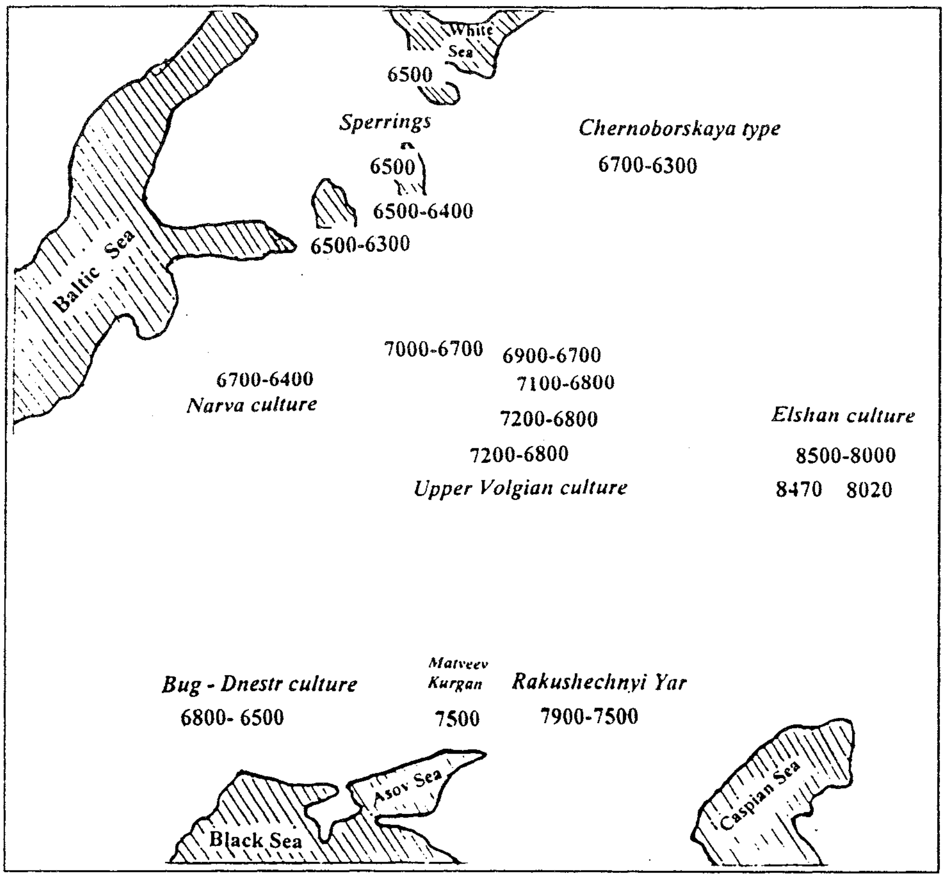

Fig. 1 : The geographical position of the most important Early Neolithic sites in Eastern Europe dated by ^{14}C.

sites of the so-called Elshan-type (or of Elshan culture) are mainly excavated in the Samara and Orenburg regions (Vasylyev, Penin, 1977 ; Vasylyev, Vybornov, 1988 ; Morgunova, 1980 ; Mamonov, 1995). The sites yield a flint industry with some Mesolithic traits (including tanged arrowpoints made on blades, of the so-called Epi-swiderian type) and archaic pointed-bottomed pottery with poor ornamentation. Some authors compare the shape of the Elshan vessels with the early vessels of the Central Asian Neolithic hunters and gatherers (Vasylyev, Vybornov, 1988, p. 40). During the last years the Lab of the Institute of the History of Material culture, St.-Petersburg, has dated samples from the multilayered site Chekalino IV, excavated by A.E. Mamonov (1995) at Sok-river, in the Sergiev district of the Samara region. The Elshan materials were discovered in the lower culture layer of the site. Concentrations of «Unio» fresh-water shells were found in this layer. Four samples of shells were dated by ^{14}C Lab. of the Institute of the History of Material Culture (Le-index). Three of them produced radiocarbon datings about 8000 BP, uncalibrated, and one was even older. A similar dating was obtained by Le on a sample of bones from the other site of Elshan-type : the lower layer of the Ivanovskaya site in the Orenburg region, excavated by N.G. Morgunova (1980, 1988). Similar datings were also produced by the Lab. of Geological Institute (GIN, Moscow) on samples from Chekalino IV and from one more site with materials of Elshan-type : Lebyazhinka IV in the Samara region. The main part of the Elshan datings are about 8000 BP or some older. The list of ^{14}C dates for these sites is presented in table 1.

According to the information published by the author of Chekalino IV about the excavations (Mamanov, 1995, p. 23) the ^{14}C dates are in good concordance with the pollen-data and the geological investigations done by E.A. Spiridonova and Yu.A. Lavrushin. They date the Elshan layer of Chekalino IV to the Boreal period.

The Elshan sites seem to be the earliest manifestations of Neolithic pottery in Eastern Europe. Information about the economy of this culture is almost absent and evidence of food-production is absent. The stone industry and the topography of the sites indicate that the economy was based on hunting, fishing and gathering. The opinion has been expressed that many traits of the Elshan Neolithic excluding the vessels shapes, distinguish it from the southern or south-eastern cultures (Mamonov, *op. cit.*, p. 22-23). It most be mentioned, that the ^{14}C datings from the Central Asian sites of hunters and food-gatherers (Jebel cave, Uchaschi 131) as well as those from the early food-producers (Jeitun culture of Turkmeniston) are later, than the datings of the Elshan-type materials.

An independent, local origin of the Early pottery in the South-Eastern Russia Forest-Steppe zone, should be considered.

Further important evidence concerning chronology of the Southern Russia Neolithic has now been obtained for the multilayered settlement Rakushechnyi Yar situated in the lower Don basin (Rostov-on-Don region). The site

Lab. index	^{14}C age, BP	Site	Material for dating
Le-4781	8990±100	Chekalino-IV	shells
Le-4782	8000±120	Chekalino-IV	shells
Le-4783	8050±120	Chekalino-IV	shells
Le-4784	7940±140	Chekalino-IV	shells
GIN-7085	8680±120	Chekalino-IV	shells
GIN-7086	7950±130	Chekalino-IV	shells
GIN-7088	8470±140	Lebyazhinka-IV	shells
Le-2343	8020±90	Ivanovskaya	bone

Tab. 1 : Radiocarbon datings of the Elshan-type Early Neolithic sites.

was excavated in the period 1960-1980's by Dr. T.D. Belanovskaya. More than one thousand square metres was investigated. Detailed stratigraphical studies revealed a succession of 23 separate culture layers and horizons (Belanovskaya, 1995). The lowest layers of the site yielded the material from the local Rakushechnyi Yar culture. The assemblage consist of the Neolithic pottery, flat- and pointed-bottomed, with rather simple ornamentation, the flint industry contain some geometric microliths (trapezes) and tools of bone and antler. The material includes some distinctive elements of food-production. Bones of domesticated animals (cattle and sheep) were found together with bones of the wilds ones (red deer dominating). A series of ^{14}C datings have been produced for the Rakushechnyi Yar layers by the Labs of Le, Ki and Bln (table 2). The datings of layer XX, one of the lowest, on pottery with preserved food crust, yields an age about 8000-7600 BP, uncal., and the samples from the upper layers of Rakushechnyi Yar culture (XV, XIV-XV) are about 7000-6800 BP, uncal. The datings of the superimposed layers of the Late Rakushechnyi Yar culture and those of the local Eneolithic coincide with the stratigraphical evidence.

The traces of long-distance influences can be recognised in the rich assemblages of the Eneolithic layers of Rakushechnyi Yar (Belanovskaya, 1995, p. 28, 174, 175). The datings of the Rakushechnyi Yar site can serve as a preliminary basis for the development of a more detailed chronology of the Neolithic and Eneolithic cultures of a large part of the Eastern European Steppe zone.

Layers	^{14}C age, BP	Lab. Index	Material
XX	7690±110 7930±140 7860±130	Ki-6476 Ki-6476 Ki-6477	Sherds with food crust
XV, XIV-XV	6930±100 6825±100 7040±100	Ki-6478 Ki-6479 Ki-6480	Sherds with food crust
IX	7180±250	Le-5344	Shells
VIII	6070±100	Bln-704	Charcoal
V	5890±105	Ki-955	Charcoal
IV	5060±230	Le-5340	Bone
III	4360±100	Bln-1177	Charcoal
II	5290±260	Le-5327	Charcoal

Tab. 2 : 14C datings of the layers of Rakuschechnyi Yar multilayered site.

Additional evidence exist from another site from the Steppe zone, Matveev Kurgan I in Rostov in the Don region, excavated by L.Ya. Krizhevskaya (1992). There were found traits of food production (including bones of cattle and sheep/goat) and some pieces of badly preserved pottery. The site is dated to 7505 ± 210, 7180 ± 70 (GrN-7199, Le-1217). The ^{14}C datings of the Rakushechnyi Yar's lowest layers, as well as these of Matveev Kurgan I confirms the early appearance of Neolithic culture in the Southern Russian Steppe zone. It should be mentioned, that in the Rakushechnyi Yar under the dated layer XX are three more thin layers, yet undated. The pottery of these layers looks rather developed. It does not look like the first manifestation of ceramic production. There are

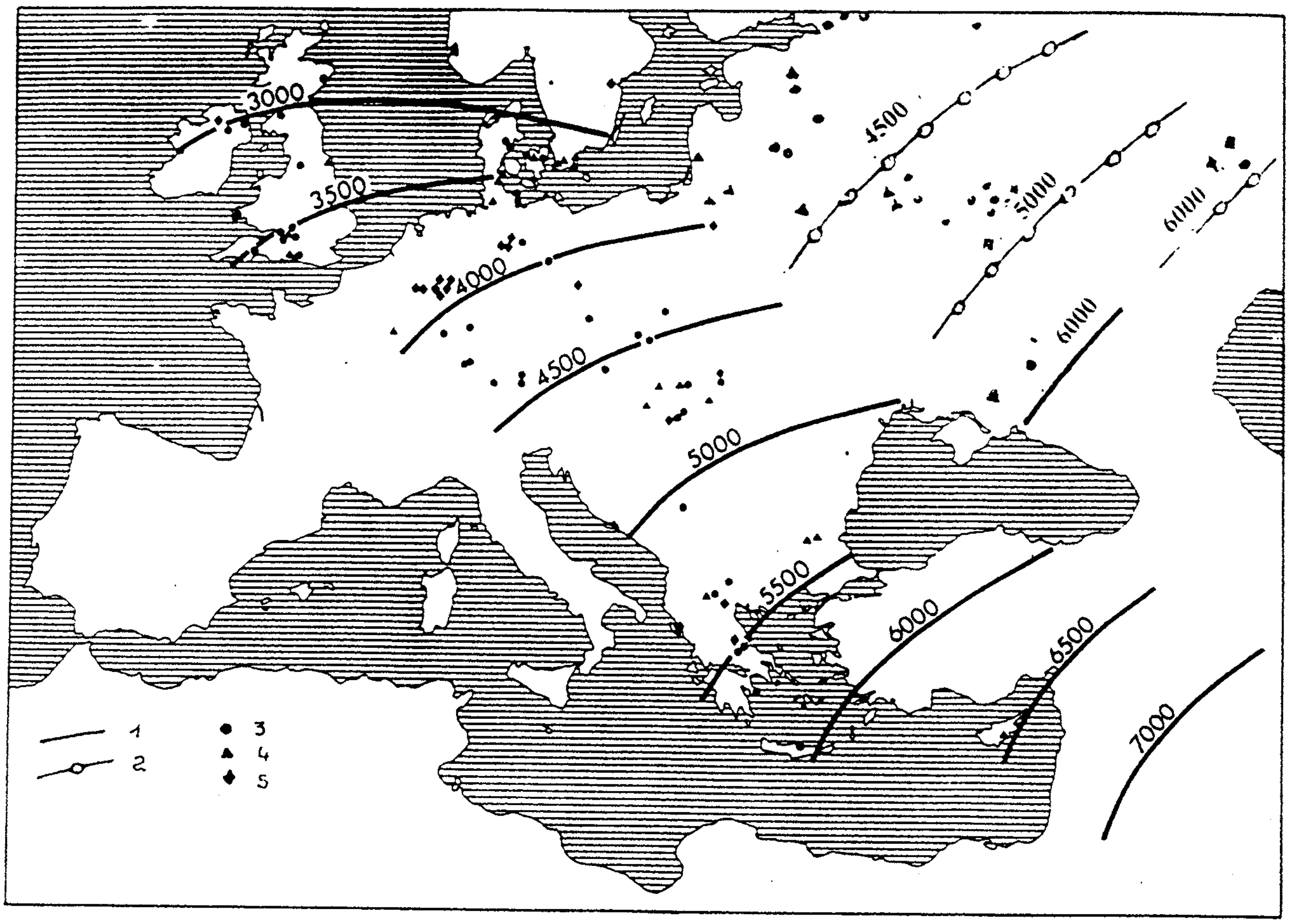

Fig. 2 : Model of the dispersion of the Neolithic in the main part of Europe, after P. Breunig (1987) with addition of Eastern European data.
1 - the chronological boundaries of the area with food-production, 2 - the chronological boundaries for the dispersion of pottery-production in the Forest/Steppe and Forest zones, 3 - sites with datings fitting into the suggested scheme, 4 - sites with datings about 300 ^{14}C-years too young, 5 - sites with datings about 300 ^{14}C-years too old.

also a number of datings for Late Neolithic - Eneolithic of the area (Timofeev, Zaitseva, 1997). According to these and to the datings of the Rakushechnyi Yar's upper layers, as well as to the new data for the Ukrainian cemeteries of Mariupol-type (Lillie, 1998), the appearance of the «Eneolithic» elements in the Steppe zone happened not later than 6000 BP, uncal. The chronological position of the more Northern Early Neolithic of the Eastern Europe Forest zone has become clearer during last years (Timofeev, Zaitseva, 1997a). It is clear now that the appearance of the «Forest Neolithic» distinguished by the appearance of the first pottery should not be dated later than 7100-7000 BP. There are about 40 ^{14}C datings for the samples from the Early Neolithic sites of the «Verhnevolzhskaya» (Upper Volgian) culture of the Central Russia area and the earliest of them are from 7200-7000 BP (*op. cit.*, p. 18, fig. 1). According to these data the first pottery appeared in the Central part of the Eastern European Forest zone before the dispersion of the Linearband pottery in Central Europe. The origin of the first Upper Volgian pottery is by the researchers (D.A. Krainov, A.T. Sinyuk, E.L. Kostyleva) connected to the more southern Early Neolithic culture of the Forest-Steppe zone in the Middle Don area. ^{14}C datings for the Middle Don culture are still absent and the datings of the Elshan sites are the only chronological indications at the moment.

The typological peculiarity of the early pottery in the Steppe and Forest-Steppe zone and the chronological evidence point to an origin of the pottery production that is independant of the more Western centres for Early Neolithic dispersion.

The Radiocarbon evidence gave a number of authors an opportunity to study the succession and the chronology of the Neolithisation in the main areas of the Near East and Europe in detail and displayed a quite systematic development from the Earliest position in the Near East to the appearance of the Neolithic in S. Europe (Greece, 7,5 - 8000 BP) and the following dispersion of Neolithic culture to Central Europe about 6700-7000 BP (Clark, 1965 ; Dolukhanov, Timofeev, 1972 ; Breunig, 1987 and others). The data which we now have for Eastern Europe allow us to refine the understanding of the Neolithisation in a large area of Eastern Europe. In fig. 2, we use the model suggested by P. Breunig (1987) to show the parallel process of the dispersion of agriculture to the Greece, Central and NW Europe and the dispersion of the Early pottery production in the Southern part of Eastern Europe and in the Forest zone. It seems as if the ^{14}C datings of the Eastern European Early Neolithic supports an interpretation of the dispersion of pottery in the Forest zone as a result of diffusion. The stone and the bone and antler industries of the Early Neolithic in the Forest zone display many similiarities with the local Late Mesolithic materials where as the first pottery has prototypes in the southern cultures. This was demonstrated in many lectures at the last conference devoted the introduction of the Neolithic in the area of the former USSR (St-Petersburg, 1990). The archaeological and chronological data from the Southern areas and the typological differences between the earliest dated pottery point to the existence of several centres for the first archaic pottery production in Eastern Europe.

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RADIOCARBONE
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DATATIONS AU RADIOCARBONE CONCERNANT LA TRANSITION ENTRE L'ÂGE DU BRONZE ET L'ÂGE DU FER DANS LA PÉNINSULE IBÉRIQUE

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Résumé : Voilà déjà plus de deux décennies que la recherche a pu déterminer que l'apogée de la culture de Cogotas I correspond au Bronze final à l'intérieur de la Péninsule ibérique. Parallèlement, certains travaux sur le terrain ont pu préciser que ce que l'on appelle culture du Soto constitue sur ce territoire la représentation du premier Âge du Fer. Même si ces deux périodes apparaissent bien définies culturellement, la question de leur chronologie n'est pas encore éclaircie de façon satisfaisante, puisqu'il reste encore à préciser le moment où se produit la transition entre ces deux cultures. Dans ce travail on recueille près de quarante dates radiocarbone quant à la transition entre le Bronze final el le premier Âge du Fer, ce qui pose le problème de savoir si la culture du Soto commence durant les derniers moments de l'Âge du Bronze ou si avec elle s'inaugure déjà l'Âge du Fer.

Abstract : The height of the Cogotas I culture corresponds to the Final Bronze in the interior of the Iberian Peninsula was established by researchers over two decades ago. Various field work campaigns have also established that the so-called Soto culture in the same area represents the First Iron Age. Although both periods have been fairly clearly defined in cultural terms, the question of their chronology has not yet been sufficiently clarified and the moment at which the transition from one period to another occurred remains to be accurately established. The present work brings together nearly forty radiocarbon datings for the transition from Final Bronze to First Iron, and asks whether the Soto culture began in the final stages of the Bronze Age or whether it in fact heralded the beginning of the Iron Age.

Mots-clés : Datations radiocarboniques, transition Bronze-Fer, séquence culturelle, culture de Cogotas I, culture du Soto, vallée du Duero, péninsule Ibérique.

Key-words : Radiocarbon dating, Bronze-Iron transition, cultural sequence, Cogotas I culture, Soto culture, Duero Basin, Iberian Peninsula.

Conformément à la chronologie traditionnelle européenne, le Bronze final et le premier Âge du Fer des terres intérieures de la péninsule Ibérique, et plus précisément de la vallée moyenne du Duero, correspondent respectivement, dans les grandes lignes, à l'apogée de la culture de Cogotas I, et à celle du Soto. Deux types d'arguments ont engendré cette façon actuelle de voir les choses : d'une part les différences de plus en plus notoires entre ces deux cultures - en ce qui concerne les modèles d'installation, la nature de l'occupation ou de l'architecture domestique, ainsi que les stratégies de subsistance, l'équipement matériel ou le rite funéraire - ; d'autre part, et c'est ce qui, ici, attire le plus notre attention, les datations radiocarbone.

En ce qui concerne le premier point mentionné, il existe de nombreux aspects qui, comme nous l'avons dit, différencient Cogotas I du Soto (Delibes et Romero, 1992, 233-251 ; Delibes *et al.*, 1995a, 49-88). En effet, bien que les populations de Cogotas I et du Soto aient occupé le même espace géographique, ils choisirent différents types d'emplacements. Les premiers érigèrent, au coeur de leur habitat typique, ces «champs de fosses» caractéristiques dans lesquels les rares demeures identifiées, de forme pararectangulaire, furent construites avec des matériaux périssables (Bellido, 1996). On y a trouvé des céramiques richement décorées de motifs géométriques, réalisés à l'aide de diverses techniques - incision, excision et «boquique» -, et incrustés de pâte blanche (Fer-

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nández-Posse, 1986 ; Delibes, Fernández et Rodríguez, 1990). L'essor d'une métallurgie archaïque - qu'on dissocie habituellement des dépôts de nature atlantique, bien représentés dans la région - se traduit par la présence de poignards à trous, d'alènes et de haches plates (Delibes et Fernández Manzano, 1991). Enfin, bien que l'on ne parvienne pas à préciser qui bénéficiait de ce rite, on sait que les morts étaient inhumés : on déposait les cadavres, peut-être de manière non systématique, dans les fosses des villages (Esparza, 1990).

Au contraire, les gens du Soto, qui ne s'installèrent que rarement sur les sites de Cogotas I, construisaient des demeures de forme circulaire, qu'ils firent dans un premier temps avec des matériaux peu résistants, mais qu'ils remplacèrent bientôt par des briques crues. Ceci, ajouté au fait que les villages successifs se superposaient fréquemment, manifeste la vocation de rester à cet endroit, ce qui s'oppose au caractère temporel, bien que certainement récurrent, des installations de leurs prédecesseurs (Romero, 1992). Tout comme ces derniers, les gens du Soto pratiquèrent une économie mixte, mais ce qui la distingue est la production agraire, basée sur la culture

Gisement	Laborat.	BP	Cal av. J.-C. 2σ	
			Interval.	%
Los Baraones (Valdegama, Palencia)	GrN-?	3220±50	1608-1551 1548-1399	11 89
Los Baraones (Valdegama, Palencia)	GrN-?	3190±30	1513-1410	100
Los Tolmos (Caracena, Soria)	CSIC-479	3180±50	1527-1370	92
Moncín (Borja, Zaragoza)	BM-2609	3150±50	1517-1300	99
Los Espinos (Mave, Palencia)	I.11117	3120±95	1549-1114	97
Ecce Homo (Alcalá de Henares, Madrid)	CSIC-163	3100±70	1512-1192	97
Moncín (Borja, Zaragoza)	BM-2608	3080±50	1435-1197	99
Moncín (Borja, Zaragoza)	BM-2606	3050±50	1410-1157	98
Ecce Homo (Alcalá de Henares, Madrid)	CSIC-165	3020±70	1412-1040	100
Los Tolmos (Caracena, Soria)	CSIC-407	3010±50	1396-1113	98
San Bartolomé (Nestares, La Rioja)	GrN-21006	2970±25	1265-1112	97
La Requejada (S. Román de Hornija, Valladolid)	I.9604	2960±95	1400-923	100
San Bartolomé (Nestares, La Rioja)	GrN-21007	2950±50	1307-999	100
La Paul (Arbiñano, Alava)	I.11590	2900±85	1313-892	97
Atapuerca (Ibéas de Juarros, Burgos)	CSIC-531	2850±50	1134-894	96
La Fábrica de Ladrillos (Getafe, Madrid)	?	2840±90	1222-817	98
Los Espinos (Mave, Palencia)	I.11116	2830±95	1221-809	98

Tab. 1 : Datations radiocarbone de la culture de Cogotas I.

Gisement	Laborat.	BP	Cal av. J.-C. 2σ	
			Interval.	%
Soto de Medinilla (Valladolid)	GrN-19051	2795±50	1048-821	100
Los Baraones (Valdegama, Palencia)	GrN-?	2770±40	993-827	100
Soto de Medinilla (Valladolid)	GrN-19052	2765±35	989-954 946-826	11 89
Los Baraones (Valdegama, Palencia)	GrN-?	2740±50	946-807	92
San Pelayo (Martinamor, Salamanca)	GrN-13970	2715±30	905-810	100
San Pelayo (Martinamor, Salamanca)	GrN-13971	2660±30	849-792	97
Soto de Medinilla (Valladolid)	GrN-19054	2640±50	910-760	96
Soto de Medinilla (Valladolid)	GrN-19055	2620±50	868-758 646-548	79 14
La Mota (Medina del Campo, Valladolid)	GrN-11307	2580±30	811-759 635-556	81 16
Soto de Medinilla (Valladolid)	GrN-19056	2580±30	811-759 635-556	81 16
La Mota (Medina del Campo, Valladolid)	GrN-11308	2555±25	801-758 644-549	58 35
Los Baraones (Valdegama, Palencia)	GrN-?	2540±45	805-514	100
San Pelayo (Castromocho, Palencia)	GrN-17306	2530±35	796-751 739-528	21 79
El Castillo (Manzanal de Abajo, Zamora)	GrN-14794	2530±60	803-479	96
La Mota (Medina del Campo, Valladolid)	GrN-17568	2525±35	795-750 746-527	18 82
Los Baraones (Valdegama, Palencia)	GrN-?	2510±20	782-751 729-531	10 90
Los Baraones (Valdegama, Palencia)	GrN-?	2485±35	773-477	94
Soto de Medinilla (Valladolid)	GrN-19057	2455±50	764-615 605-406	42 58
Soto de Medinilla (Valladolid)	GrN-19058	2450±50	764-617 604-404	41 59

Tab. 2 : Datations radiocarbone de la culture du Soto.

des graminées, et notamment du blé (Delibes, Romero et Morales, 1995). Quant à la céramique, elle est lisse, ou à peine décorée de motifs simples incisés ou imprimés, à tel point que les rares modèles ornés de peintures se détachent à titre d'exception (Romero, 1980). La métallurgie, encore de bronze en majorité, est en géneral associée au contexte domestique, comme le certifient les découvertes fréquentes d'éléments impliqués dans le procès productif - creusets, moules, etc. -, ou même de manufactures, innovatrices dans certains cas, et dans d'autres, fruits de l'évolution des modèles antérieurs. Du point de vue technologique, il faut souligner l'augmentation considérable des alliages contenant du plomb (Delibes *et al.*, à paraître). Enfin, nous n'avons aucune preuve d'enterrement, c'est pourquoi l'on suppose qu'on pratiquait un rite funéraire qui n'a pas laissé de traces archéologiques. Seules des inhumations infantiles ont été découvertes sous le sol des demeures ; mais, étant donné que l'on a trouvé occasionnellement des restes d'ovicaprins à la place de ceux d'enfants, il est difficile de savoir s'il s'agit d'enterrements ou de sacrifices de fondation (Delibes *et al.*, 1995a, 77-79).

Toutes ces données permettent la délimitation entre deux réalités culturelles différentes, délimitation confirmée, comme nous l'avons déjà dit, par le recours aux datations radiocarboniques. Il est nécessaire de remarquer, à partir du moment où le sujet de notre recherche est la transition entre ces deux mondes, que les datations absolues sélectionnées pour la confection des tableaux 1 et 2 sont, en ce qui concerne Cogotas I, les plus modernes et, dans le cas du Soto, les plus antiques. En effet, peu importent ici les dates relatives aux origines de Cogotas I, qui remontent au XVIIème siècle cal av. J-C. (Castro, Micó et Sanahuja, 1995), de même que les dates les plus récentes du Soto, pour la même raison, et d'autant plus qu'elles correspondent habituellement à des gisements périphériques du groupe dans lesquels celui-ci survécut, nous en sommes certains, pendant une partie du deuxième Âge du Fer (Esparza, 1986, 368). Nous avons laissé de côté, de même, les datations qui posaient des problèmes de contextualisation, ou une déviation standard élevée -supérieure à ± 100 pour celles de Cogotas I, et à ± 70 pour celles du Soto -. Nous avons utilisé le programme CALIB Rev 3.0.3 de Stuiver et Reimer (1993) pour leur calibration ; celle-ci a été faite à 2 «sigma», et dans les tableaux mentionnés nous n'avons exposé que les intervalles de confiance supérieurs à 10 %. Enfin, nous nous devons de signaler que les limites chronologiques des diverses phases du Bronze final présentées dans la figure 1 correspondent à celles que préconise Sperbe (1987) pour l'Europe Centrale, établies à partir de séries de radiocarbone calibré et de dendrochronologie, et présentant peu de différences avec les datations «de base historique» - qui ont des ancrages héladico-chypriotes - défendues par Giardino (1995, 3-5) pour la périodisation de la Méditerranée Centrale.

Malheureusement, la nature même des gisements de Cogotas I - dont l'évolution dans le temps s'est traduit par une amplification de superficie, et non par la formation de strates verticales - a empêché d'obtenir des séries ordonnées de datations absolues. Cependant (tab. 1 et fig. 1), nous disposons de quelques dates régionales - La Requejada (San Román de Hornija, Valladolid), Los Espinos (Mave, Palencia) - qui nous permettent de fixer la fin de Cogotas I autour de l'an 1000 cal av. J-C., ce qui serait confirmé par les datations établies pour d'autres enclaves dans des régions limitrophes - La Paul (Arbiñano, Álava), Moncín (Borja, Zaragoza) - (Delibes et Fernández-Miranda, 1986-87 ; Castro, Micó et Sanahuja, 1995).

Ce type d'information est la preuve que, tout du moins dans la Meseta, l'essor du Cogotas I le plus avancé a coïncidé avec une grande partie du Bronze final. Ceci, d'ailleurs, n'était pas difficile à soupçonner étant donné l'association des céramiques classiques, excisées et du «boquique», avec certains éléments métalliques dotés d'une signification chronologique notable : les fibules coudées (San Román de Hornija, Valladolid), les fibules «ad occhio» (Perales del Río, Madrid), les épées pistiliformes (Solacueva de Lacozmonte, Álava), les poignards type langue de carpe (Frechilla de Campos, Palencia) ou les lances tubulaires (le moule pour les fondre de Mucientes, Valladolid) (Delibes et Fernández Manzano, 1991). Et, en complément, nous pouvons de même attribuer aux gens de Cogotas I beaucoup des «dépôts» d'objets métalliques, qui sont toujours décontextualisés et totalement en marge des lieux d'habitation, et que l'on trouve sur la bordure montagneuse au nord du Duero. C'est le cas de ceux de Huerta de Arriba (Burgos), Covaleda (Soria), Saldaña (Palencia) o Camposalinas (León), dont la position chronologique, ne serait-ce que par la typologie de ses composants, ne peut pas être postérieure à l'horizon initial des épés en forme de langue de carpe, c'est-à-dire à la première moitié du Bronze final III (Fernández Manzano, 1986).

La situation est bien différente en ce qui concerne la culture du Soto (tab. 2 et fig. 1), car grâce à un sondage stratigraphique réalisé ces dernières années dans le gisement qui a donné son nom à l'ensemble - El Soto de Medinilla (Valladolid) - on a pu obtenir une série de datations 14C (Delibes *et al.*, 1995b). Elle présente une grande logique interne, puisqu'elle obéit à un rythme décroissant inexcusable qui conduit depuis le milieu du Xème siècle jusqu'au Vème siècle cal av. J.-C. De plus, elle entre avec beaucoup de cohérence dans le cadre de chronologie absolue actuellement établi pour la Préhistoire Récente de l'intérieur de la Péninsule ibérique, car elle constitue une excellente frontière ante-quem pour Cogotas I. Seules les dates initiales de la séquence mentionnée peuvent attirer l'attention par leur antiquité ; mais il ne faut pas oublier que d'autres dates radiocarbone, obtenues dans Los Baraones (Valdegama, Palencia) et le Cerro de San Pelayo (Martinamor, Salamanca), concernant des contextes clairement postérieurs à Cogotas I, et formant partie de celui du Soto, nous situent au IXème siècle cal av. J.-C. dans son ensemble. Il convient de souligner, au surplus, quelques données en rapport avec les deux gisements cités auparavant. Los Baraones - qui a fourni une série intéressante de datations radiocarbone, bien qu'elles fassent partie de divers secteurs du gisement dont nous ignorons pour le moment la correspondance stratigraphique - offre des occupations relatives aux deux horizons que nous analysons ici, sans que l'on puisse établir aucune connexion entre elles (Barril, 1995). Dans la couche à laquelle correspondent les dates de San Pelayo, on a récupéré un vase peint de type orientalisant (Benet, 1990), qu'il faut mettre en relation avec la présence phénicienne dans la Péninsule ibérique, et considérer comme un témoin authentiquement antique des relations entre le Soto et le monde colonial, étant donné les chronologies absolues dont nous disposons à ce sujet (Aubet, 1994, 317-323).

En conclusion, on assiste, entre Cogotas I et le Soto, à un changement culturel évident, que l'on peut interpréter en termes de rupture, étant donné la profondeur des transformations qui s'effectuent à tous les niveaux entre les deux cultures (Delibes et Romero, 1992, 242-243). Il ne serait pas pertinent d'essayer de donner ici la justification de ce phénomène, car il s'agit plutôt pour l'instant de signaler qu'il eut lieu à un moment plus ou moins précis au cours du Xème siècle. Il se serait déroulé durant la transition du Bronze final IIIa/IIIb, comme le mettent en évidence certains élements du bagage matériel, et notamment la métallurgie : de la même façon que la fibule coudée de La Requejada peut être assimilée à l'horizon Ría de Huelva, la plupart des éléments en bronze de la culture du Soto peuvent être mis en relation avec Baiões-Vénat (Delibes *et al.*, à paraître).

Ainsi, en définitive, étant donné les transformations qui eurent lieu entre le IIème et le Ier millénaire cal. av. J.-C., et en accord avec les propositions formulées pour d'autres sites européens - entre autres en France (Brun,

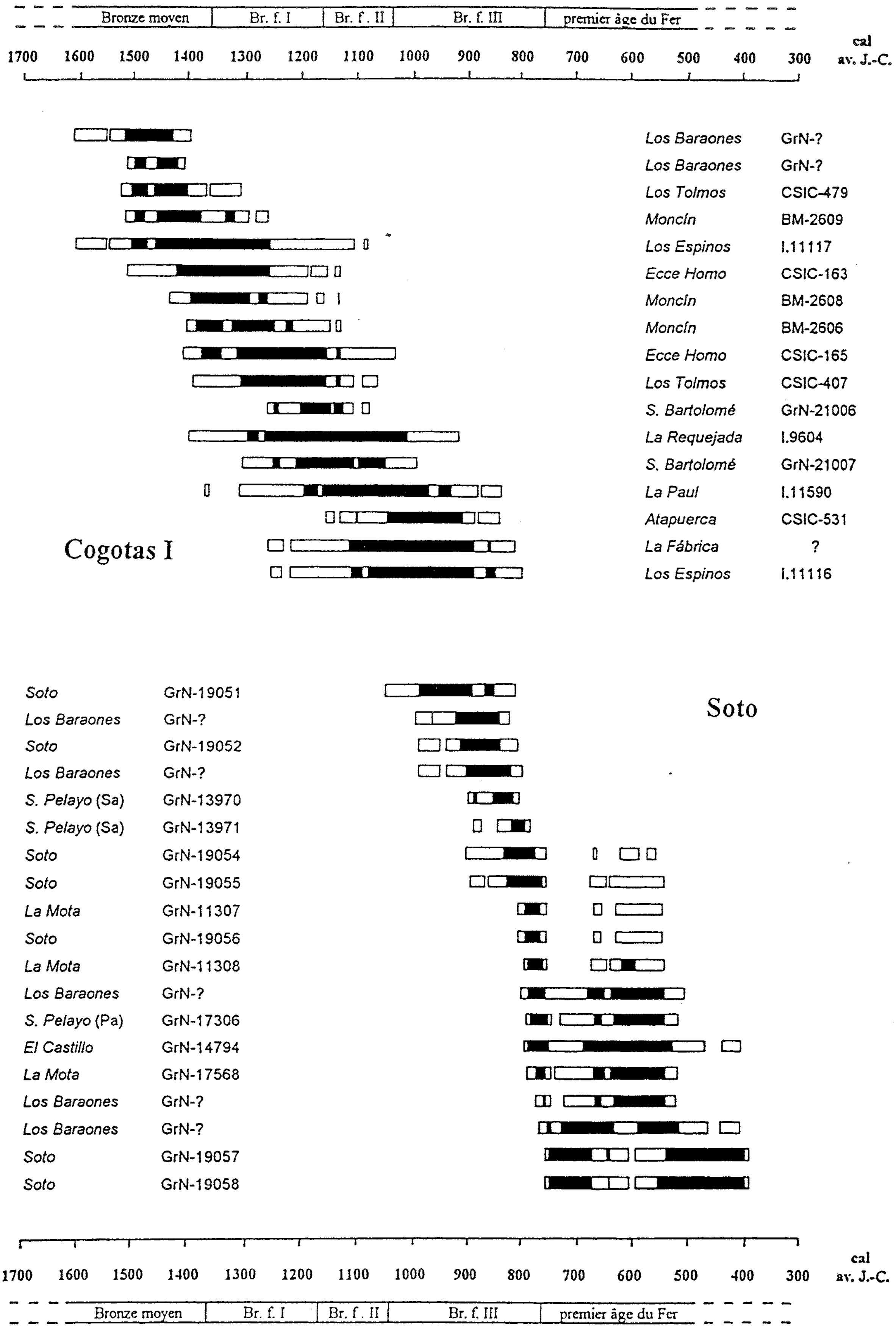

Fig. 1 : Datations au radiocarbone concernant la transition entre l'Âge du Bronze et l'Âge du Fer dans la Péninsule ibérique.

1984) -, nous penchons pour situer ce changement culturel - et par conséquent, la transition entre Cogotas I et le Soto, donc entre l'Âge du Bronze et l'Âge du Fer - entre le Br. f. IIIa, et le Br. f. IIIb que nous considérons donc comme formant partie de l'Âge du Fer - contrairement à l'idée que le Soto a débuté à la fin de l'Âge du Bronze -.

La culture du Soto, pendant les temps conventionnels du premier Âge du Fer, présente des preuves de son incorporation à l'hinterland tartésique du midi péninsulaire (Romero et Ramírez, 1996) : c'est alors que nous considérons qu'elle passe de ce qu'on appelle sa phase initiale ou de formation, à celle d'apogée (Delibes *et al.*, 1995a, 83-88), mais ceci dépasse déjà les limites de ce qui nous intéresse ici.

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LES OCCUPATIONS LITTORALES DES LACS ALPINS FRANÇAIS DE LA PROTOHISTOIRE À NOS JOURS

Yves BILLAUD et André MARGUET**

Résumé : Depuis 1980, des prospections et des évaluations de sites archéologiques lacustres sont réalisées par le DRASSM (ex-CNRAS) ou avec sa collaboration. L'utilisation systématique de datations objectives étend et précise les schémas des années 70 (pour lesquels les dates radiocarbone, trop imprécises, ne peuvent plus être retenues). Des occupations sont mises en évidence depuis le début du Néolithique moyen jusqu'à l'époque actuelle. Leurs natures et leurs concentrations (en lieu et en temps) traduisent les contraintes taphonomiques mais également culturelles. Sur le plan méthodologique, radiocarbone et dendrochronologie, loin de s'exclure, s'avèrent complémentaires.

Abstract : Since 1980, surveys and evaluations of lake-dwelling sites were realised by or in collaboration with the DRASSM (ex-CNRAS). Systematic use of absolute dating extend and refine the 1970s schemes (for which radiocarbon dates, lacking in precision, are now unreliable). They revealed various age's settlements, from Middle Neolithic to Actual, which nature, temporal repartition and spatial distribution are linked to environmental constraints but also cultural influences. From methodological point of view, radiocarbon dating and dendrochronology are not antagonist but complementary.

Mots-clés : Alpes, lac, habitat lacustre, datation, radiocarbone, dendrochronologie, Néolithique, Age du Bronze, Age du Fer, Antiquité, Moyen-Age, époque moderne.

Key-words : Alpes, lake, lake-dwelling settlement, datation, radiocarbon, dendrochronology, Neolithic, Bronze Age, Iron Age, Middle Age, post-medieval.

Le présent bilan concerne l'Avant-pays savoyard où sont situés les grands lacs de la partie française de l'arc alpin avec, du Nord vers le Sud, le lac Léman, le lac d'Annecy, le Bourget et le lac d'Aiguebelette (fig. 1). Il intègre les données anciennes et les résultats récents obtenus lors de prospections systématiques et d'évaluation de sites.

Le lac de Paladru, encore plus au Sud, dans les collines molassiques du Dauphiné, pour lequel les données chronologiques ont été obtenues dans le cadre de fouilles d'envergure n'est pris en compte que comme élément de comparaison.

1 - HISTORIQUE

Découvertes au milieu du XIXème siècle, les «*stations lacustres*» des Alpes françaises ont fait l'objet, pendant plusieurs décennies, de «*pêches aux antiquités*» aussi fructueuses que dépourvues de tout cadre chronostratigraphique.

Il faudra attendre 1954 pour que soient réalisées les premières observations *in situ* grâce à des précurseurs comme R. Laurent qui utilisent les premiers développements de la plongée autonome et jettent les premières bases de techniques spécifiques (relevé par triangulation...). Dès cette époque, le radiocarbone est mis à contribution pour l'établissement d'un cadre chronologique. 29 datations seront ainsi réalisées de 1965 à 1975, Ly9 étant la première d'entre-elles (tab. 1).

En 1972, en raison d'un projet d'aménagement des rives du lac de Paladru, des fouilles extensives débutent sur la station néolithique des Baigneurs (Bocquet, 1994) et sur le site médiéval de Colletière (Colardelle et Verdel, 1993). Elles permirent la mise au point d'une méthodologie d'exploitation des gisements subaquatiques.

Par ailleurs, à la fin des années 70, des plongeurs bénévoles entreprennent, dans un tout autre contexte, de revisiter les gisements des lacs du Bourget et d'Annecy. Ces bonnes volontés seront relayées, à partir de 1980, par le CNRAS (Centre National de Recherches Archéologiques Subaquatiques) devenant, à partir de 1995, le DRASSM. Plus récemment, à la tâche d'inventaire et d'évaluation de sites de cet organisme, s'est associée l'AREOLL (Association pour la Recherche et l'Etude des Occupations Littorales Lacustres).

* *DRASSM (Département des Recherches Archéologiques Subaquatiques et Sous-Marines), 58 bis, rue des Marquisats, 74000 ANNECY.*

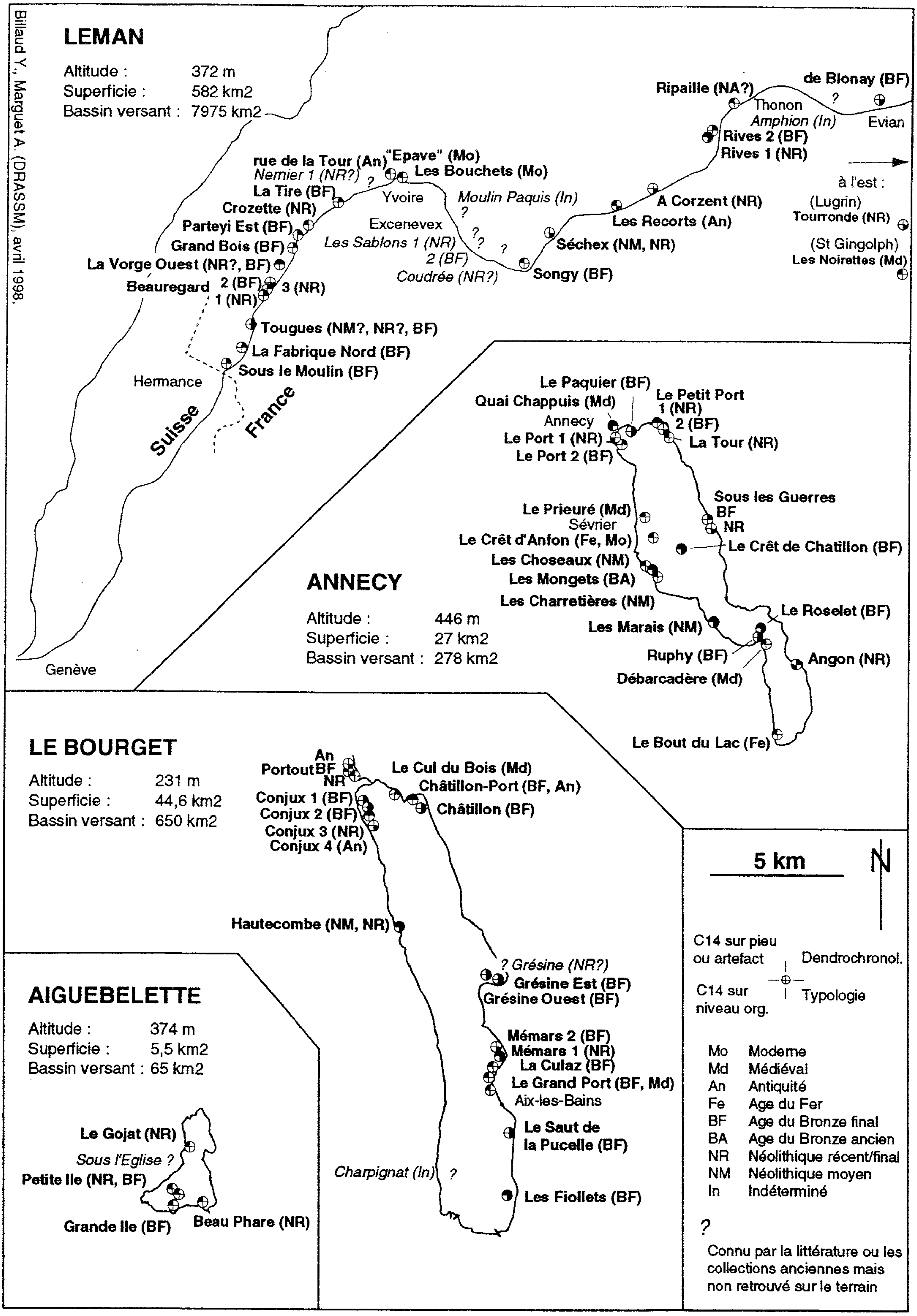

Fig. 1 : Localisation des gisements lacustres du domaine savoyard et haut-savoyard.

Réf lab	Date BP	Commune/Site	L	M
Gif 222	2480±150	St-Alban-de-Montbel/La Petite Ile	Ai	P
Ly 9	3060±100	Chindrieux/Châtillon	Bo	P
Ly 17	2700±100	Chindrieux/Châtillon	Bo	Br
Ly 18	2730±160	Chindrieux/Châtillon	Bo	Ch
Ly 19	3040±140	St-Alban-de-Montbel/La Petite Ile	Ai	P
Ly 20	4150±180	St-Alban-de-Montbel/La Petite Ile	Ai	P
Ly 47	2700±100	Chindrieux/Châtillon	Bo	Br
Ly 63	3400±600	Sévrier/Le Crêt de Chatillon	An	Ob
Ly 117	1460±170	Sévrier/Le Crêt de Chatillon	An	Ch
Ly 190	4060±120	Brison-St-Innocent/Mémard 1	Bo	Ob
Ly 191	3030±150	Sévrier/Le Crêt de Chatillon	An	P
Ly 192	3030±150	Sévrier/Le Crêt de Chatillon	An	P
Ly 273	1630±100	Sévrier/Le Crêt de Chatillon	An	Br
Ly 274	2670±110	Chindrieux/Châtillon	Bo	P
Ly 275	1968±100	Chindrieux/Châtillon	Bo	P
Ly 276	2140±110	Brison-St-Innocent/Mémard	Bo	P
Ly 506	1280±120	Brison-St-Innocent/Grésine I	Bo	Pq
Ly 507	1500±360	Brison-St-Innocent/Grésine I	Bo	Pq
Ly 508	2840±300	Brison-St-Innocent/Grésine 1	Bo	P
Ly 688	4600±120	Lépin-le-Lac/Aiguebelette 1	Ai	P
Ly 689	2710±90	Lépin-le-Lac/La Grande Ile	Ai	P
Ly 1323	3970±140	Conjux/Conjux 3	Bo	M
Ly 1324	3970±140	Conjux/Conjux 3	Bo	Ch
Ly 1325	3820±140	Conjux/Conjux 3	Bo	Br
Ly 1326	2870±140	Conjux/Conjux 4	Bo	P
Ly 1951	2700±140	Sévrier/Le Crêt de Chatillon	An	Pg
Ly 2305	3740±130	Brison-St-Innocent/Mémard 1	Bo	Pg
Mc 81	2500±100	Duingt/Le Roselet	An	P
S 228	2440±130	Thonon/Le Port II	Le	P

Tab. 1 : Liste des analyses par le radiocarbone réalisées dans les années 1960-70 par R. Laurent sur des vestiges des lacs savoyards. Colonne L (lac) : Ai : Aiguebelette, An : Annecy, Bo : Le Bourget, Le : Léman. Colonne M (matériaux) : Br : brindilles, B? : bois en place (tronc), Ch : charbon, Ep : épave, M : madrier, No : niveau organique, Ob : Objet, Os : ossement, P : pieu , Pg : pirogue , Pq : piquet.

2 - INVENTAIRE ET DIAGNOSTIC

Constatant le décalage entre l'abondance de la documentation ancienne (collections et littérature) et le peu de connaissances sur les sites eux-mêmes, le CNRAS et l'AREOLL, bien qu'étant des structures de nature et de taille différentes, ont élaboré de façon conjointe, une démarche et des méthodes dans un but d'inventaire des gisements et de connaissance des peuplements palaffitiques (Billaud et Marguet, 1997).

Depuis 1980, des prospections et des diagnostics de sites littoraux ont été réalisés en Savoie (Aiguebelette, le Bourget) et en Haute-Savoie (Annecy, le Léman). Ce travail vise, en premier lieu, au repérage des gisements, à la délimitation des emprises archéologiques et à l'estimation de leur état de conservation. Ponctuellement, des séries typologiques de référence sont recherchées par des sondages. Dans tous les cas, des échantillons (pieux pour l'essentiel), préalablement topographiés, sont prélevés pour l'obtention de calages chronologiques absolus.

Depuis le bilan dressé à l'occasion du colloque de l'UISPP de Nice (Bocquet et Laurent, 1976), le nombre de stations connues, toutes périodes confondues, a doublé, passant de 41 à 83 et se répartissant en 6 pour Aiguebelette, 25 pour le Bourget, 21 pour Annecy et 31 pour le Léman (fig. 1).

3 - CADRE CHRONOLOGIQUE

L'utilisation systématique des datations objectives permet de disposer de 45 séquences dendrochronologiques et de 66 nouvelles dates radiocarbone. Ces dernières, publiées pour partie dans le cadre de plusieurs synthèses par période (Billaud et Marguet, 1997, 1998 ; Marguet, 1995) sont ici réunies dans leur totalité (tab. 2). Leur utilisation en terme d'appartenance culturelle n'est pas encore possible en raison de la taille du corpus et des lacunes dans les données typologiques dues à l'état de certains sites (couche non conservée) et surtout au faible nombre de sondages réalisés. Mais cet ensemble de dates fournit un cadre chronologique depuis le tout début du Néolithique moyen jusqu'à l'époque actuelle (fig. 2 et fig. 3). Il apparaît alors que le schéma classiquement admis pour l'occupation des bords de lacs (Néolithique final, Bronze final et an Mil) doit être révisé, avec la mise en évidence de nouveaux jalons.

NÉOLITHIQUE ANCIEN/MOYEN

Les premières occupations littorales de la seconde moitié du Vème millénaire, connues en Suisse orientale et en Allemagne, sont maintenant attestées sur le lac d'Annecy par une petite structure sans mobilier archéologique à Sévrier/Les Charretières (5315±50 B.P.).

NÉOLITHIQUE MOYEN

- Début du IVème millénaire

Comme pour le Plateau suisse, les occupations se développent avec une première phase individualisée à St-Pierre-de-Curtille/Hautecombe (le Bourget) en -3842 et vers -3835 (Cortaillod, NMB, Chasséen ?) et à St-Jorioz/Les Marais (Annecy) en -3783 (Cortaillod classique ?).

- Milieu du IVème millénaire

Trois gisements pourraient se rapporter à la période de transition Cortaillod tardif–Cortaillod Port-Conty : Annecy-le-Vieux/La Tour (4832±41 B.P.), Sévrier/Les Choseaux (4775±75 B.P.) et Conjux/La Chatière (4730±180 B.P.). Mais, à la différence des lacs du Jura, aucune couche ni mobilier ne sont conservés.

- Deuxième moitié du IVème millénaire

Période peu représentée avec seulement quelques pieux à St-Pierre-de-Curtille/Hautecombe (4540±50 B.P.).

NÉOLITHIQUE RÉCENT

La fin du IVème millénaire, connue dans le Jura et la Suisse occidentale, n'est observée dans notre domaine que par quelques sites ayant livré peu ou pas de matériel : Annecy-le-Vieux/Le Petit Port (-3058 à -3026) et sur le Léman, Thonon-les-Bains/Le Port de Rives (-3094 à -3049) et Chens-sur-Léman/Beauregard (d'environ - 3043 à -3035).

NÉOLITHIQUE RÉCENT/FINAL

Sept sites datés par le radiocarbone des 29/26ème s. av. notre ère attestent, pour tous les lacs, une forte densité d'installations attribuables au groupe de Lüscherz : Conjux/La Chatière, Messery/Crozette, Aiguebelette-le-Lac/Beau Phare, St-Alban-de-Montbel/La Petite Ile, Thonon-les-Bains/Rives, Novalaise/Le Gojat, Brison-St-Innocent/Mémars. Les rares vestiges recueillis sont très comparables à ceux de Charavines/Les Baigneurs, seul gisement de référence pour cette période et dont l'occu-

Réf lab	Date BP	Commune/Site	L	M
ARC 246	4090±50	Thonon-les-Bains/Rives 1	Le	P
ARC 369	4450±55	St-Jorioz/Les Marais	An	P
ARC 371	5055±60	St-Pierre-de-Curtille/Hautecombe	Bo	P
ARC 473	4775±75	Sévrier/Les Choseaux	An	P
ARC 524	3465±50	Sévrier/Les Mongets	An	P
ARC 528	3595±50	Sévrier/Les Mongets	An	P
ARC 584	Actuel	Yvoire/"Epave"	Le	Ep
ARC 671	5050±55	St-Jorioz/Les Marais	An	P
ARC 697	125±50	Sévrier/Vers Rives	An	P
ARC 705	2265±50	Doussard/Le Bout du Lac	An	P
ARC 706	5315±50	Sévrier/Les Charretières	An	P
ARC 736	1240±50	Sévrier/Le Prieuré	An	P
ARC 743	2745±50	Aix-les-Bains/Le Grand Port	Bo	P
ARC 770	1355±120	Aix-les-Bains/Le Grand Port	Bo	Pq
ARC 827	1305±50	Duingt/Débarcadère	An	M
ARC 922	1866±50	Chindrieux/Châtillon Port	Bo	P
ARC 1022	4540±50	St-Pierre-de-Curtille/Hautecombe	Bo	P
ARC 1028	5135±50	St-Jorioz/Les Marais	An	P
ARC 1071	2640±50	Aix-les-Bains/La Culaz	Bo	P
ARC 1076	315±50	Annecy/Quai E. Chappuis	An	P
ARC 1077	3490±50	Sévrier/Les Mongets	An	P
ARC 1126	2998±40	Chindrieux/Châtillon Port	Bo	P
ARC 1139	8735±64	Annecy/Quai E. Chappuis	An	No
ARC 1154	2728±49	Tresserve/Les Fiollets	Bo	Pq
ARC 1157	8885±60	Annecy/Quai E. Chappuis	An	No
ARC 1163	774±40	Annecy/Quai E. Chappuis	An	M
ARC 1164	420±40	Annecy/Quai E. Chappuis	An	No
ARC 1220	4832±41	Annecy-le-Vieux/La Tour	An	P
ARC 1222	4920±47	St-Jorioz/Les Marais	An	P
ARC 1265	2693±40	Sciez/Songy	Le	P
ARC 1308	787±47	Annecy/Quai E. Chappuis	An	Os
ARC 1338	1125±40	Annecy/Chenal du Thiou	An	Pq
ARC 1491	4000±40	Brison-St-Innocent/Mémars	Bo	Pq
ARC 1562	4170±45	Messery/Crozette	Le	P
ARC 1563	3950±45	Messery/Crozette	Le	P
ARC 1578	1770±40	Nernier/Rue de la Tour	Le	P
ARC 1579	110±40	Yvoire/Les Bouchets	Le	Pq
ARC 1653	345±40	St-Gingolph/Les Noirettes	Le	Ep
ARC 1654	5720±50	Thonon-les-Bains/Ripaille	Le	B?
ARC 1656	2085±40	Anthy-sur-Léman/Les Recorts	Le	P
ARC 1691	3645±40	Brison-St-Innocent/Mémars	Bo	Pq
ARC 1705	3065±40	Chens-sur-Léman/La Vorge	Le	P
Gif 5625	3890±70	Sévrier/Le Prieuré	An	P
Gif 6044	4580±70	Annecy-le-Vieux/Le Petit Port	An	P
Gif 6045	4590±70	Annecy-le-Vieux/Le Petit Port	An	P
Gif 6485	860±50	Sévrier/Le Prieuré	An	P
Gif 6486	2950±60	Duingt/Le Roselet	An	P
Gif 6487	2880±60	Duingt/Le Roselet	An	P
Gif 6687	Actuel	Sévrier/Le Crêt d'Anfon	An	Pq
Gif 6688	2090±50	Sévrier/Le Crêt d'Anfon	An	Pq
Gif 6700	2600±80	Chanaz/Portout	Bo	P
Gif 6770	3760±60	Conjux/La Chatière	Bo	No
Gif 6771	4250±70	Conjux/La Chatière	Bo	No
Gif 7338	4010±70	Chanaz/Portout	Bo	M
Gif 7339	1590±70	Chanaz/Portout	Bo	P
Gif 8142	1940±50	Annecy/Le Port	An	No
Gif 8143	3440±70	Annecy/Le Port	An	No
Gif 8144	3035±55	Annecy/Le Port	An	No
Gif 8145	3910±50	Talloires/Angon	An	No
Gif 8146	4730±180	Conjux/La Chatière	Bo	No
Gif 8337	2770±50	St-Alban-de-Montbel/La Petite Ile	Ai	P
Gif 8338	4020±50	Novalaise/Le Gojat	Ai	P
Gif 8339	4160±50	Aiguebelette-le-Lac/Beau Phare	Ai	P
Ly113 oxa	3745±70	Chindrieux/Châtillon	Bo	No
Ly114 oxa	2830±55	Chindrieux/Châtillon	Bo	No
Ly 6924	2700±45	Chindrieux/Châtillon	Bo	No

Tab. 2 : Analyses C14 réalisées depuis 1980 sur des vestiges lacustres du domaine savoyard. Mêmes abréviations que le tableau 1. Pour ARC, jusqu'à 1222 : âge brut ; au delà : âge conventionnel avec $\delta\,^{13}C$ estimé de -25 ‰. Pour Gif, âge conventionnel avec $\delta\,^{13}C$ mesuré.

pation est située par la dendrochronologie de -2670 à -2580 (Bocquet, 1997, p. 307).

NÉOLITHIQUE FINAL

La fin du Néolithique, connue par des trouvailles anciennes, a été mise en évidence à Messery/Crozette (3950±45 B.P.), Talloires/Angon (-2446, -2435) et Conjux/La Chatière (-2440). Une perduration des occupations jusqu'au moins au 21ème s. av. notre ère est envisageable sur la base, d'une part, de datations malheureusement anciennes et peu précises (3740±130 B.P. pour la pirogue de Mémars sur le lac du Bourget) et d'autre part d'un âge plus fiable obtenu récemment sur des piquets formant une palissade à Mémars (3645±40 B.P.).

BRONZE ANCIEN

Ponctuellement identifiée sur la rive suisse du Léman, cette période a été reconnue à Sévrier/Les Mongets (3595±50, 3490±50 et 3465±50 B.P., abattages de -1716 à -1665, avec réserve), sur une petite station au plan particulièrement lisible (palissades, chemin de rondins, alignements d'habitations).

BRONZE FINAL

Pour les trois lacs, 22 sites ont fourni 27 séquences dendrochronologiques indiquant des abattages de -1071 à -814 se répartissant en trois groupes, deux pour la phase moyenne et un pour la phase récente du Bronze final alpin.

LA TÈNE

L'Age du Fer n'est représenté que par une structure en limite de berge (appontement ?) à Doussard/Le Bout du Lac (2265±50 B.P.).

ANTIQUITÉ À ÉPOQUE MODERNE

La période de 2000 B.P. à l'Actuel, est documentée par 15 dates. Il est à noter que pour la charnière X-XIème siècle, il n'a pas encore été trouvé en domaine savoyard d'installation de l'ampleur de celles des rives du lac de Paladru comme Colletière occupé de 994 à 1021 (Colardelle et Verdel, 1993). Les indices repérés à ce jour ne correspondent plus à des occupations littorales au sens strict mais sont seulement des aménagements des rives, marquant ainsi une rupture dans la dynamique lacustre et dans l'emprise humaine sur le terroir.

4 - BILAN ET PERSPECTIVES

CHRONOTYPOLOGIE

Les sondages concernent les stations du Néolithique et de l'Age du Bronze. Ils sont encore peu nombreux (8) et de surfaces réduites. Malgré tout, ils ont livré des séries importantes de matériel repérées en stratigraphie et pour la plupart calées en chronologie absolue. Ces nouveaux jalons chronotypologiques, associés à des observations taphonomiques, montrent qu'il est nécessaire d'aborder les collections du siècle dernier avec la plus extrême prudence (récoltes en surface des gisements

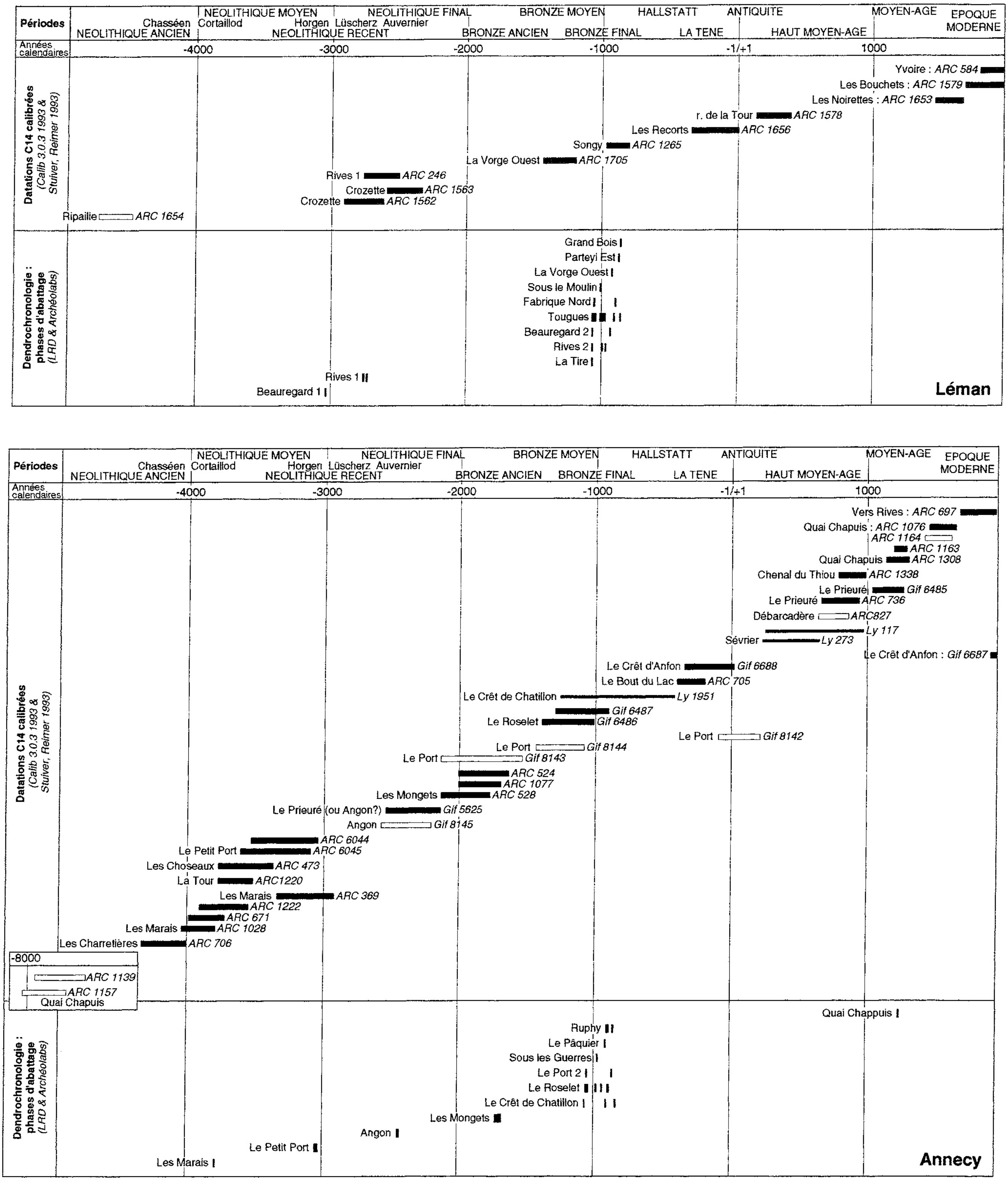

Fig. 2 : Bilan (en avril 1998) des datations par le radiocarbone et par la dendrochronologie pour les sites du lac Léman et du lac d'Annecy. Pour le radiocarbone, segment principal de la date calibrée à deux sigma ; en noir, date sur pieu, objet ou embarcation et en blanc encadré, sur niveau organique ou bois "naturel" ; simple largeur pour les dates des années 1960-70 et double largeur pour les dates postérieures à 1980.

dans des horizons de condensation, provenances douteuses ou incorrectes de certains lots d'objets, mélanges de collections...).

CHRONOLOGIE, CLIMAT, CULTURE ET TAPHONOMIE

Plusieurs périodes ne sont pas représentées dans le cadre chronologique précédemment esquissé (fig. 4). Ces hiatus sont de plusieurs types :

- Certaines périodes sont attestées par du mobilier (fin du Néolithique, phase ancienne du Bronze final à Annecy/ Le Port). Il s'agit de lacunes d'observation incitant à reprendre les investigations dans certaines portions du littoral.
- L'influence du climat est prépondérante pour le Bronze moyen et le début de l'Age du Fer marqués par des péjorations climatiques. Pour la transition Néolithique final-Bronze ancien, l'absence de stations, alors que

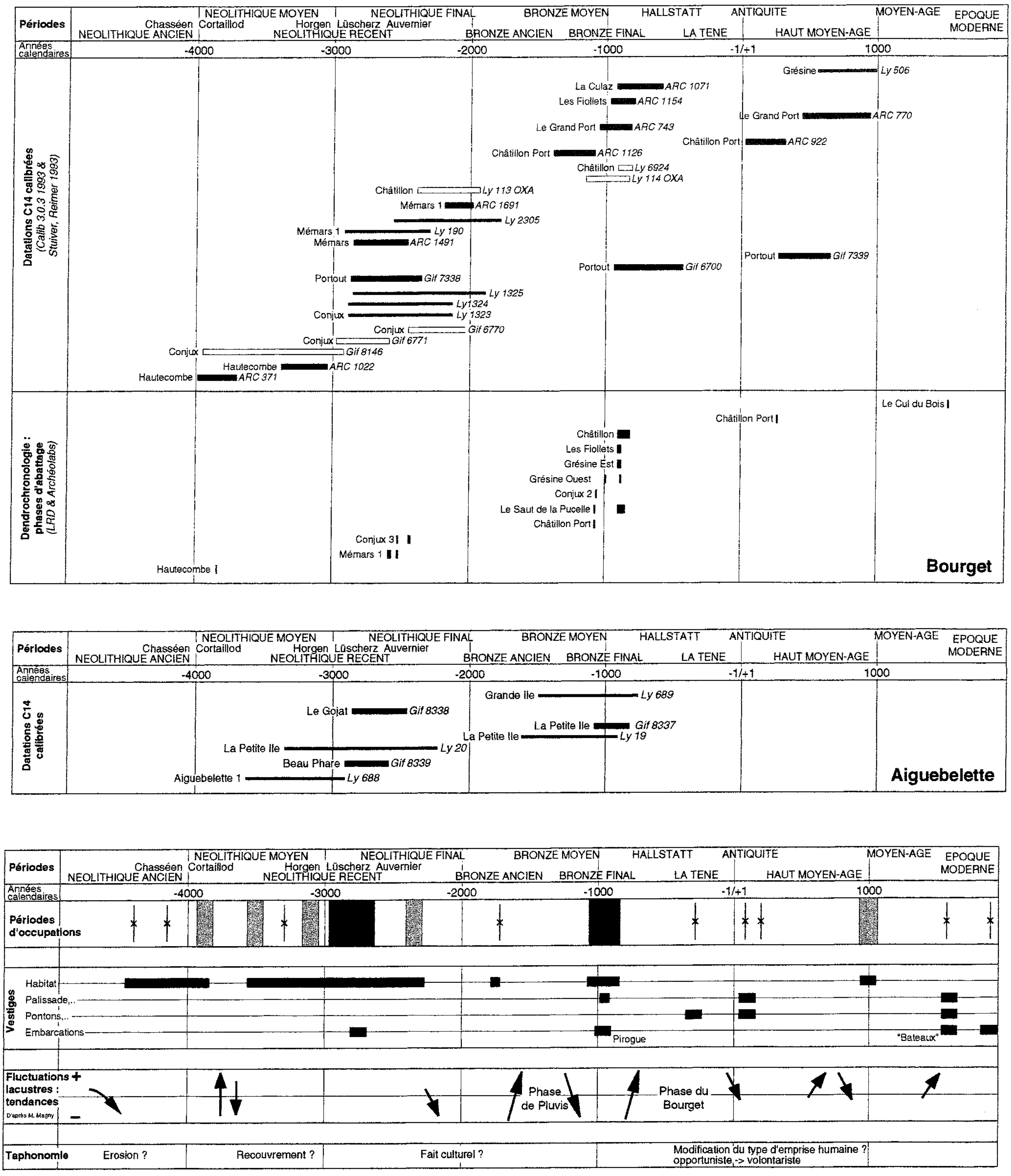

Fig. 4 : Périodes d'occupation actuellement reconnues et nature des vestiges. Parallèle avec les principales fluctuations du niveau lacustre.

se développe une phase régressive majeure, permet d'envisager des phénomènes culturels (Magny, 1993).

- Enfin, il apparaît nécessaire de prendre en compte l'évolution taphonomique des rivages (érosion, exondation, enfouissement par progradation des berges) comme biais dans le cadre de la restitution de l'évolution des peuplements.

RÔLE ET EMPLOI DES DATATIONS PAR LE RADIOCARBONE

- Radiocarbone et dendrochronologie

Si la dendrochronologie est quasi-exclusive pour l'Age du Bronze et de plus en plus performante pour le Néolithique, le radiocarbone reste un outil essentiel dans de nombreux cas. L'utilisation d'une démarche rigoureuse dans l'échantillonnage permet d'augmenter l'efficacité des datages (sélection des échantillons, mise en évidence de groupes par la dendrochronologie...). Ainsi le radiocarbone apporte une information chronologique pour des groupes ne pouvant être synchronisés avec des références (séquences trop courtes, absence de référence régionale ou pour l'essence concernée). Dans d'autres cas (pieux sans matériel associé, périodes peu étayées), il peut guider la recherche de la position sur les références.

- Calibration

Lorsque le ^{13}C n'est pas dosé, il apparaît souhaitable pour les bois gorgés d'eau de préférer à la valeur standard, une valeur estimée plus faible, de l'ordre de -27 à -28,7 ‰ (ainsi que l'indiquent les quelques données disponibles).

- Séquences sédimentaires

En dehors des sites eux-mêmes, le radiocarbone, grâce aux récentes facilités d'accès aux analyses à l'accélérateur, devient d'un emploi fréquent lors de l'étude sédimentologique et palynologique de colonnes sédimentaires prélevées par carottage et destinées à la reconstitution des paléoenvironnements. Le corpus, en cours de constitution, débute actuellement à 12490±90 B.P. à Sévrier/Les Mongets sur le lac d'Annecy (travaux de M. Magny et H. Richard, Laboratoire de chrono-écologie, Besançon).

DATATIONS EN COURS ET PRÉVUES

Le bilan sommairement présenté ici est amené à être rapidement dépassé. Les sites pour lesquels nous ne disposons encore que des données des années 70 (aux sigma très 'larges') seront prochainement documentés. Après la prospection-inventaire du lac Léman de 1995 à 1997, celle du lac d'Aiguebelette s'est achevée en avril 1998 (direction A. Marguet). Les analyses actuellement en cours concernent principalement le Néolithique, l'Age du Bronze et l'Antiquité. Dans les deux prochaines années, un travail similaire sera mené sur le lac du Bourget avec également des datations systématiques. Parallèlement, de nouveaux sondages seront réalisés sur des sites de l'Age du Bronze final.

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RADIOCARBON DATING OF METALWORK FROM THE BRITISH BRONZE AGE

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Abstract : We report here how radiocarbon dating has been used to define the chronology of British Bronze Age Metalwork. The project has depended on a rigorous selection of material, and the use of Bayesian statistics in the calibrated dates. It also requires AMS dating at relatively high precision. The results very clearly show how AMS radiocarbon dating may be deployed for constructing absolute chronologies which previously has not been possible.

Résumé : Nous exposons ici comment la datation radiocarbone a été employée pour définir la chronologie des objets en métal de l'Age du Bronze de Grande-Bretagne. Le projet a reposé sur une sélection rigoureuse du matériel et sur l'emploi de la statistique Bayesienne pour la calibration des dates ; la datation par accélérateur a demandé beaucoup de précision. Les résultats montrent très clairement comment la datation par accélérateur peut être utilisée pour construire des chronologies absolues.

Key-words : Radiocarbon dating, AMS, metalwork, bronze.

Mots-clés : Datation par le carbone 14 en SMA, métallurgie, bronze.

INTRODUCTION

The reduction in sample size requirement to about 1 milligram carbon for radiocarbon dating, using AMS methods, has enabled both a wider range, and a greater selectivity, of archaeological material to be directly dated. This has made possible a shift towards dating objects for their intrinsic, rather than for their contextual, information. The dating of metalwork provides a striking example since depositional contexts often lack stratigraphic control, but there is rich typological information. It is of course typology in conjunction with the evidence of associations which has been used to establish synchronisms and successions between different forms of metalwork. This has relied on assessment of affinity and thus synchrony between different regional sequences. Radiocarbon dating is an alternative, and here we show how it provides an independent chronology for Britain. A fuller account of this work, especially from the archaeological perspective, is to be found in Needham *et al.,* 1998.

PROJECT DESIGN

The most critical technical demands of the radiocarbon measurement are those of (i) sufficient precision (to be useful a standard deviation of ~ 40 years is needed) and (ii) clear identification of the material to be dated (so that the possibility of incorporation of carbon from other sources can be discounted or chemically removed). Most samples were of wood, identified to species ; this often survives thanks to the biocidal properties of high local concentrations of copper leaching from the metalwork, as well as the frequent occurrence of metalwork deposited in wet environments.

However, using a radiocarbon measurement to construct part of a chronological framework for bronze metalwork raises, in an acute form, many of the issues generally encountered when using radiocarbon dates in archaeology. The following have to be addressed :-

(a) the relationship between the radiocarbon date of the sample and both the time of use, and the time of manufacture, of the metal object,

(b) how the object relates typologically to the assemblage it is held to represent,

(c) how the object relates contextually to its "assemblage", ie. does it come from an associated find itself ?

(d) the extent to which a given metalwork assemblage is represented by the examples selected for radiocarbon measurement,

(e) the interpretation of the statistical properties of the calibrated data in terms of synchronicity and succession,

(f) the extent to which radiocarbon date results may be used to refine the selection and coherence of the assemblages being measured.

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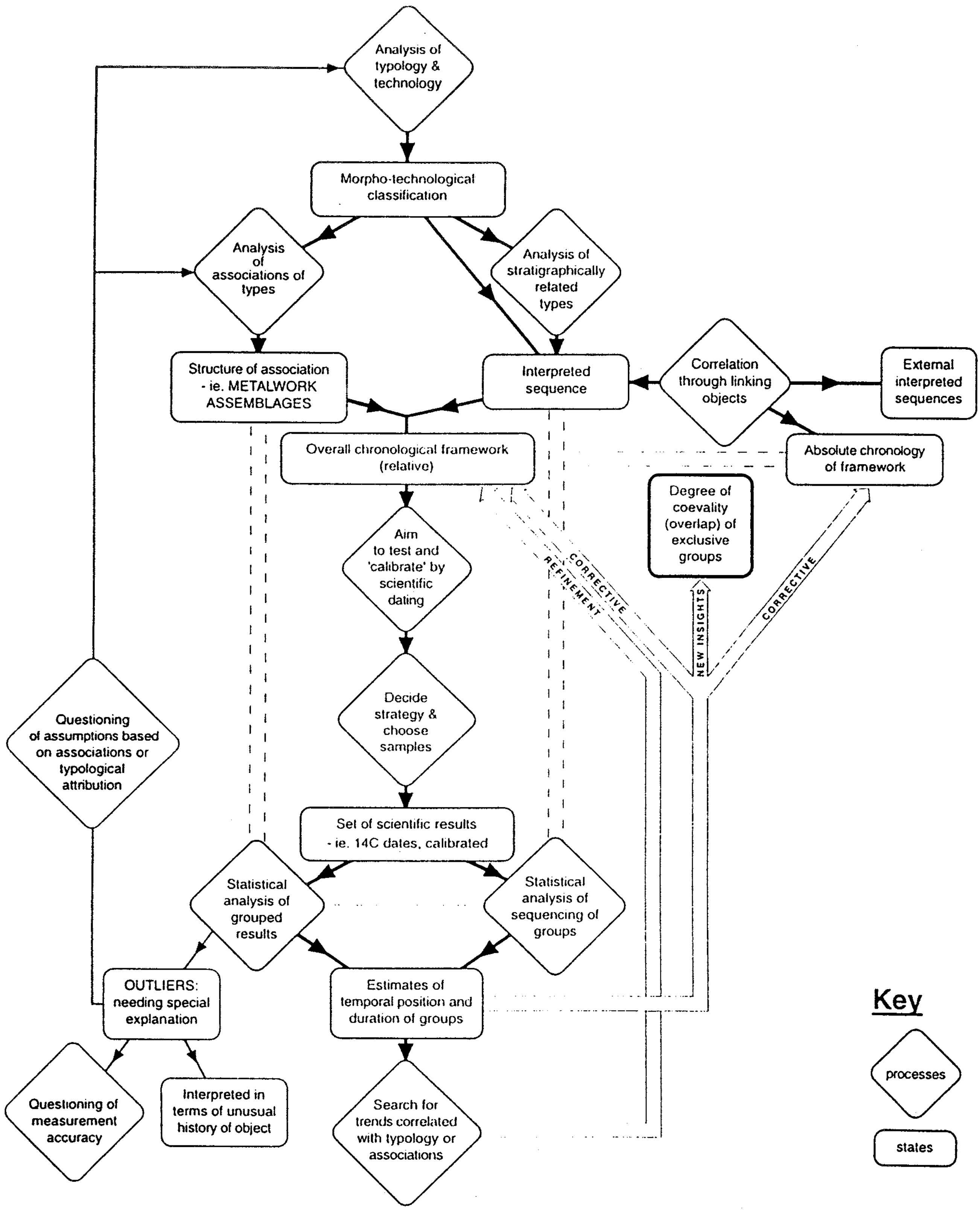

Fig. 1 : A flow diagram showing the logical structure behind the dating programme, and in particular how the relationship between sample, assemblage, metalwork type, and dating for a given phase is established.

Figure 1 shows a flowchart which delineates how the relationships listed above are implicated in the dating of archaeologically defined assemblages.

THE MATERIAL

For the most part, only material with direct functionally associated organic remains was sampled and measured. A few previously run dates were drawn into the interpretation ; these included other types of association, such as co-occurrence within the same closed context as in a pit fill, which can be considered reasonably direct. In any case, all associations were critically considered and the type of association is noted in table 1. The material was at the same time selected to be diagnostic of recognised metalwork assemblages, and is so identified here. Overall, for this first project, this has led to some geographical bias, and a temporal focus on the Middle

Assemblage	Metalworktype	County & site	Context	Association	Organic identification	Lab. ref.	Result BP
Migdale	Bead, tubular sheet	Highland Region, Migdale	hoard, dryland	1 a core	twig	OxA-4659	3655±75
Willerby	Flat axe, decorated, class 4E	Norfolk, Methwold, Whiteplot	single, wetland	1 b misc.	*Taxus baccata*	OxA-4714	3995±75
Acton	Palstave, broad-bladed, shield pattern	Norfolk, Thetford, Melford Common	? area find/river	1 a shaft	*Fraxinus sp*	OxA-4651	3220±80
Acton & Taunton	Spearhead, side-looped	Greater London, Mortlake, Thames	river find	1 a shaft	*Fraxinus sp*	OxA-5948	3225±65
Acton & Taunton	Spearhead, basal-looped, leaf	Greater London, Strand nr Kew, Thames	river find	1 a shaft	*Fraxinus sp*	OxA-5949	3110±50
Acton & Taunton	Spearhead, basal-looped, leaf	Greater London, Wandsworth, Thames	river find	1 a shaft	*Fraxinus sp*	OxA-6177	3055±50
Acton & Taunton	Spearhead, basal-looped, leaf	Buckinghamshire, Datchet, Thames	river find	1 a shaft	*Fraxinus sp*	OxA-5196	3035±40
Acton & Taunton	Spearhead, side-looped	Lincolnshire, Ruskington	single, dryland	1 a shaft	*Betula sp*	OxA-5958	0840±40
Taunton	Palstave, broad-bladed, shield + midrib	Norfolk, Woodbastwick	? burnt mound	1 b charcoal	Maloideae	OxA-4505	2865±45
Later MBA	Tanged razor, bifid	East Sussex, Blackpatch	settlement pit	2 pit group	grain	HAR-2940	3020±70
Taunton / Penard	Palstaves, looped, tridents & midribs	Hereford &Worcs, Lambscott, Gamage Farm	hoard, dryland	2 pit group	charcoal	OxA-1762	3210±70
Taunton / Penard	Palstaves, looped, tridents & midribs	Hereford &Worcs, Lambscott, Gamage Farm	hoard, dryland	2 pit group	charcoal	OxA-1761	3000±70
Penard	Rapier, group IV, Appleby type	Oxfordshire, Sandford-on-Thames	river group	1 a hilt	Maloideae	OxA	failed
Penard	Spearhead, basal-looped, triangular	Cambridgeshire, St. Ives, Meadow Lane	? wet-land	1 a shaft	*Fraxinus sp*	OxA-5187	3045±55
Penard	Spearhead, basal-looped, triangular	Gloucestershire, Fairford, Dudgrove Farm	? single	1 a shaft	" wood "	OxA-1526	3030±100
Penard	Spearhead, pegged, tear-drop blade	Greater London, Hammersmith, Thames ballast	? river / foreshore	1 a shaft	Maloideae	OxA-5954	3025±55
Penard	Spearhead, basal-looped, triangular	Greater London, Isleworth, Thames	river find	1 a shaft	*Fraxinus sp*	OxA-5953	3015±45
Penard	Palstave, Transitional type	Greater London, Barnes, Thames	pile dwelling' in river	1 a shaft	*?Fraxinus sp*	OxA-5951	2980±45
Penard	Spearhead, sword-bladed	Buckinghamshire, Taplow, Thames	river find	1 a shaft	*Fraxinus sp*	OxA-4504	2965±65
Penard	Spearhead, basal-looped, triangular	Greater London, Mortlake, Thames ballast	? river / foreshore	1 a shaft	*Corylus sp*	OxA-5952	2965±45
Penard	Ferrule, conical	Cambridgeshire, Fengate Power Station	wetland ritual complex	1 a shaft	*Fraxinus sp*	OxA-5959	2965±45
Penard	Ferrule, conical	Buckinghamshire, Amerden, Thames	river find	1 a shaft	*Fraxinus sp*	OxA-5183	2930±40
Penard	Ferrule, conical	Surrey, Chertsey, Mixnam's East	single, ?palaeo-channel	1 a shaft	*Quercus sp*	OxA-4653	2910±55
Penard-Wilburton	Socketed axe, square-section	Greater London, Twickenham, Thames	river find	1 a shaft	*Fraxinus sp*	OxA-5950	2910±45
Wilburton	Chape, long tongue	Greater London, Thames	river find	1 a shaft	*Fraxinus sp*	OxA-4656	3005±75
Wilburton	Chape, long tongue	Greater London, Battersea/Chelsea, Thames	river find	1 a shaft	*Acer sp* bark *Corylus sp* wood	OxA-4503	2930±55
Wilburton	Ferrule, long tubular	Greater London, Kingston, Thames	river find	1 a shaft	Maloideae	OxA-4502	2925±50
Wilburton	Spearhead, pegged, round midrib	Cambridgeshire, Wilburton Fen	wetland hoard	1 a shaft	*Acer campestre*	OxA-5036	2920±50
Wilburton	Chape, long tongue	Thames	river find	1 a shaft	*Fraxinus sp*	OxA-5197	2910±50
Wilburton	Spearhead, lunate-opening	Greater London, nr. Hampton Court, Thames	river find	1 a shaft	*Fraxinus sp*	OxA-5955	2900±45
Wilburton	Spearhead, lozenge section	Cambridgeshire, Wilburton Fen	wetland hoard	1 a shaft	*Fraxinus sp*	OxA-5035	2900±45
Wilburton	Spearhead, fillet-defined	Cambridgeshire, Wilburton Fen	wetland hoard	1 a shaft	*Fraxinus sp*	OxA-5034	2890±45
Wilburton	Spearhead, fillet-defined	Surrey, Thames, Staines (?)	river find	1 a shaft	*Fraxinus sp*	OxA-5956	2850±50
Wilburton	Chape, long tongue	Greater London, nr. Teddington, Thames	river find	1 a sheath	*Fraxinus sp*	OxA-5198	2820±70
Wilburton	Spearhead, lunate-opening	North Yorkshire, Thirsk	wetland hoard	1 b misc.	*Juncus sp*	OxA-4715	0455±45
Blackmoor	Spearhead, decorated, slender leaf blade	Hampshire, Blackmoor	wetland hoard	1 a shaft	*Fraxinus sp*	OxA-5186	2840±40
Blackmoor	Spearhead, stepped blade	Hampshire, Blackmoor	wetland hoard	1 a shaft	*Fraxinus sp*	OxA-5184	2830±65
Blackmoor	Spearhead, stepped blade	Hampshire, Blackmoor	wetland hoard	1 a shaft	*Quercus sp*	OxA-5185	2770±50
LBA with early features	Spearhead, offset blade bases	Berkshire, near Windsor, Thames	river find	1 a shaft	Maloideae	OxA-4506	2825±50
LBA with early features	Spearhead, fillet-defined	Surrey, Shepperton, Thames ballast	?river find	1 a shaft	Maloideae	OxA-4655	2760±50
Ewart Park	Spearhead, decorated mouth, flame blade	Surrey, Staines, Thames	river find	1 a shaft	*Fraxinus sp*	OxA-5957	2810±45
Ewart Park	Chape, bag-shaped	Norfolk, Thetford, Melford Common	? area find/river	1 a scabbard	*Fraxinus sp*	OxA-4716	2780±50
Ewart Park	Spearhead, flared mouth	Norfolk, Blackborough Pit	? wetland	1 a shaft	*Fraxinus sp*	OxA-5188	2780±35
Ewart Park	Socketed knife, Thorndon type	Surrey, Chelsham, Nore Hill	area find, enclosure	1 a handle	*Quercus sp*	OxA-4654	2765±45
Ewart Park	Socketed axe, class B	Cambridgeshire, Fengate Power Station	wetland ritual complex	1 a shaft	Prunoideae	OxA-5976	2740±45
Ewart Park	Socketed gouge, flat collar moulding	Anglesey, Cors Bodwrog	hoard in bog	1 a handle	*Salix/Populus*	OxA-4652	2720±45
Ewart Park	Socketed axe, class B	Powys, The Breiddin	hillfort settle-ment	1 a shaft	Willow	BM-798	2704±50
Ewart Park	Spearhead, flame blade	Kent, Birchington, Minnis Bay	beach, single	1 a shaft	*Fraxinus sp*	OxA-5962	2685±60
Ewart Park	Socketed sickle, Thames type	East Sussex, Eastbourne, Shinewater Levels	wetland, settlement	1 a handle	*Acer sp**	OxA-6176	2655±50
Ewart Park	78 varied bronzes	Surrey, Egham, Petters Sports Field	hoard in settlement complex	3 TAQ	Animal bone	BM-1624N	2630±70
Ewart Park	78 varied bronzes	Surrey, Egham, Petters Sports Field	hoard in settlement complex	3 TPQ	Animal bone	BM-2596	2610±60
Ewart Park	Socketed chisel, morticing	Norfolk, Feltwell, Whiteplot	area find / ? hoard	1 a handle	*Fraxinus sp*	OxA-5977	2620±45
LBA(?)	Socketed gouge, plain	Cambridgeshire, Fengate Power Station	wetland ritual complex	1 a handle	? Prunoideae	OxA-5960	3230±45
LBA	Fleshhook, double prong	Co Antrim, nr. Ballymoney, Dunaverny	bog	1 a shaft	*Quercus sp*	OxA	failed
LBA	Spearhead, pegged	Co Durham, Jackscar Cave	cave (?)	from socket'	wood "	OxA-121	2670±120
LBA(?)	Lump with flesh-hook fragment	Essex, Little Bentley	single, dryland	1 b charcoal	*Alnus sp*	OxA-4657	0525±50
Llyn Fawr	Socketed axe, Sompting type	Greater London, Kew Deer Park, Thames	river find	1 a shaft	*Salix/Populus*	OxA-4658	2545±55

All organic identifications by Caroline Cartwright, with * identification by Maisie Taylor

Table 1 : Radiocarbon results obtained on organic material associated with the metalwork.

and Late Bronze Age sequence. We note that the identification of wood species and estimation of growth stage of the wood actually used has been particularly useful in evaluating the relationship. About 20 mg of wood or 5-10 mg charcoal was removed, carefully examined for signs of preservatives, and treated using standard methods. These can be summarised as acid-base-acid treatment for charcoal, and additional chlorite bleach for wood cellulose, and a preliminary solvent extraction where application of preservative was thought to be a possibility.

RESULTS

Radiocarbon dates are presented in the table. Note that they are grouped according to the metalwork assemblage they are considered to represent. Cases for which attribution of a type to an assemblage is not straightforward are discussed in detail in Needham *et al.,* 1998.

INTERPRETATION

The careful selection of the sample generally ensures that issues listed under (a) (above) do not invalidate a radiocarbon date of an object from representing a date for the metalwork assemblage for which it is diagnostic. There can not, however, be foresight of the later re-use of a Bronze Age object, such as seems to have occurred with a spearhead from Ruskington (OxA-5958). As figure 1 shows, there is room for subsequent re-definition of what constitutes the best choice of objects as constituting an assemblage, or of trends within an assemblage ; in practice, this dating project produced a rather coherent picture : the radiocarbon dates rarely show any inconsistencies within assemblages, and no gross refinement of the structure of association has been necessary. The next phase of analysis was to agglomerate the dates for members of each assemblage into dates for 'phases', and to investigate the extent to which these phases are coeval and/or are sequential. This analysis has been carried out using the OxCal program.

Oxcal is able to estimate the start, end and duration of each phase on the assumptions that they were independent, and that the dates were on objects which are equally representative of all periods within the phase. Such an analysis shows the metalwork phases to have been sequential, and is consistent with there being little or no overlap between phases. This question can obviously be reexamined as more dates become available, thus improving the statistical reliability of the conclusion. Assuming there was indeed no overlap, it is possible to estimate the time at which the transition from one phase to the next took place. We should point out that OxCal operates by first calibrating the radiocarbon date to a calendrical date, and re-appraising the uncertainty in the spread of calendrical dates for the whole group or assemblage in the light of the assumptions of the whole corpus of dates. (This re-appraisal is based on Bayesian methods (Bronk Ramsey, 1997)).

DISCUSSION AND CONCLUSIONS

Firstly, the chronological framework proposed by the OxCal interpretation of the radiocarbon dates is somewhat different from what has been previously accepted, although the clear sequential ordering of assemblage types is identical with the traditional framework. This is illustrated in table 2.

There are, however, differences in the absolute dates, and in the estimated duration of phases. The shifts in date are mainly not unexpected, but the change for the Wilburton type assemblage is large and significant. It has important implications for Continental linkages in that Wilburton can no longer be considered to overlap substantially wtih Hallstatt B1 as was formerly believed. The framework also implies (strictly, it is consistent with) a quite limited period of transition between phases defined by assemblage types, and this will have repercussions for our understanding of the way these changes were effected.

Another important consequence of this project is the reconciliation of two largely divorced branches of Bronze Age evidence (Needham, 1996). The chronologies for settlement, landscape and pottery had already become dependent on calibrated radiocarbon measurements, whereas bronze metalwork still relied on the traditional links across Europe, linking ultimately, but at many removes, to historical chronologies of the eastern Mediterranean. By establishing an independent

Estimates for the **dates of transitions** between assemblages. Earlier chronological schemes compared with absolute dating. C-14 values result from statistical analysis. (Dates in BC/cal BC)

Metalwork assemblage		Burgess 1979	Gerloff 1980	Butler 1990	**C-14 Dating** 1997
		1450		1500	**~ 1500**
Acton	>				
		1375		1400	[1400] (inferred)
Taunton	>				
		1225/1200	1250	1300	**~ 1275**
Penard	>				
		1000	1000	1000	**~ 1140**
Wilburton	>				
		900	900		**~ 1020**
Blackmoor	>				
		900	830/800		**~ 920**
Ewart Park	>				
		700	700		**~ 800**
Llyn Fawr	>				
		600			[? 700](inferred)

Table 2 : A comparison of the various metalwork phases as dated through typology and linkage, and as dated by radiocarbon.

radiocarbon chronology for the metalwork, it is now possible to correlate it better with settlement phases, pottery groups, etc. The bifurcation of chronological structures between radiocarbon dated habitation sites and typologically dated bronze metal forms has finally been erased.

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RADIOCARBON DATING AND DENDROCHRONOLOGY OF NEOLITHIC AND LUSATIAN CULTURE SETTLEMENTS FROM CENTRAL POLAND

Anna PAZDUR, Michel FONTUGNE**, Tomasz GOSLAR*, Marek KRAPIEC***, Adam MICHCZYNSKI*, Jaroslaw ROLA**** and Magdalena SUCHORSKA - ROLA******

Abstract : Interdisciplinary analyses (radiocarbon, dendrochronological and archeologival dating) of material collected in systematical excavations in Biskupin and Zulawka Mala, Great Poland, permitted to distinguish several phases of occupation from the Neolithic and Bronze periods. Radiocarbon studies of the fortified settlement of the Lusatian Culture (Bronze Age and Early Iron Age) in Biskupin have been started in 1981 and were continued since 1994 with participation of Gliwice and Gif-sur-Yvette radiocarbon laboratories. The results of conventional radiocarbon dating of series of wood and charcoal samples collected from archaeological trenches locate the Biskupin settlement between 850 and 400 cal BC. Dendrochronological studies gave the date of 747 BC for the building of the fortified settlement. This date is supported by wiggle matching technique. Excavations at Site 1 in Zulawka Mala have been carried since its discovery in 1992. The material, identified in the course of excavations and analysed using ^{14}C and dendrochronological methods, enabled to distinguish eight occupation phases for Neolithic and Bronze Periods.

Résumé : Des analyses radiocarbone, dendrochronologiques et typologiques du matériel collecté pendant les fouilles des sites de Biskupin et Zulawka Mala en Grande Pologne ont permis de distinguer plusieurs phases d'occupation depuis le Néolithique jusqu'aux périodes de l'Age du Bronze. Les datations radiocarbone des occupations fortifiées attribuées à la civilisation Lusacienne (Ages du Bronze et du Fer ancien) à Biskupin ont été effectuées entre 1981 et 1994 par les laboratoires de Gliwice et de Gif-sur-Yvette. Les résultats des datations conventionnelles des bois et des charbons de bois prélévés dans les tranchées du site de Biskupin situent les occupations entre 850 et 400 ans avant J.-C. Les études dendrochronologiques donnent une date de 747 avant J.-C. pour la construction de l'ensemble fortifié, en accord avec celle obtenue par la technique de «wiggle matching». Au site de Zulawka Mala, découvert en 1992 le matériel identifié et analysé par le carbone 14 et la dendrochronologie a permis de distinguer huit phases d'occupation depuis le Néolithique jusqu'à l'Age du Bronze.

Key-words : Radiocarbon dating, dendrochronology, Neolithic, Late Bronze age, Early Iron age, Lusatian culture, Poland.

Mots-clés : Datation radiocarbone, dendrochronologie, Néolithique, Bronze final, 1er Age du Fer, Culture Lusacienne, Pologne.

INTRODUCTION

In this paper, we present the dating of two sites in the region of Great Poland, where archaeological excavations have been/are being proceeded on a large scale. The site in Biskupin is especially famous for its extremely well preserved wooden fortifications of settlement from the 1st millennium BC. Unfortunately, that fortified settlement appeared constructed through a short time during period where calibration of single radiocarbon date does not give unique result. The site in Zulawka Mala (Site 1), on the other hand, contains material from the time span of several thousand years, and each cultural horizon contains there significant admixture of material from other levels. Four supplementary methods were used to investigation of settlement ages : archeological evidence, dendrochronological studies, wiggle-matching procedure and radiocarbon dating.

BISKUPIN SITE

The history of Biskupin archaeological site (52°47'N, 17°44'E) starts with the flood controls of the Gasawka River in 1932, which resulted in a lowering of the water

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level in the Biskupin Lake and exposure of the remains of wooden structures sticking out of the water near the peninsula. The first excavations began there in 1934, and were held by J. Kostrzewski and Z. Rajewski from the University in Poznan. The fortified settlement at Biskupin has been classified as representing habitation of the decline of Lusatian Culture and was built on an island. The present location on peninsula is a result of climatically-induced hydrological changes. The carefully planned layout of the settlement and its construction indicate a high level of technical knowledge as well as advanced social organization. Basing on results of these excavations, the settlement was dated to 700-400 BC (Piotrowski, 1991).

The excavations have led to detailed reconstruction of the internal layout of the settlement, which is shown in fig. 1. Excavations conducted on Site 4, coinciding with the fortified settlement, have led to distinguishing six cultural layers :

Layer I - recent soil with mixed cultural material of the Lusatian Culture and Early Medieval pottery ;

Layer II - humus, containing mostly Early Medieval artefacts in the middle and eastern part of the site, and Lusatian artefacts in the western part of the site ;

Layer III - silt, containing Lusatian material mixed with Early Medieval artefacts ;

Layer IV - clay with wooden structures of the younger settlement ;

Layer V - sandy silt, separating two levels of wooden structures ;

Layer VI - black peaty soil with wooden structures of the older settlement.

The duration of the settlement was evaluated to ca. 120 yr by Z. Rajewski and to ca. 50 yr by other authors (*cf.* Miklaszewska-Balcer, 1991a). The opinions of different archaeologists concerning the age of the settlement were also highly diverse. One of this is based on analysis of certain features of the pottery from Site 4, and some authors claim this dating is confirmed by the alleged Scythian invasion, which has led to devastation of the settlement. However, the origin of a fragment of horse harness, the only artefact discovered at Biskupin which could be attributed to the Scyths, is highly problematic. According to recent detailed studies of the pottery from the Site 4 (including the so-called pseudo-cord ornaments of inlaid vessels characteristic to the Pomeranian culture) it is expected that the settlement arose in the Hallstatt C period and its downfall occured at the beginning of the Hallstatt D period. Taking into account the most recent chronologies of the Polish lowland cultures, based on contacts with territories of central and southern Europe, the Biskupin settlement is dated archaeologically to 650-500 BC (Miklaszewska - Balcer, 1991b).

RADIOCARBON DATING

First radiocarbon dates were obtained in Gif-sur-Yvette and Berlin Radiocarbon Laboratories in late sixties. The results were published by Pazdur *et al.*, (1991) together with results obtained on series of five samples of wood, charcoal and charred wood from the well stratified remnants of transverse street in the NW part of the settlement, discovered in test trench in 1981. Subsequent series of samples for radiocarbon studies were collected in 1991 and 1992 from three test trenches. The results are collected in Table 1. The radiocarbon dates have been calibrated using the program GdCALIB, developed in the

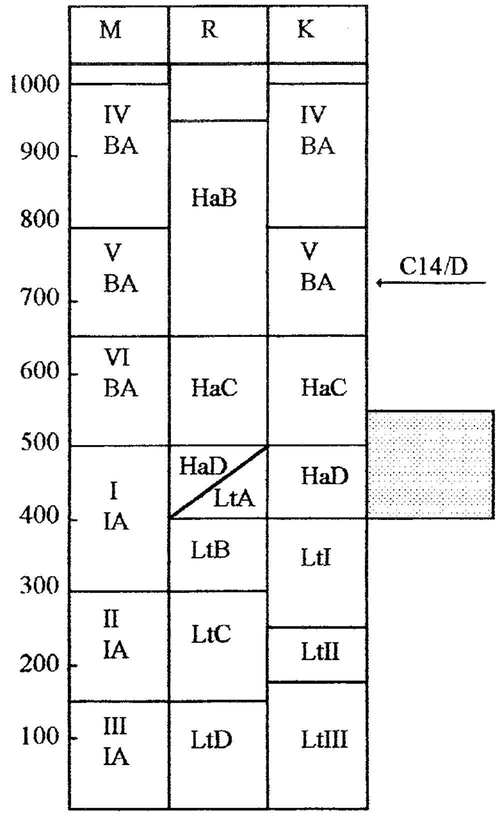

Fig. 1 : Comparison of chronological scales used in prehistoric studies with indicated actual archeological dating of the Biskupin settlement (dashed area) and results of dendrochronological and radiocarbon dating of establishing of the older settlement (arrow).

Gliwice Radiocarbon Laboratory (Pazdur and Michczynska, 1989). The calendar age is represented by the median of probability distribution of calendar age, and its uncertainty is given by the interquartile (50 % confidence) interval.

The joint probability distribution of calendar age of the series of related dates (fig. 2) enables us to distinguish two time intervals : the older (900-770 BC), and younger one (750-400 BC). These intervals correspond to the phases of older and younger settlements, documented in layers VI and IV (fig. 1).

DENDROCHRONOLOGICAL STUDIES

Samples for dendrochronological studies were collected in 1992 by T. Wazny and W. Piotrowski from three locations within the fortified settlement : A) remnants of the gate and transverse street ; B) breakwater near the gate ; C) rampart and roundabout street in NE part of the settlement. The locations are shown in fig. 1. Timbers in locations A and B were excavated ca. 50 years ago and are badly preserved because of atmospheric exposition. Some logs forming the breakwater which are still in the vertical position, partly sticking in the ground, are much more useful for dendrochronological dating as they are well preserved and some of them reveal presence of sapwood. Timbers at location C remained below water table and therefore preserved relatively well. Altogether 70 samples were collected for dendrochronological studies. It was possible to cross-correlate 60 tree-ring sequences which yielded 166 yr long floating oak

Sample	Lab. no.	Age BP	Median cal AD/BC	Age range cal AD/BC
		Early dates		
B1/81	Gd-3069	2470±50	610 BC	690 BC-530 BC
B2/81	Gd-3074	2470±50	610 BC	690 BC-530 BC
B3/81	Gd-3075	2610±40	805 BC	815 BC-795 BC
B4/81	Gd-3077	2690±50	860 BC	890 BC-840 BC
B5/81	Gd-3078	2710±40	865 BC	890 BC-840 BC
B1/66ZR	Gif-495	2510±150	625 BC	750 BC-500 BC
B2/66ZR	Gif-492	2570±150	680 BC	810 BC-550 BC
B3/66ZR	Gif-493	2570±150	680 BC	810 BC-550 BC
B4/66ZR	Gif 494	2670±150	840 BC	960 BC-670 BC
B1/70ZR	Bln-640	2615±100	770 BC	840 BC-620 BC
		Trench II/91		
B2/91	Gd-4767	1710±100	320 AD	240 AD-400 AD
B4/91	Gd-6554	1960±120	30 AD	70 BC-120 AD
B5/91	Gd-7008	2520±50	640 BC	720 BC-580 BC
B6/91	Gd-6556	2790±120	990 BC	1100BC-900 BC
B7/91	Gd-6566	2340±110	460 BC	610 BC-350 BC
B15/91	Gd-7012	2120±60	165 BC	240 BC-110 BC
B16/91	Gd-7016	2450±50	590 BC	690 BC-500 BC
B16A/91	Gd-6561	2570±110	670 BC	790 BC-570 BC
		Trench I/91		
B9/91	Gd-3537	2750±70	910 BC	970 BC-870 BC
B11/91	Gd-3539	2480±70	610 BC	700 BC-520 BC
B11/91	Gd-7015	2370±50	480 BC	540 BC-430 BC
B12/91	Gd-7017	2790±50	950 BC	990 BC-910 BC
B13/91	Gd-7035	2440±60	580 BC	690 BC-490 BC
B18/91	Gd-7034	2200±40	280 BC	330 BC- 230 BC

Tab. 1 : Conventional radiocarbon and calibrated ages of the samples from Biskupin site.

Figure 2

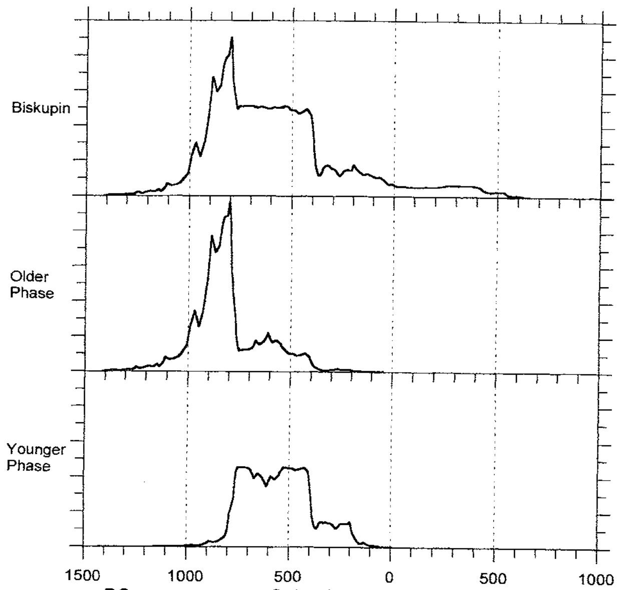

Fig. 2 : Cumulative probability distribution of calibrated ^{14}C ages of 25 samples from Biskupin. Cumulative probability distribution of calendar ages of samples from Biskupin, divided into two phases of the settlement.

chronology. That chronology was then synchronized with the oak chronology of Lower Saxony, elaborated by Leuschner and Delorme (1988). It was found that most of the trees used to construct the investigated elements of the Biskupin settlement were cut down in the late autumn or winter 738/737 BC (Wazny, 1993).

WIGGLE-MATCHING DATING

Series of six trunks from localities A and B with well-developed tree ring sequences has been selected for the purpose of wiggle-match dating. The samples were divided into subsamples comprising 10 tree-rings and yielding a series of 16 subsamples covering time span of 160 years. The wiggle-matching dating has been used for dating of tree ring sequences. In this method (Pearson, 1986) one looks for the age of the series which gives the best fit of obtained radiocarbon dates to the calibration curve. The quality of fit is represented by mean-square difference between ^{14}C ages of samples and radiocarbon ages derived from the calibration curve. Results of wiggle-matching procedure are shown in fig. 3. These results are in rough agreement with the dendrochronological dating.

ZULAWKA MALA SITE 1

Zulawka Mala is situated in the proglacial stream valley of the Notec and Warta rivers in its Wyrzysk section (Kozarski and Szupryczynski, 1958). The form of the valley is clearly visible in the surface relief (Krapiec *et al.*, 1996a), and it contains a system of 4 terrace levels. In Zulawka Mala, only 2 terraces are visible. A distinct form of terrace relief is a meridional dune, where the fragments of prehistoric constructions were discovered first.

Excavations conducted on Site 1 (53°05'N, 17°10"E) in 6 trenches have led to distinguishing 8 cultural layers, the main of these are :

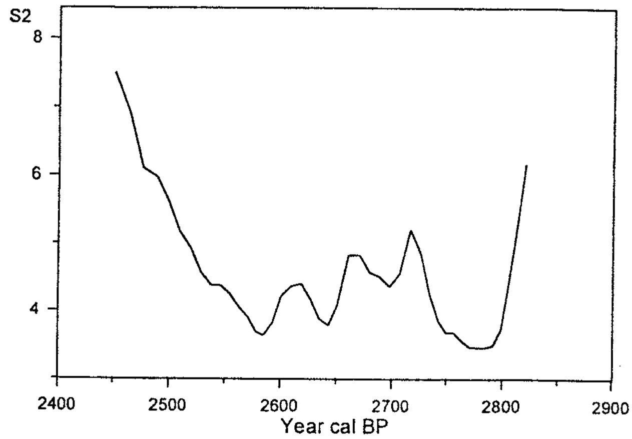

Fig. 3 : Results of the wiggle-matching procedure for radiocarbon dates from the oak trunks chronology of older settlement, Biskupin site.

Lusatian Culture - organogenic sediment with ceramic fragments, animal bones, charcoal, wooden structure and carpenter's wood - rods and an amount of odd chips dated to 2690±50 BP ;

Early Bronze Age - organogenic sediment with small pottery fragments, flintstone splinters, hewed rods and timbers, dated to 3750±50 BP ;

Globular Amfora Culture - pottery artifacts, flintstone and bone tools, animal bones and hewed wood belonging to the construction of «dike», have been found at the bottom of biogenic and top of sandy layer. A number of samples from the «dike» construction is dated to 4020±110, 4330±60, and 4470±60 BP ;

Funnel Beaker Culture - the artefacts have been found in the bottom layer of fine-grained sand. Only a few fragments of ceramics, but numerous boards of oak wood were found. Radiocarbon age of wood samples ranges from 4740±140 to 5190±60 BP.

RADIOCARBON DATING

Only well preserved, relatively small fragments of wood and charcoal were dated by radiocarbon method. The results of dating are presented in table 2.

The joint probability distribution of calendar age of all samples is shown in fig. 4. The maxima of probability density function correspond to separate phases of settlement. The particular samples have been attributed to one of 8 phases and prescribed to the following archeological cultures : I - Linear Band Ceramics, II - Late Band Ceramics, III - Funnel Beaker, IV - Globular Amphorae, V - Corded -Ware Pottery, VI and VII - Early Bronze Age and VIII - Lusatian Culture (Krapiec *et al.*, 1996b). By separate calibration of ^{14}C dates of individual phases, the probability distributions of dates belonging to given phase and the durations of phases have been determined. In the phases III i VIII two subphases : IIIa i IIIb oraz VIIIa i VIIIb, have been distinguished. The time intervals of particular phases are given in table 3.

DENDROCHRONOLOGICAL ANALYSIS

Dendrochronological investigations were carried out on an oakwood. Altogether, 82 samples were examined ; 77 samples of timbers from the dike and its neighbourhood, while the remaining 5 being subfossil oak stems naturally accumulated in the underlying peat and alluvial sediments. Dendrochronological investigations

Sample	Lab. no.	Age BP	Median cal BC	Age range cal BC
ZM1/82/93p	Gd-7419	2690±50	844	879 - 822
ZM1/156/94	Gd-11168	2800±80	954	1019 - 894
ZM1/280/94	Gd-10193	2950±70	1148	1222 - 1072
ZM1/8/92p	Gd-7288	3010±50	1237	1293 - 1179
ZM1/10/92p	Gd-7287	3110±50	1359	1400 - 1320
ZM1/80/93p	Gd-3755	3160±30	1425	1444 - 1412
ZM1/23/94	Gd-10169	3180±90	1440	1502 - 1367
ZM1/6/93	Gd-11167	3210±70	1474	1517 - 1431
ZM1/26/94	Gd-11171	3270±60	1540	1592 - 1487
ZM1/44/93p	Gd-10046	3390±110	1677	1771 - 1586
ZM1/11/92p	Gd-7289	3480±50	1791	1846 - 1746
ZM1/9/92p	Gd-6823	3700±110	2085	2192 - 1981
ZM1/91/93p	Gd-3688	3750±50	2145	2195 - 2076
ZM1/170/94	Gd-11170	3900±70	2364	2429 - 2294
ZM1/256/94	Gd-10195	3980±90	2481	2565 - 2385
ZM1/149/94	Gd-11172	4000±170	2514	2571 - 2455
ZM1/42/93p	Gd-10041	4020±110	2545	2665 - 2438
ZM1/92/93p	Gd-7410	4080±60	2626	2738 - 2563
ZM1/20/93p	Gd-7456	4130±40	2701	2812 - 2644
ZM1/7/92p	Gd-7286	4180±50	2748	2806 - 2689
ZM1/12/92p	Gd-7290	4200±50	2761	2809 - 2705
ZM1/35/93p	Gd-7496	4260±60	2809	2895 - 2752
ZM1/1/94	Gd-9394	4290±150	2899	3050 - 2735
ZM1/98/93p	Gd-7416	4330±60	2959	3009 - 2910
ZM1/54/93p	Gd-7495	4370±40	2986	3017 - 2945
ZM1/47/93p	Gd-7484	4420±40	3029	3078 - 2969
ZM1/117/93p	Gd-3687	4470±60	3155	3254 - 3059
ZM1/126/93p	Gd-6989	4740±140	3495	3603 - 3381
ZM1/76/93p	Gd-10035	4790±100	3558	3631 - 3461
ZM1/119/93p	Gd-7409	4890±60	3681	3720 - 3651
ZM1/6/92p	Gd-7270	4890±70	3682	3730 - 3643
ZM1/289/94	Gd-9399	5120±150	3922	4042 - 3812
ZM1/118/93p	Gd-3686	5190±60	3998	4047 - 3964
ZM1/129/93p	Gd-7492	5610±50	4428	4467 - 4394
ZM1/45/93p	Gd-7490	5690±50	4525	4571 - 4490
ZM1/290/94	Gd-11169	6050±80	4953	5025 - 4884
ZM1/43/93p	Gd-7500	6180±50	5120	5176 - 5070

Tab. 2 : Conventional and calibrated ages of the samples from Zulawka Mala Site 1.

I	II	IIIa	IIIb
5130-4950 BC	4530-4420 BC	4040-3870 BC	3690-3530 BC
IV	V	VI	VII
2950-2570 BC	2190-2040 BC	1830-1670 BC	1560-1410 BC
VIIIa	VIIIb		
1260-1120 BC	960-840 BC		

Tab. 3 : Established time intervals of occupation phases of the Zulawka Mala Site 1.

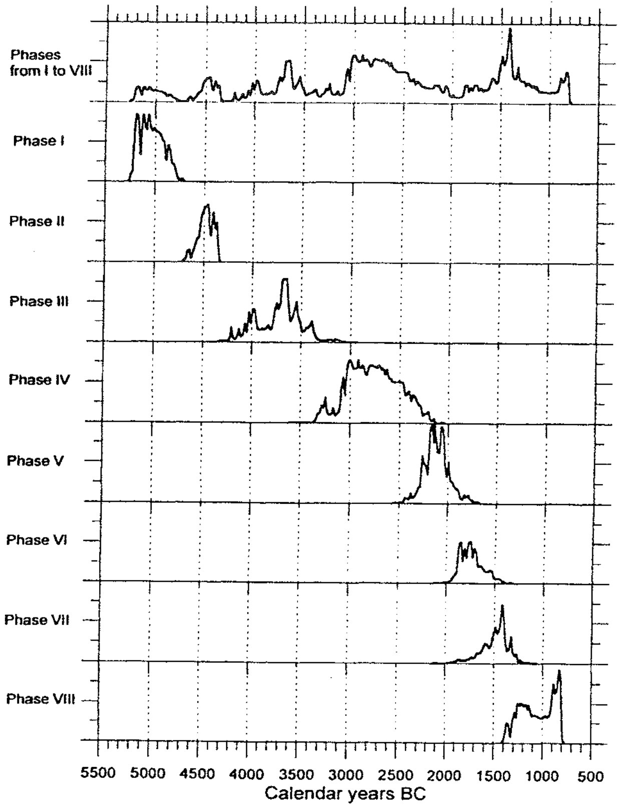

Fig. 4 : Cumulative probability distribution of calibrated ^{14}C ages of 37 samples from Zulawka Mala Site 1. Cumulative probability distributions of calendar ages of samples from Zulawka Mala, divided into phases corresponding to different cultures.

were carried out with standard, commonly used methods (Schweingruber, 1988 ; Krawczyk and Krapiec, 1995 ; Krapiec, 1996).

The most numerous timbers are younger and they can be connected with the construction of the dike covering the period of 151 years. Datings of individual samples indicate that the dike was exploited and repaired during at least 50 years and successive pieces were added in several years' intervals. Radiocarbon datings (see table 2) of samples ZM1/76, ZM1/54 and ZM1/149 indicate the absolute age ca. 4500 cal BP. Two older floating chronologies are based on smaller numbers of samples. The first chronology was built on only two samples and one of them was dated to ca. 4600 cal BP. The second chronology was constructed on four curves from trees successively felled in several years intervals. Radiocarbon analysis of sample ZM/35 enabled to date that chronology to ca. 5500 cal BP. The results given above reveal, that the examined timbers descend from different periods of time, but most samples represent the so called dike level. Unfortunately, the attempts of absolute dating of the elaborated floating chronologies with respect to the standards for the area of Germany gave no satisfactory, univocal results.

SUMMARY

Complex interdisciplinary analyses of material collected in systematic excavations in Biskupin and in Zulawka Mala, Great Poland, permitted to distinguish two occupation phases of the Bronze Age for Biskupin, and eight occupation phases from Neolithic and Bronze periods for Zulawka settlements.

The results of radiocarbon dating of wood and charcoal samples collected from archeological trenches show some scatter and locate the Biskupin settlement between 850 and 400 cal BC. Dendrochronological studies gave the date of 747 BC for building of the older settlement. This date is seriously supported by wiggle matching technique, which as applied to series of ^{14}C dates of oak chronology spanning ca 160 years, leads to the estimate of 780±30 BC.

The composite probability distribution of the series of calibrated radiocarbon dates, gives the time intervals of 900-700 BC and 750-400 BC for the older and younger phases of settlement, respectively. It is thus highly probable that the date of construction the fortifications represents the initial stage of the younger phase of settlement.

Several tens samples of wood and charcoal from Zulawka Mala have been analysed with radiocarbon and dendrochronological method. Limits of particular occupation phases (5130-4950 BC, 4530-4420 BC, 4040-3530 BC, 2950-2570 BC, 2190-2040 BC, 1830-1670 BC, 1560-1410 BC, 1260-840 BC) have been established using the cumulative probability distributions of calendar ages of 37 radiocarbon dates. Dendrochronological analysis of oak wood from exposed construction enabled to establish 4 floating chronologies. Dendrochronological and radiocarbon analyses show jointly that all the oak wood samples are roughly of the same age (ca 3100 BC), in resonable agreement with the archaeological data (Krapiec *et al.*, 1996a).

ACKNOWLEDGMENTS

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LES DATES RADIOCARBONE DU CAMPANIFORME EN EUROPE OCCIDENTALE : ANALYSE CRITIQUE DES PRINCIPALES SÉRIES DE DATES

Maxence BAILLY et Laure SALANOVA***

Résumé : Nous avons reconsidéré les dates radiocarbone se rapportant au Campaniforme en Italie, en Suisse, en France, en Espagne et au Portugal pour répondre à deux questions : la genèse du Campaniforme en Europe et son insertion dans les cultures de la fin du IIIe millénaire.
On observe un décalage très important entre le Sud-Ouest (Portugal, Espagne, sud de la France), où le Campaniforme apparaît vers 2900-2800 av. J.-C., et le Nord-Est (Suisse, Italie, nord de la France), où les dates ne sont pas antérieures à 2500. Cependant, à en croire les dates C14, le Campaniforme durerait 1000 ans (2900-1900), ce qui est incompatible avec les données archéologiques. Les problèmes liés à la courbe de calibration expliquent en grande partie cette fourchette trop longue.
Les mêmes problèmes sont invoqués pour expliquer la contemporanéité radiométrique de plusieurs ensembles culturels de la fin du IIIe millénaire, pourtant bien différents. Néanmoins, la contemporanéité du Campaniforme avec les cultures du Néolithique final est démontrée par plusieurs données archéologiques.

Abstract : We have reexamined the radiocarbon dates concerning the Bell Beakers in Italy, Switzerland, France, Spain and Portugal to answer two questions : the genesis of Bell Beakers in Europe and its insertion in the cultures of the end of the IIIrd millenium.
We observe a very important gap between the southwestern part of Europe (Portugal, Spain, Southern France), where the Bell Beakers appear about 2900-2800 cal. BC, and the northeastern one (Switzerland, Italy, northern France), where the dates are not prior to 2500 cal. BC. Nevertheless, according to the radiocarbon dates, the Bell Beaker phenomenon could last 1000 years (2900-1900 cal. BC), which is incompatible with the archaeological data. This problem linked with the calibration curve explain to a great extent this too long duration.
The same problems could explain the radiometric contemporaneity of several cultural entity of the late IIIrd millenium, however quite different. The contemporaneity of the Bell Beakers with the cultures of the late Neolithic is nevertheless proved by several archaeological data.

Mots-clés : Néolithique final, Campaniforme, courbe de calibration, dendrochronologie.

Key-words : Late Neolithic, Bell Beakers, calibration curve, dendrochronology.

INTRODUCTION

Le phénomène campaniforme est principalement défini par des céramiques en forme de cloche, richement décorées, que l'on retrouve dans la seconde moitié du IIIe millénaire, mais sa durée exacte n'est pas connue. Cette céramique constitue la composante principale d'un assemblage d'objets reconnus dans une grande partie de l'Europe.

Le Campaniforme est étudié depuis un siècle maintenant sans qu'une explication pertinente quant à son apparition et son extension n'entraîne l'adhésion des chercheurs. La multiplication des données depuis la fin des années 70 remet en cause les interprétations classiques d'invasions de populations ou de circulation de biens de prestige.

Étudier le Campaniforme revient en fait à traiter d'un problème classique en archéologie : celui de la relation entre l'espace et le temps. Ce problème atteint son paroxysme avec le Campaniforme étant donné l'étendue géographique du phénomène et les bouleversements socio-économiques sous-tendus.

Les problèmes chronologiques sont nombreux malgré l'existence de séries de dates radiocarbone. Grâce à la calibration et au traitement informatique, elles nous permettent de poser à nouveau certaines questions.

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- Le Campaniforme apparaît-il de façon simultanée dans toutes les régions et quelles sont les évolutions postérieures ? Nous avons cherché à répondre à cette question en examinant les dates d'Europe sud-occidentale.

- Le Campaniforme est-il contemporain ou diachrone des cultures attribuées à la fin du Néolithique ? En un mot, le Campaniforme est-il une culture au sens archéologique du terme ? Pour répondre à cette dernière question, nous avons choisi deux exemples : le nord-ouest de la France et le couloir Saône-Rhône.

CORPUS ET MÉTHODOLOGIE

Des inventaires de dates se rapportant au Campaniforme ont déjà été dressés, notamment dans les travaux de J.-L. Voruz (1991, 1995, 1996) ou ceux de J. Gasco (1992, 1996). Toutefois ces travaux n'ont pas pris en compte la fiabilité des contextes des échantillons datés, même si certaines dates jugées aberrantes ont été éliminées.

Nous avons inventorié 137 dates parmi lesquelles 25 ont été rejetées car elles ne se rapportaient pas clairement à un niveau ou à des structures campaniformes. Les 112 dates retenues proviennent de 55 sites suisses, italiens, français, espagnols et portugais. Il est en effet impossible de traiter toute l'Europe occidentale : en Grande Bretagne un programme récent de datation systématique a été réalisé par une équipe du British Museum (Kinnes *et al.*, 1991), mais le contexte des dates n'est pas spécifié ; d'autre part le mobilier correspond principalement aux phases récentes du Campaniforme britannique, en aucun cas comparable avec le reste de l'Europe. Aux Pays-Bas le corpus de dates a été publié dans les années 70, mais le contexte des dates réalisées est l'objet de désaccord, celles-ci étant effectuées sur des charbons de sépultures fouillées anciennement. Quant à l'Allemagne, aucune synthèse se rapportant aux dates campaniformes n'est à notre connaissance disponible. Enfin, nous avons rejeté les datations épicampaniformes qui participent pleinement de l'évolution de l'Age du Bronze.

Nous avons calibré les dates à deux sigmas avec la courbe Décadale de 1993 (Stuiver et Becker, 1993) exploitée par le logiciel Oxcal. Pour chaque graphique nous avons confronté la distribution des probabilités des ensembles de dates. Aucun test statistique (moyenne de série de dates et test du Khi 2 par exemple) n'a été réalisé pour comparer mathématiquement chacune des séries de dates.

LES DATES CAMPANIFORMES EN EUROPE SUD OCCIDENTALE

Le corpus de dates le plus important provient d'Espagne (41 dates retenues), essentiellement de sa partie orientale. Les données sont par contre déficitaires dans l'ouest de la Péninsule ibérique et en France, où seuls les ensembles méridionaux font l'objet d'un grand nombres de datations.

Dans un premier temps, les dates ont été classées par pays et les histogrammes ont été disposés du sud-ouest vers le nord-est (fig. 1, en haut). On observe tout d'abord un étalement des dates sur la totalité du IIIe millénaire. Les dates les plus anciennes proviennent du Sud-Ouest (Espagne, Portugal, sud de la France) : le Campaniforme y apparaît vers 2900 av. J.-C. Plus on se dirige vers le nord et l'est de l'Europe, plus les dates sont récentes, c'est-à-dire postérieures à 2500 av. J.-C.

Ce résultat va à l'encontre du modèle hollandais (Lanting et Van der Waals, 1976) qui stipule l'apparition du Campaniforme dans l'estuaire Rhin-Meuse à partir de la *Single Grave Culture* au début du IIIe millénaire av. J.-C. Il s'oppose également à une autre idée communément admise : celle de la diffusion du Campaniforme en Europe de façon simultanée. Cette hypothèse n'est pas démontrée par les datations à notre disposition, ce qui repose le problème de l'origine de cet assemblage.

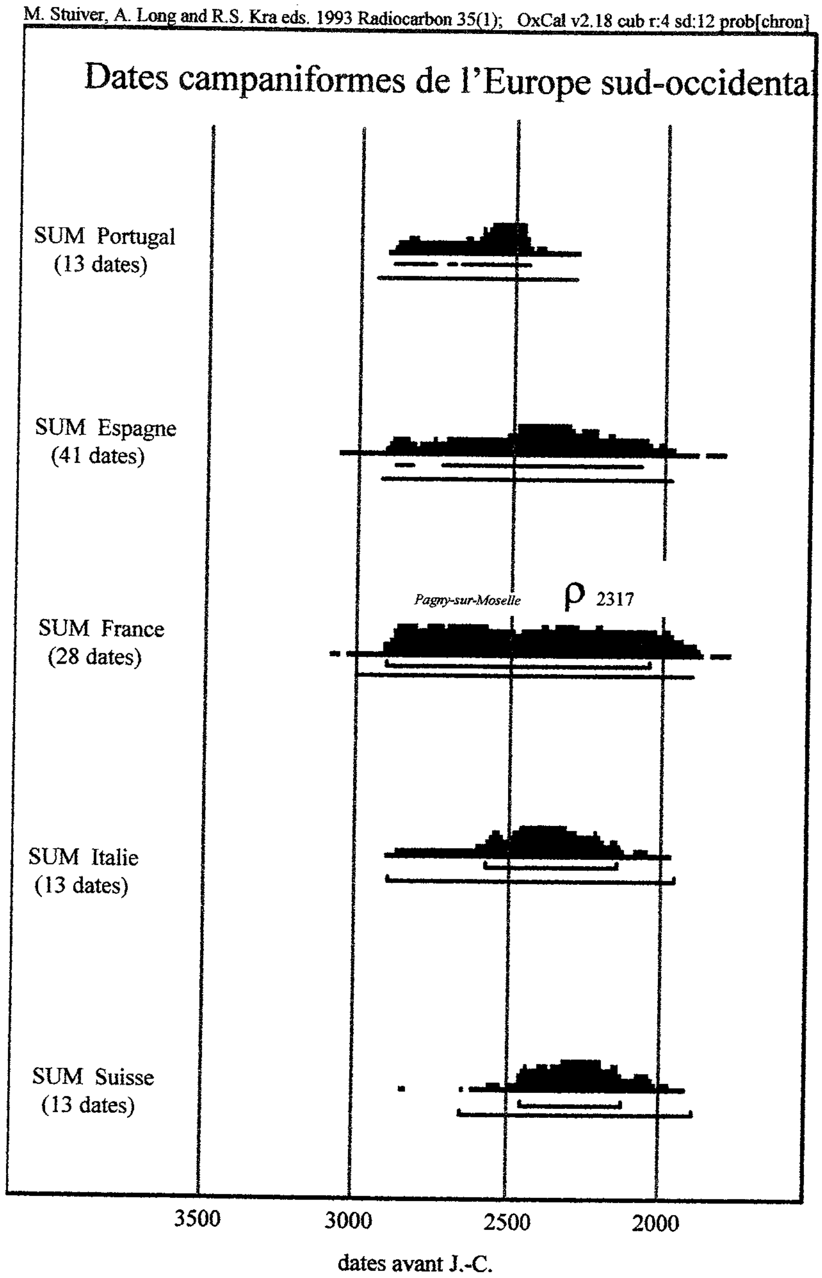
Autre paradoxe : le Campaniforme, connu principalement pour ses sépultures individuelles, est surtout daté par des habitats. Seuls 17 % des dates de notre corpus proviennent de contextes funéraires. Pourtant on considère généralement que l'assemblage campaniforme représente dans un premier temps un bien de prestige funéraire, avant de se "populariser" dans la sphère domestique (Guilaine, 1984). Cette idée constitue le fondement de toutes les chrono-typologies établies pour le Campaniforme. En séparant les dates issues de contextes funéraires et les dates issues des habitats, il est impossible de se prononcer sur une quelconque antériorité (fig. 1, en bas). Ceci est en partie dû au faible nombre de dates en sépultures, mais, dans les deux cas, les fourchettes chronologiques couvrent une période comprise entre 2900 et 1900 av. J.-C.

Cette longue fourchette pose un problème d'interprétation archéologique. trois facteurs différents peuvent l'expliquer : le problème de la forte erreur sur la mesure d'âge de certaines dates, particulièrement celles réalisées anciennement ; les difficultés liées au profil de la courbe de calibration, défavorable pour la période qui nous intéresse ; enfin, un problème archéologique lié à l'imprécision de la définition du campaniforme. On peut effectivement distinguer parmi le mobilier céramique un standard, commun à toute l'Europe, et des styles locaux qu'on ne peut vraiment comparer à l'échelle européenne. Seules 33 dates concernent le standard en Europe sud-occidentale. Nous avons tenté de ne prendre en compte que ces dates, mais une tendance comparable à celle observée sur le premier tableau se répète de façon plus nette, tout en conservant une extension chronologique comparable.

Le décalage très important observé entre les régions, pour ce phénomène Campaniforme supposé de courte durée, s'explique mal. On peut accepter la non-simultanéité de l'apparition du Campaniforme en Europe, mais le décalage entre le sud-ouest et le reste de l'Europe nous semble trop important. Ce problème est sans doute lié à la courbe de calibration qui resserre les segments de calibration des dates anciennes (antérieures à 2500) et qui -au contraire- étale et multiplie les segments de calibration des dates récentes (celles de la seconde moitié du IIIe millénaire). L'enjeu est pourtant capital : il concerne l'interprétation du phénomène campaniforme que l'on peut résumer à trois modèles déjà proposés : soit le Campaniforme et le Néolithique final représentent deux horizons chronologiques distincts (Pétrequin et Pétrequin, 1988) ; soit ce sont deux phénomènes synchrones qui s'excluent géographiquement, donc deux populations (Gallay, 1988) ; ou encore ce sont deux ensembles partiellement contemporains ou diachrones d'une manière non sensible à l'échelle archéologique (Roger, 1995). C'est à cette question que nous avons tenté de répondre à travers deux exemples régionaux.

LE NORD-OUEST DE LA FRANCE

Nous avons pris en compte toutes les dates, de la Bretagne au Bassin parisien inclus, se rapportant aux sépultures et aux habitats de la fin du IIIe millénaire. Cette période est très mal connue dans le nord-ouest de la France et nous disposons de très peu de dates.



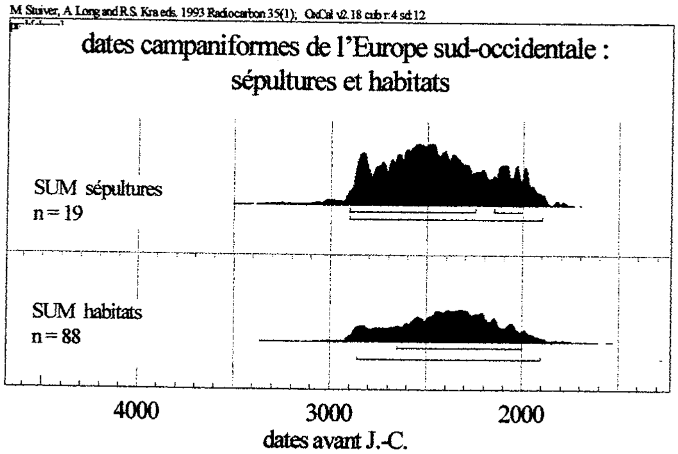
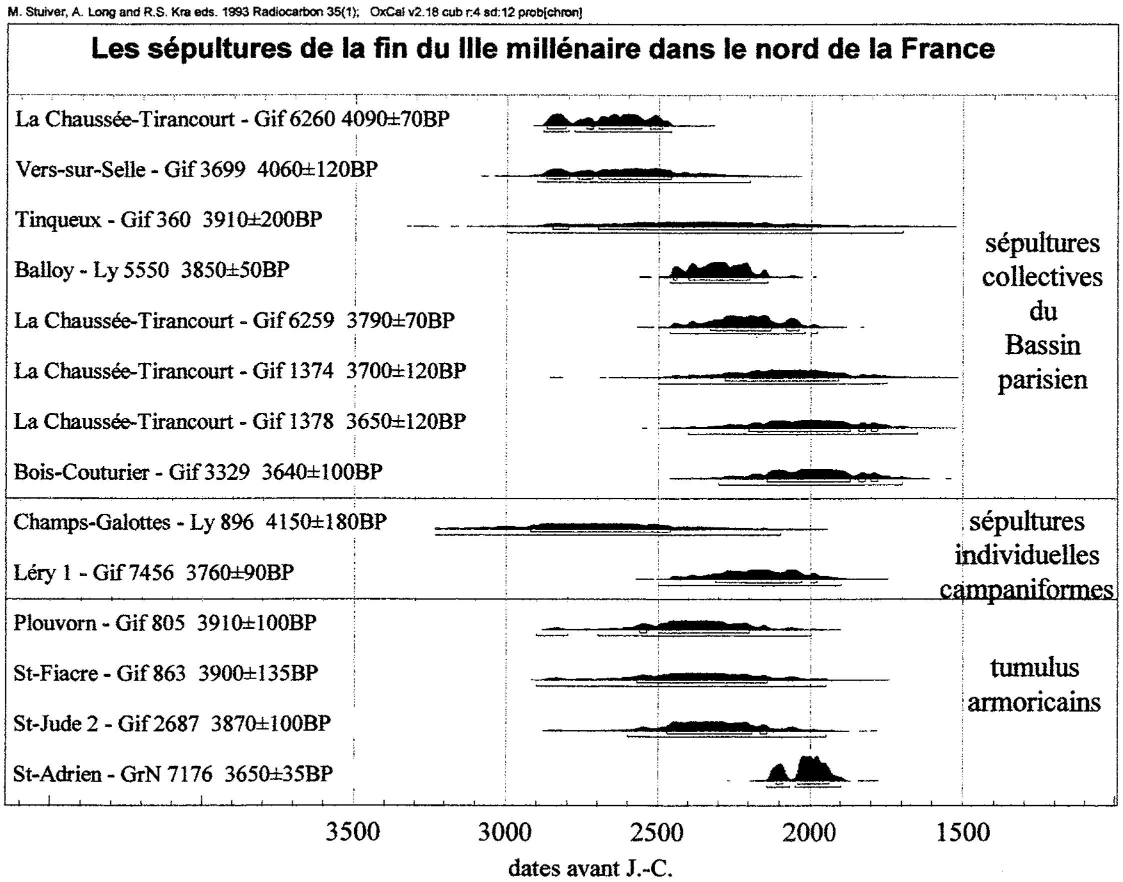


Fig. 1 : Le Campaniforme en Europe sud-occidentale.

Seules deux sépultures individuelles campaniformes ont été datées. Nous avons comparé ces dates à celles de couches d'inhumations récentes de sépultures collectives du Bassin parisien (fig. 2, en haut) et à celles de tumulus armoricains dans lesquels les structures centrales en bois ont été datées (nous avons bien sûr exclu les dates sur charbons provenant des sols sous-jacents aux tumulus). Ces trois pratiques funéraires sont très différentes et pourtant les dates se recouvrent. Dans les sépultures collectives aucune trace de mobilier campaniforme n'a été décelé. De même, les tumulus armoricains appartiennent vraiment aux sociétés de l'Age du Bronze, tant par les pratiques funéraires que par le mobilier associé aux défunts (haches et poignards en bronze, pointes de flèches ogivales en silex).

En ce qui concerne les habitats, les dates sont encore moins nombreuses (fig. 2, en bas). Trois habitats campaniformes ont fait l'objet d'une datation. Ils sont comparés à quatre habitats du Néolithique final du Bassin pari-



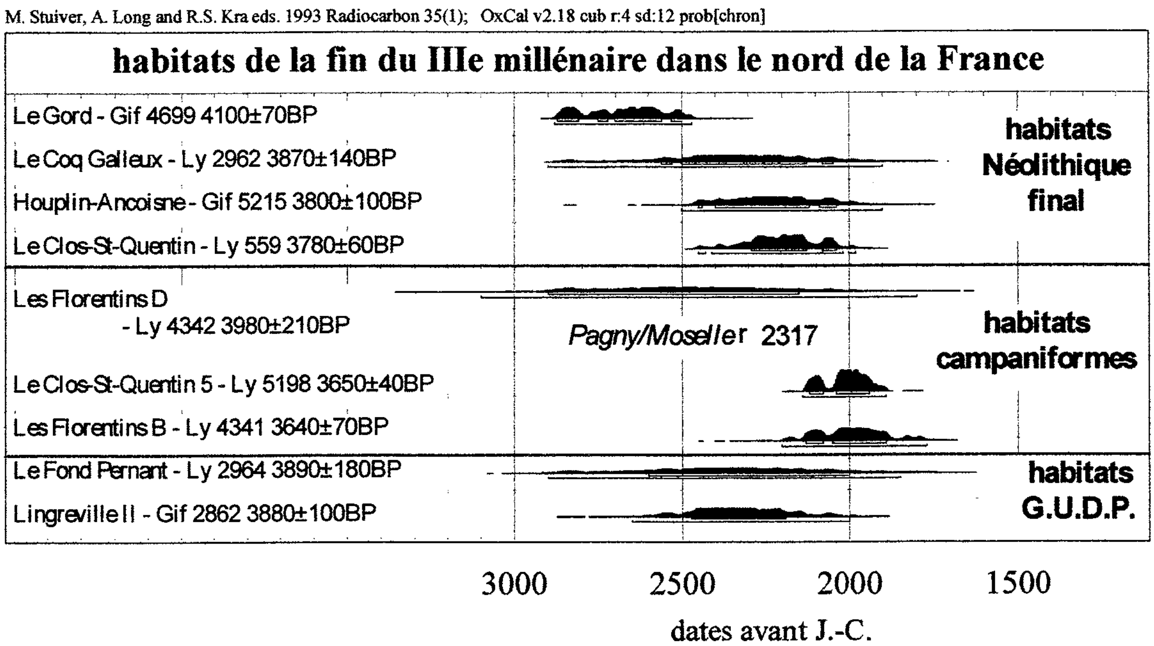
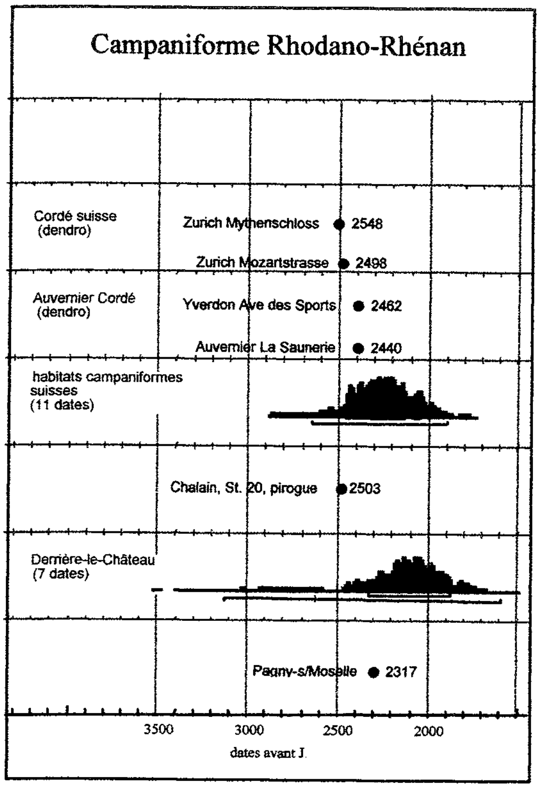


Fig. 2 : La moitié nord de la France.

sien et deux habitats du Groupe des Urnes à Décors Plastiques, censés représenter le début de l'Age du Bronze. Là encore, ces trois phénomènes semblent radiométriquement contemporains.

M.Stuiver, A. Long and R.S. Kramer eds. 1993 Radiocarbon 35(1) ; OxCal v2.18.



M.Stuiver, A. Long and R.S. Kramer eds. 1993 Radiocarbon 35(1) ;OxCal v2.18.

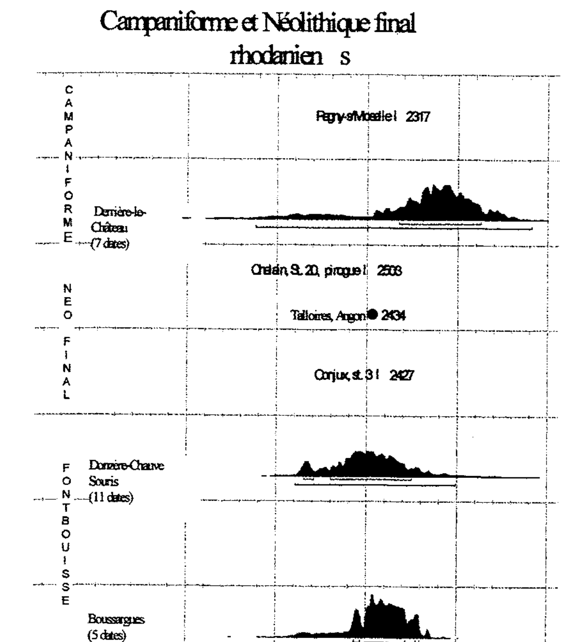


Fig. 3 : Campaniforme et Néolithique final de l'axe Rhône-Saône.

LE COULOIR SAÔNE-RHÔNE

Contrairement au Néolithique final du nord-ouest de la France, la fin du IIIe millénaire est bien détaillée par une série de stations littorales datées par la dendrochronologie de Zürich au Dauphiné. On y reconnaît également depuis une vingtaine d'années une petite série d'habitats campaniformes.

Les stations littorales attestent d'un phénomène général d'abandon des rives ou de démantèlement complet des sites archéologiques à partir du 25e siècle av. J.-C. Au nord-ouest des Alpes, les dernières phases d'abattage s'achèvent entre 2550 et 2440 av. J.-C.

Outre la nécropole de Sion Petit-Chasseur, les sites d'habitat campaniformes connus ont permis à A. Gallay de définir le complexe Rhodano-Rhénan interprété comme une culture archéologique à part entière. Celle-ci est issue de la diffusion de la thématique campaniforme à la totalité de la culture matérielle, ce qui caractérise l'ultime phase du Néolithique final centrée autour du 24e siècle. Cette hypothèse est confirmée par les dates radiocarbone récentes dans les habitats. Deux exceptions sont à noter : une date à 4200 BP à Derrière-le-Château (Ain) et une date à 4000 BP à Oberwil (ZG).

La confrontation des dates dendrochronologiques et des dates se rapportant aux habitats campaniformes nous amène à quelques remarques (fig. 3, en haut). On ne peut exclure une contemporanéité entre les stations littorales d'obédience cordée et les sites d'habitat campaniformes. On ne peut exclure l'existence de sites littoraux campaniformes aujourd'hui démantelés, comme l'attestent les rares découvertes de Chalain, Station de la prise d'eau et de Clairvaux, la-Motte-aux-Magnins. Cet ensemble de données repose le problème de l'identité ethnique campaniforme.

En ce qui concerne la moitié sud de la vallée du Rhône, on doit reconnaître une période de coexistence entre les sites Fontbouisse les plus récents, les rares dates dendrochronologiques alpines et les datations du Campaniforme (fig. 3, en bas). On notera enfin que cette contemporanéité n'est pas réfutable et que, là également, l'exclusion complète entre sites campaniformes et sites non campaniformes n'est pas définitive.

CONCLUSION

L'exploitation des séries de dates radiocarbone permet de supposer que l'apparition du Campaniforme n'est pas simultanée en Europe et que ce phénomène se superpose à d'autres cultures, au moins matérielles. Ceci est prouvé non seulement par les dates, mais aussi par le mobilier. Il existe en effet dans plusieurs régions d'Europe des formes céramiques du Néolithique final à décor campaniforme et des formes céramiques campaniformes à décor Néolithique final.

Par contre, nous avons évoqué les limites de la méthode du radiocarbone à plusieurs reprises, ce qui nous conduit à considérer comme importants pour notre problématique les éléments techniques suivants : la nécessité de réduire les erreurs standard sur les mesures d'âge dont souffrent certaines dates. Celles-ci deviennent inutilisables pour les problématiques précises que développent aujourd'hui les néolithiciens. Le rôle de la calibration dont la multiplication des segments pour le IIIe millénaire éparpille les résultats. On peut espérer l'élaboration d'un traitement statistique et informatique plus efficace. Enfin on peut souhaiter la généralisation des datages par AMS dans le but d'augmenter l'homogénéité des échantillons carbonés soumis à datation et assurer réellement l'association élément dateur/élément daté. On peut citer comme exemple la datation réalisée sur le site campaniforme de Derrière-le-Château dans l'Ain sur un caramel alimentaire d'un tesson campaniforme décoré (Ly 283Oxa : 3710 ± 55 BP : 2213-1920 -96 %).

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THE ABSOLUTE CHRONOLOGY OF THE ROMANIAN NEOLITHIC AND AENEOLITHIC/CHALCOLITHIC PERIODS. THE STATE OF THE RESEARCH

*Cornelia-Magda MANTU**

Abstract : The Romanian Prehistory has a small number of radiocarbon data, compared with the neighbouring countries. This fact is connected with the absence of a specific radiocarbon laboratory, with financial problems, but it is also due to the archaeologists' attitude towards this dating method.

In the last years, I have tried to obtain more radiocarbon data, covering a larger geographical area. The north-eastern part of Romania (Moldavia) has up to now the largest number of radiocarbon data, from the Neolithic period to the Bronze Age. Based on 180 radiocarbon data for these periods (58 for the Neolithic, 84 for the Aeneolithic/Chalcolithic and 25 for the Transition period to Bronze Age) we believe that the Neolithic has evolved between 6000/5900-4700 CAL B.C., the Aeneolithic between 4700-3500 CAL B.C. and the Transition period to Bronze Age, between 3500-3000 CAL B.C. at least.

In the future it will be necessary to obtain a largest number of radiocarbon data, for the geographical territories or the archaeological units which are not represented well enough.

Résumé : La préhistoire roumaine a très peu de dates radiocarbone, en comparaison avec les pays voisins. Ce fait est lié à l'absence de laboratoire spécialisé, à des problèmes financiers, mais aussi à l'attitude des archéologues roumains face à cette méthode de datation.

Au cours des dernières années, j'ai tenté d'obtenir un grand nombre de données sur un important espace géographique. Le nord-est de la Roumanie (la Moldavie) est la région la mieux représentée avec des dates radiocarbone allant du Néolithique jusqu'à l'Age du Bronze.

En se basant sur l'analyse de 180 dates radiocarbone pour la Roumanie de cette période (58 dates pour Néolithique, 84 pour Enéolithique et 20 dates pour la période de Transition à l'époque du Bronze) on estime que le Néolithique a évolué entre 6000/5900-4700 CAL B.C., l'Enéolithique entre 4700-3500 CAL B.C. et la période de Transition vers l'Age du Bronze, entre au moins 3500-3000 CAL B.C.

A l'avenir, il sera nécessaire d'obtenir plus de dates radiocarbone pour les territoires géographiques ou pour les divisions archéologiques qui sont moins bien représentées.

Key-words : Radiocarbon dating, Romania, Neolithic, Aeneolithic/Chalcolithic, Transition period to Bronze Age, geographical distribution, chronological sketch.

Mots-clés : Datation radiocarbone, Roumanie, Néolithique, Enéolithique/Chalcolithique, transition vers l'Age du Bronze, distribution géographique, esquisse chronologique.

The archaeological researches from the Romanian territory show for prehistory a large number of cultures, cultural groups or local aspects, different or related between them, with foreign connections, especially with south-eastern or central Europe. The specification of absolute chronology of these cultures and their length has always preoccupied and attracted the interest of many archaeologists. The use of radiocarbon results could be explained to establish the period evolution of these units. Unfortunately, in Romania there is still no radiocarbon laboratory. About 5 years ago, in Cluj, the Institute of Isotopes tried to organise such a laboratory. It is also important to mention that, comparatively with the neighbouring countries, the radiocarbon data for Romania very scarce.

We intend here to study the use of radiocarbon data for the Romanian Neolithic and Aeneolithic/Chalcolithic. From their own excavations D. Berciu (Berciu, 1966a, 15 ; 1966b, 232, 301) and Vl. Dumitrescu collected the first archaeological samples for dating. Vl. Dumitrescu played a special role in this field and also published the first chronological sketch of the mentioned period, based

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on the radiocarbon data, in 1974 (Dumitrescu, 1974a, 23-40 ; 1974b, 99-105).

The problems of radiocarbon dating in its beginnings affected the trust of archaeologists regarding the results of the method, an attitude that still persists today, even if this kind of problems have already been solved. Few archaeologists collect samples for radiocarbon dating (Marinescu-Bîlcu, 1971, 37 ; Roman, 1976, 67 ; Simon, 1989, 109).

In 1984, D. Monah presented the new radiocarbon data regarding the Cucuteni culture (uncalibrated), in the larger context of the Cucuteni-Tripolie cultural complex, contributing to the increase of the data (Monah, 1987, 76-80).

A large number of samples were collected by M. Nica from Oltenia, from both the Neolithic and Transition period to the Bronze Age period (Mantu, 1995, 214). Recently, other radiocarbon data from Aeneolithic/Chalcolithic settlements where collected by I. Paul (Paul, 1992, 127), Fl. Drasovean (Drasovean, 1996, 106), D. Popovici (information from D. Popovici and P. Hasotti) or Gh. Lazarovici.

As early as in 1989, we collected samples for radiocarbon dating, from our own excavations, or from other colleagues', from sites framing from Neo-Aeneolithic, Transition period to Bronze Age, or from the beginning of the Bronze Age period, all over the Romanian territory (and even from Bessarabia/Republic of Moldavia). We tried to increase the amount of information for a larger geographical area and also to cover all the chronological units : 56 new radiocarbon data have already been obtained, another 30 samples are being analyzed in Heidelberg and Berlin.

Concerning the analysis of the radiocarbon data, to which we intend to refer here, an important and special contribution is connected with the names of famous specialists in radiocarbon dating. We must first mention H. Quitta and G. Kohl from Berlin (Kohl & Quitta, 1963, 297 ; 1964, 163- 202 ; Quitta & Kohl, 1969, 238-240, 249-251 ; 1971, 38-63), J. C. Vogel and H. T. Waterbolk from Groningen (Vogel & Waterbolk, 1963, 184-185 ; 1964, 314, 355 ; 1972, 70), or T. W. Linick from La Jolla, USA (Linick, 1979, 196-197 ; 1980, 186-202). On this occasion we address our thanks to Dr. B. Kromer from Heidelberg, Dr. E. Gilot from Louvain, Prof. Dr. M. F. Pazdur and Prof. Dr. A. Pazdur from Gliwice, or to Dr. J. Görsdorf from Berlin, who have analysed our samples from the last years. Prof. Dr. H. Hauptmann, Prof. Dr. Ch. Strahm and Prof. Dr. M. Otte also helped us in our first contacts with these laboratories and gave us financial support for the datings. In the last years, we published part of the new radiocarbon data (Mantu, 1995, 213-235) and we intend to go on (Gilot, Mantu, Lazarovici mss. ;

1974	1998
	Neolithic
	- Starcevo-Cris culture = 5 data
	- Cârcea III group / Starcevo-Cris IV = 4 data
	-Vinca culture (A2=1 ; B2=1 ; C1=2) = 4 data
	- Banat culture (I= 4 ; II = 10) = 14 data
	- Dudesti-Vinca group (B=4 ; C=4) = 8 data
	- Dudesti culture (II-III) = 1 datum
-Linear pottery culture = 2 data	- Linear pottery culture = 2 data
-Hamangia culture = 1 datum	- Hamangia culture (III) = 2 data
-Boian culture (Spantov phase) = 10 data	- Boian culture (Spantov phase) = 13 data
-Precucuteni culture = 1 datum	- Precucuteni culture (II=1 ; III=4) =5 data
	Aeneolithic/Chalcolithic
	- Petresti culture (A phase) = 3 data
-Gumelnita culture = 14 data	- Gumelnita culture (A2 phase) = 18 data
-Cucuteni culture = 4 data	- Cucuteni culture (A=37 ; A-B=3 : B=8) = 48 data
	- Decea Mureslui group = 1 datum
-Sãlcuta culture = 2 data	- Sãlcuta culture (II=3 ; III=4) = 7 data
	- Aeneolithic (?) = 2 data
-Cernavoda I = 3 data	- Cernavoda I = 5 data
	Transition period to Bronze Age
	- Horodistea culture = 4 data
	- Celei group = 4 data
	- Ochre graves =5 data
	- Cotofeni culture (I=4 ; II=2 ;III=6) = 7 data
	Bronze Age
	- Monteoru culture (IC2) = 1 datum
	- Livezile group = 1 datum
	-Noua culture = 4 data
Sum = 37 data	Sum = 172 data

Tab. 1.

- Bln / Berlin = 75 data (± 160 - ± 15) ; 34 data has an error distribution over ± 100 ;
- Hd / Heidelberg = 27 data (with ± 100 only 2 data, the rest of them, between ± 63 - ± 18) ;
- Lv / Louvain = 19 data (± 160 - ± 70) ; 8 data has an error distribution more than ± 100 ;
- GrN / Groningen = 13 data (± 90 - ± 45) ;
- LJ / La Jolla, San Diego, USA = 9 data (± 100 - ± 50) ; one data has an error distribution of ± 100 ;
- ? / Leipzig (KIA) = 1 datum (± 40)
- Ly / Lyon = 3 data (± 46 - ± 55) ;
- Gd / Gliwice = 8 data (± 150 - ± 60) ; 5 data has an error distribution over ± 100 ;
- Deb / Debrecin = 3 data (± 60 - ± 40) ;
- KN / Köln = 5 data (± 160 - ± 65) ; 2 data with an error distribution over ± 100 ;
- SMU / Southern Methodist, Dallas, USA = 2 data (± 77) ;
-UZ/ Zürich = 3 data (± 70 - ± 75).

Tab. 2.

Mantu, 1998). Compared with 1974, when Vl. Dumitrescu published for the first time all the radiocarbon data for the Neo-Aeneolithic period, today the situation is as in table 1.

To these radiocarbon data we could add other 14, coming from Bessarabia/Republic of Moldavia, for the Starcevo-Cris culture (2 data), Precucuteni culture (2 data), Stoicani-Aldeni cultural aspect (2 data) and Cucuteni culture (8 data).

In the Romanian Neo-Aeneolithic period about 27 cultures, cultural groups, local aspects are identified and for 9 of them we have no radiocarbon data at all. From the transition period to the Bronze Age, represented by 11 of these structures, there is an absolute chronology information only for 4 of them. Most of the archaeological cultures, based on the stratigraphical and tipological-stylistical analysis of different kind of artefacts (especially pottery) evolve through more phases and even stages, which are not equally and enough represented by the radiocarbon data, as one can observe in our presentation, fig. 1.

Our effort to secure samples from more geographical areas to cover almost all the evolutionary phases of different cultures does not end successfully. Most of the material from older excavations, which could be used for dating, are lost or useless and in the last years the geographical areas and cultures have not been studied enough. This is the reason why we selected samples from Republic of Moldavia/Bessarabia, for some Cucuteni B late settlements ; for the chronological analysis, some radiocarbon data for some common cultures with the rest of Moldavia province could be used.

When studing the extent maps of the cultures dated by the radiocarbon method for Romania, one can observe an ununiform distribution of the information about the historical provinces. Most of the radiocarbon data comes from Moldavia (the North-East part of Romania). The next in line, but at a certain distance, are Oltenia (South-West part of Romania), Wallachia (South part of Romania), or Transylvania (main central part of Romania, between the Carpathian arch). Crisana (North-West part of Romania) and Maramures (North part of Romania) have no radiocarbon data at all.

This situation should be corrected in the future. Special attention will be paid to the areas and cultures which are not at all represented, but also for the south-west part of Romania where, from an archaeological point of view, it is possible to observe a larger cultural diversity, continuously in change.

Radiocarbon data for Romania are analysed in more laboratories, as in table 2.

The precision and dating accuracy are connected of course, with the quality of the collected samples, their nature, but they are also marked by the moment when these kind of analysis are made. 55 data have an error distribution over ± 100 and in the future, such kind of information might not be suitable anymore. The greatest number of radiocarbon data for the period that we present here were obtained in German laboratories. This comes from the strong relations between Romanian archaeologists and German universities, as well as from the interest of our German colleagues towards the cultural evolution of central and south-east Europe.

The issue of the Neolithic period in the Romanian territory is connected with a cultural migration process, of southern origin ; the new-coming population probably assimilated the autochtone communities (which where still in a Mesolithic type of life). For the first neolithic communities, of Cârcea-Gura Baciului-Ocna Sibiului type we have not radiocarbon data (Mantu, 1998), but based on an archaeological analysis and taking into account the similar manifestations in Bulgaria (Pavuk, 1993, 29 ; Görsdorf & Boiadjiev, 1996, 122-123), Greece (Liritzis *& al.*, 1991, 308) or Anatolia (Roodenberg, 1993, 256, 259 ; Özdogan, 1993, 185-186), we believe that this horizon starts in around 6000/ 5900 B.C. (Mantu, 1998).

The Neolithic period has an evolution of about 1300 years, between 6000/5900-4700 Cal B.C. It is a period represented by many cultures, cultural groups or local evolutions, as one can see in the chronological table (tab. 3).

The next period, Aeneolithic/Chalcolithic probably evolved in the period 4700-3500 Cal B.C. A more stabile cultural situation can then be observed, as well as a smaller number of cultures, which evolved over longer periods and on a larger geographical area. But for the Chalcolithic period, there are still some local groups, or aspects, with a particular evolution, which have not been well defined from an archaeological point of view.

At the same time, during Neolithic and Aeneolithic/ Chalcolithic periods, in the present Romanian territory, different groups of communities are entering. During the Neolithic period, they rather come from the South or the North-East and during the Aeneolithic rather from the eastern part of Europe than from the northern or the western part. These movements can explain the dislocation or even disappearance of some cultures and the birth of new ones.

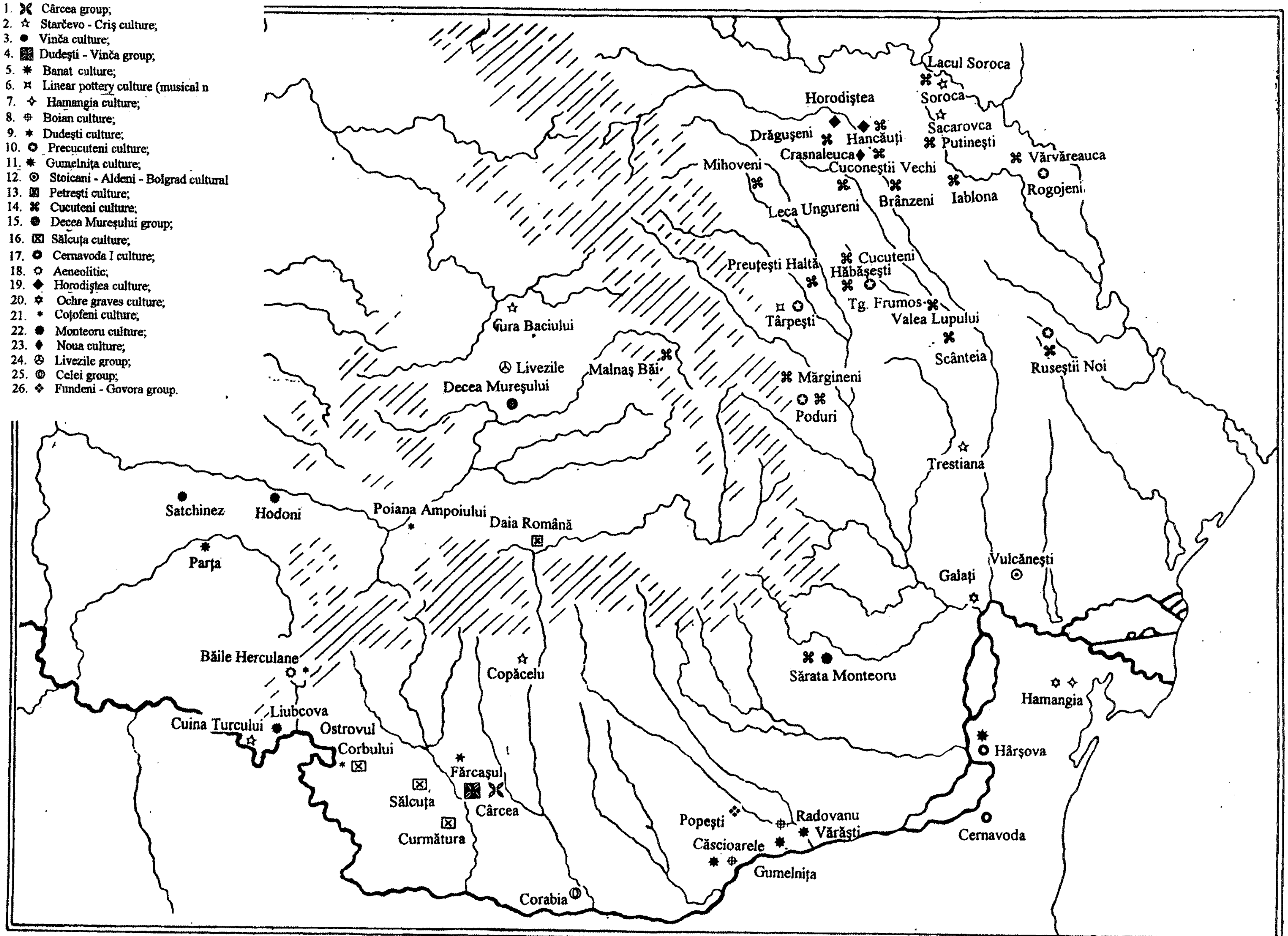
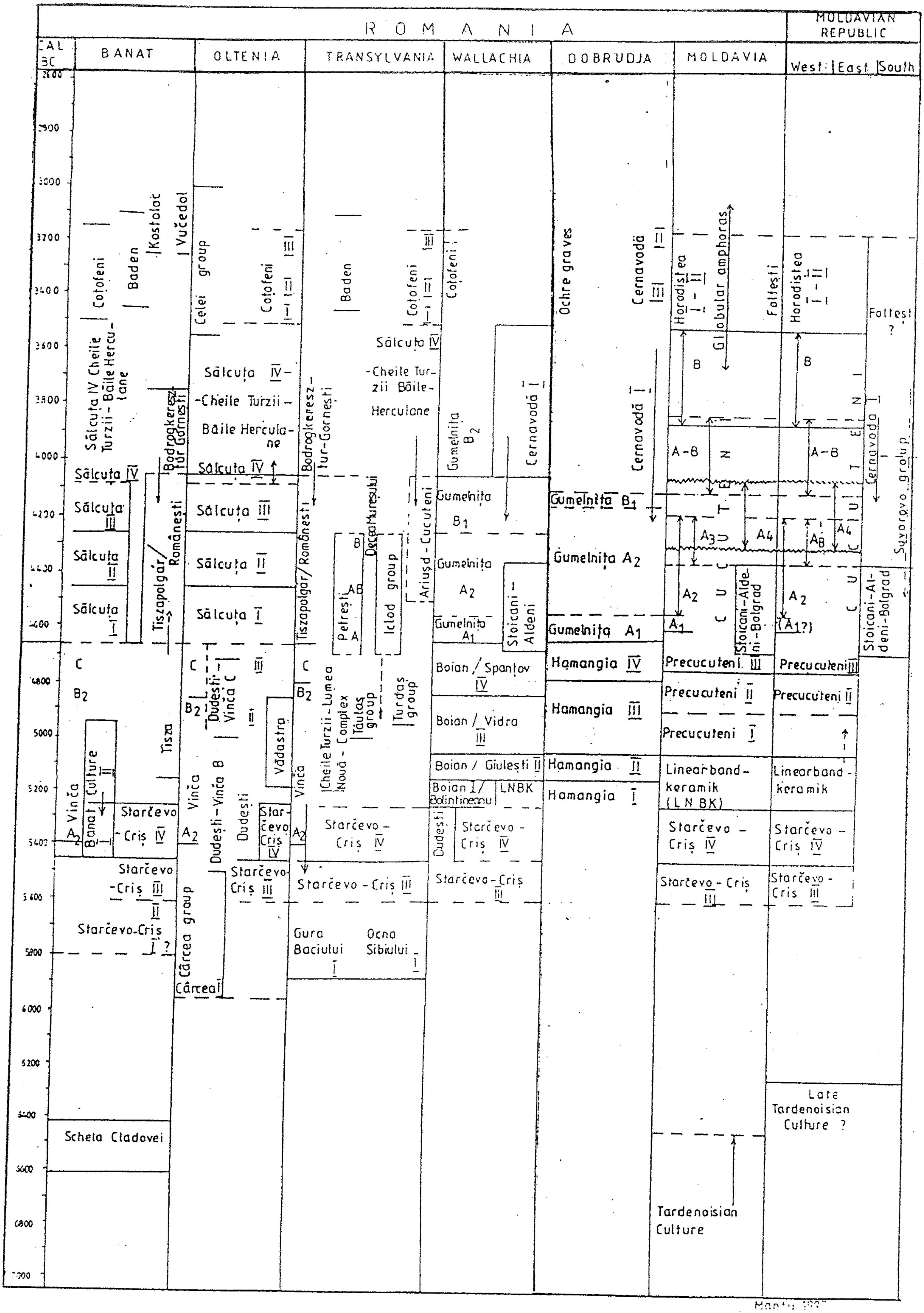

1. Cârcea group;
2. Starčevo - Criş culture;
3. Vinča culture;
4. Dudeşti - Vinča group;
5. Banat culture;
6. Linear pottery culture (musical n
7. Hamangia culture;
8. Boian culture;
9. Dudeşti culture;
10. Precucuteni culture;
11. Gumelniţa culture;
12. Stoicani - Aldeni - Bolgrad cultural
13. Petreşti culture;
14. Cucuteni culture;
15. Decea Mureşului group;
16. Sălcuţa culture;
17. Cernavoda I culture;
18. Aeneolitic;
19. Horodiştea culture;
20. Ochre graves culture;
21. Coţofeni culture;
22. Monteoru culture;
23. Noua culture;
24. Livezile group;
25. Celei group;
26. Fundeni - Govora group.
Lacul Soroca
Soroca
Horodiştea
Sacarovca
Putineşti
Drăguşeni
Hancăuţi
Vărvăreauca
Crasnaleuca
Cuconeştii Vechi
Mihoveni
Rogojeni
Brânzeni
Iablona
Leca Ungureni
Cucuteni
Preuteşti Haltă
Hăbăşeşti
Tg. Frumos
Târpeşti
Valea Lupului
Gura Baciului
Scânteia
Ruseştii Noi
Livezile
Malnaş Băi
Mărgineni
Decea Mureşului
Poduri
Trestiana
Satchinez
Hodoni
Poiana Ampoiului
Daia Română
Vulcăneşti
Parţa
Galaţi
Băile Herculane
Copăcelu
Sărata Monteoru
Hamangia
Liubcova
Cuina Turcului
Ostrovul
Corbului
Hârşova
Fărcaşul
Sălcuţa
Cârcea
Popeşti
Radovanu
Vărăşti
Cernavoda
Curmătura
Căscioarele
Gumelniţa
Corabia

Fig. 1.



ROMANIA
MOLDAVIAN REPUBLIC
CAL BC
BANAT
OLTENIA
TRANSYLVANIA
WALLACHIA
DOBRUDJA
MOLDAVIA
West
East
South
Coțofeni
Baden
Kostolac
Vučedol
Celei group
Baden
Ochre graves
Cernavodă III
Horodiștea
Globular amphoras
Folteşti
Sălcuța IV Cheile Turzii - Băile Herculane
Sălcuța IV - Cheile Turzii - Băile Herculane
Sălcuța IV
Bodrogkeresztúr-Gornești
Gumelnița B2
Cernavodă I
Gumelnița B1
Gumelnița A2
Gumelnița A1
Stoicani-Aldeni
Sălcuța III
Sălcuța II
Sălcuța I
Tiszapolgár/Românești
Petrești
Iclod group
Ariușd-Cucuteni
Decea Mureșului
Precucuteni III
Precucuteni II
Precucuteni I
Hamangia IV
Hamangia III
Hamangia II
Hamangia I
Boian/Spanțov IV
Boian/Vidra III
Boian/Giulești II
Boian I/Bolintineanu
LNBK
Tisza
Dudești-Vinča C
Vădastra
Cheile Turzii-Lumea Nouă-Complex
Tăulaș group
Turdaș group
Linearbandkeramik (LNBK)
Vinča A2
Banat Culture
Dudești-Vinča B
Dudești
Starčevo-Criș IV
Starčevo-Criș III
Starčevo-Criș II
Starčevo-Criș I
Cârcea group
Cârcea I
Gura Baciului I
Ocna Sibiului I
Late Tardenoisian Culture ?
Schela Cladovei
Tardenoisian Culture
Cucuteni
Suvorovo group
Cernavoda
Stoicani-Aldeni-Bolgrad

Tab. 3.

The transition period to Bronze Age was considered by Romanian archaeologists as a short period of transition between the Aeneolithic/Chalcolithic period and the Bronze Age. Radiocarbon data demonstrate that even this period has a longer life than it is assumed, about 500 years, between 3500-3000 CAL B.C.

We believe that the next coming radiocarbon data and the new archaeological researchers will bring enough arguments to help and bring new meanings to some aspects connected with the chronology of the period we present here. At the same time, we do not believe that the new data will change our conclusions radically.

From the present data, it is very clear that the north-eastern part of Romania is better represented on a radiocarbon dating point of view. This kind of information cover a big interval of time, even if unequally distributed, from the middle Neolithic till the end of the Transition period to Bronze Age. In this geographical area, the Cucuteni culture has a special position. For this culture, we have the largest number of radiocarbon data, that is for all Romania, 48 : Cucuteni A, 37 data ; Cucuteni A-B, 3 data ; Cucuteni B, 8 data. Based on these data (also taking into account the results from Tripolie area), we have established that this culture had a duration of about 1100 years, in the interval 4600-3500 CAL B.C. (Mantu, 1998a). The Cucuteni A phase was the longest, about 550 years (4600-4050 CAL B.C.), in comparison with the Cucuteni A-B phase, 280/300 years (4100-3800 CAL B.C.), or the Cucuteni B phase, 300/350 years (3850-3500 CAL B.C.). The analysis of radiocarbon data shows the overlapping of the phases and even the stages of the Cucuteni A phase, where there are the largest number of radiocarbon data. This kind of overlapping can sometimes be noticed even by an archaeological analysis (Dumitrescu, 1985, 39-40 ; Ellis, 1984, 64-65). For the Cucuteni A-B and B phases, because of the small number of radiocarbon data, it was not possible to establish the evolution of the stages (only determined by archaeological analysis so far).

We do not intend to present the duration of each culture belonging to the Neolithic, Aeneolithic/Chalcolithic or Transition period to Bronze Age. The example of the Cucuteni culture is very eloquent because it shows that when we have more data, and a better established archaeological evolution, the situation doesn't seem to be very simple. The cultural evolution is not regular. Stages and even phases in some areas seem to be longer than in other ones. Some local groups evolution could also be sketched, but more observations will be made when we have more radiocarbon data and a complete and correct publication of the archaeological material.

In conclusion, we can consider that in the future it will be necessary to collect and to analyse a larger number of samples, especially for the geographical area and cultures which are not enough represented. If for the Romanian Paleolithic there is a large number of radiocarbon data (Chirica, 1981, 1984, 1985 ; Honea, 1984a, 1984b, 1986a, 1986b) and those, together with the ones for the Neolithic, Aeneolithic/Chalcolithic and Transition period to Bronze Age offer us quite an acceptable chronological sketch, the number of such data appears to be very small for the Bronze Age (Ciugudean, 1996, 145-146 ; 1997, 117-119 ; Palincas, 1996, 244-245 ; László, 1997, 247 ; information Dr. N. Boroffka and L. Dascălu). In our opinion, the number of radiocarbon data available is also connected with the attitude of different archaeologists, which are working on each of these period. We believe therefore that a different perception of the radiocarbon methods and their results is necessary.

The corroboration of all facts we have already mentioned will contribute in the future to a better representation of the Romanian pre- and protohistory.

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RADIOCARBON CHRONOLOGY OF ARCHAEOLOGICAL SITES IN SOUTH-EASTERN EUROPE

Bogomil OBELIC, Nada HORVATINCIC* and Aleksandar DURMAN***

Abstract : Results of ^{14}C measurements of samples from various archaeological sites in SE Europe, spanning from Mesolithic to the Middle Ages, are presented. Radiocarbon results were calibrated by using the Oxford University OxCal program.

Résumé : On présente les résultats de datations ^{14}C d'échantillons provenant d'une grande variété de sites archéologiques de l'Europe du Sud-Est datant du Mésolithique au Moyen-Age. Les dates ont été calibrées avec le programme OxCal de l'Université d'Oxford.

Key-words : SE Europe, Archaeology, Calibrated ^{14}C results.

Mots-clés : Sud-Est Europe, archéologie, résultats calibrés de radiocarbone.

INTRODUCTION

Radiocarbon Laboratory of the Ruder Boškovic Institute in Zagreb, Croatia, has throughout last 30 years analyzed about 3000 samples of archaeological, paleontological, geological, hydrogeological and environmental interest. About 500 archaeological samples of charcoal, wood, grains human and animal bones from Slovenia, Croatia, Bosnia and Herzegovina, Yugoslavia, Macedonia and from Hungary (fig. 1) were collected at a great number of excavation sites and range from Paleolitic Age to recent periods[1,2,3,4].

Radiocarbon results were calibrated by using the program OxCal, version 2.18 of the Oxford University (RLAHA)[5]. Samples are grouped according to archaeological sites and summation of probability distribution for each site was performed. Results of this calculation are presented on tables 1 to 8, showing the total probability distribution for each site, as well as the upper and the lower limit of settlement for each site.

RESULTS

The Paleolithic presence has mainly been traced in several caves in the north-west of this area (*Divje babe* in SW Slovenia, *Vindija* in NW Croatia, *Velika pecina* in Central Croatia, *Pupicina pec* and *Šandalja* in Istria and *Kopacina* on Brac is.). Radiocarbon results spread from Early Holocene to the upper limit of detection obtained in our laboratory (37 000 years BP).

Mesolithic is typically connected with the caves along the Adriatic coast (*Gospodska pecina* in Dalmatia and *Odmut* in Montenegro) and the narrow region around the Danube Gorge, the so-called Iron Gate, with the earliest permanent settlements (*Lepenski Vir, Vlasac*). It appears that already at the time of full bloom of Mesolithic, the Neolithic way of life (**Starcevo** culture) had been established in the lowlands of Macedonia (*Topolcani, Tumba*) and south of the Pannonian valley (*Divostin* in C. Serbia), as well as along the Adriatic coast (**Impresso** culture represented in *Vela spilja* on Korcula is.).

According to ^{14}C dates, in addition to the available archaeological evidence, the Late Neolithic period can clearly be identified in following vast region : a firm nucleus around the **Vinca** culture in the middle Danube region (*Selevac, Grivac, Divostin*), a distant offshoot in Montenegro (*Beran Krš*), and satellite cultures : **Sopot-Lengyel** (*Privlaka, Sopot, Otok, Pepelane*) and **Tisza** (site *Gorzsa* in eastern Hungary).

The transition of the Final Neolithic into the Early Eneolithic is distinctly present in Slovenia. This gradual shift can best be noted in the transition of the Alpine type of the **Lengyel** culture into the **Lasinja-Balaton** culture (on the localities of the

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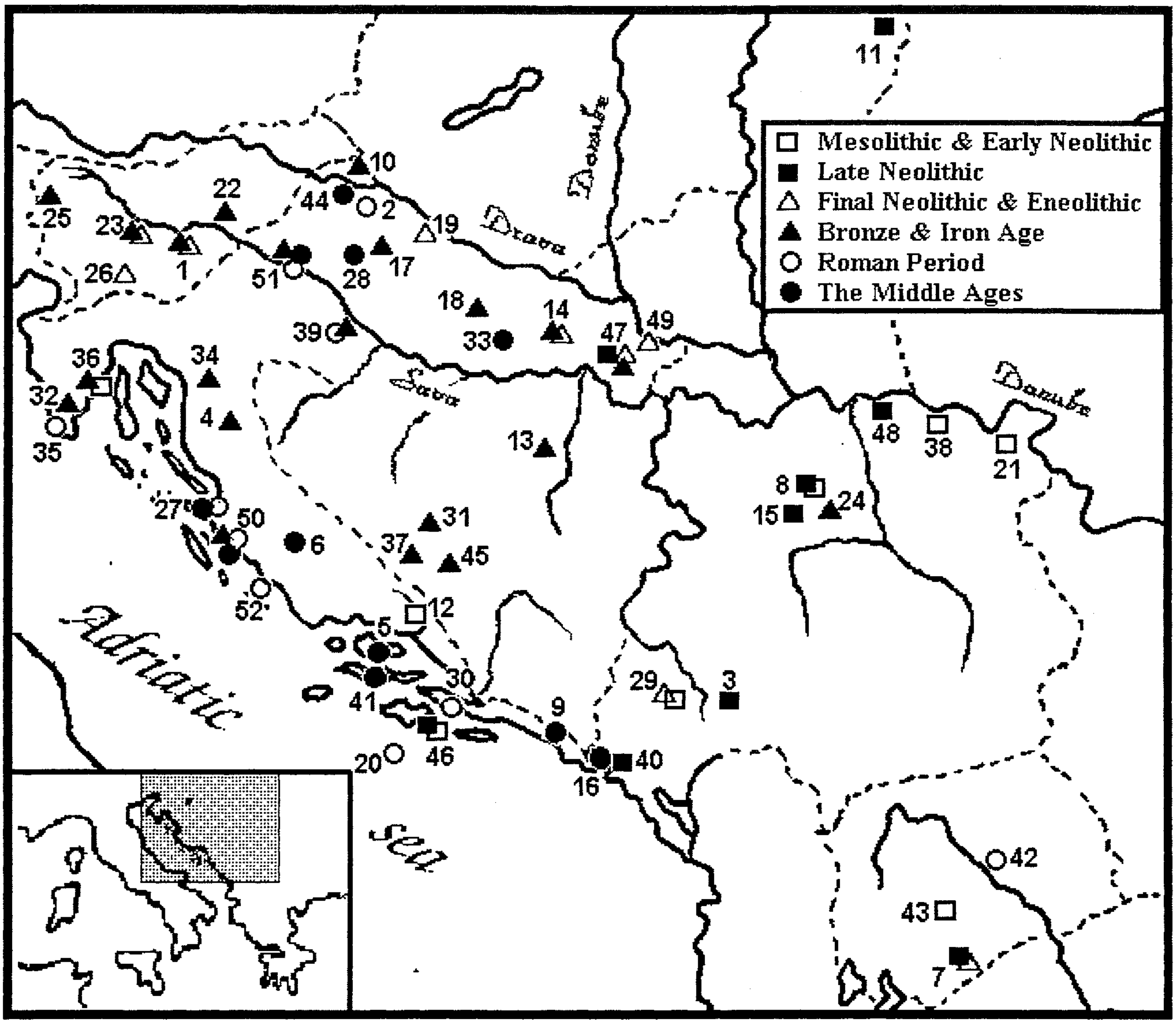

Fig. 1 - Archaeological sites.

1. Ajdovska jama
2. Aquae Iassae (Varazdin)
3. Beran krš (Ivangrad)
4. Bezdanjaca (Lika)
5. Bol (Brac is.)
6. Bribir
7. Crnobuki (Bitola)
8. Divostin (Kragujevac)
9. Dubrovnik
10. Gorican (Cakovec)
11. Gorzsa
12. Gospod. pecina (Cetina)
13. Grabovica (Doboj)
14. Grabrovac (Đakovo)
15. Grivac (Kragujevac)
16. Herceg Novi
17. Igrišce (Kalnik)
18. Kaptol (Pozega valley)
19. Koprivnica
20. Lastovo is.
21. Lepenski vir
22. Libna (Krško)
23. Ljublj.Barje
24. Ljuljaci (Kragujevac)
25. Most na Soci
26. Moverna vas (Crnomelj)
27. Nin
28. Nova Raca (Bjelovar)
29. Odmut (Montenegro)
30. Pelješac
31. Pod (Bugojno)
32. Podosojna (Pula)
33. Pozega
34. Prozor (Otocac)
35. Pula
36. Pupicina pec (Pula)
37. Pustopolje (Kupres)
38. Selevac (Smed.Palanka)
39. Sisak
40. Spila (Boka kotorska bay)
41. Starigrad (Hvar)
42. Stobi
43. Topolcani (Prilep)
44. Varazdin
45. Varvara
46. Vela spilja (Korcula.)
47. Vinkovci
48. Vlasac (D.Milanovac)
49. Vucedol (Vukovar)
50. Zadar
51. Zagreb
52. Zlarin is.

Ajdovska Jama cave, *Šafarsko, Maharski Prekop* near Ljubljana), as well as in NW Croatia (*Koprivnicki bregi*). The **Lasinja** culture can be traced all the way down to the *Odmut* cave in Montenegro.

The Late Eneolithic period is related to the invasion of the cattle-herder population from the East (Indoeuropeans), of which the **Baden** culture is typical, and its amalgmation with the autochthonous population of the **Kostolac** and **Vucedol** cultures in the south of the Pannonian valley. All the three cultures are clearly stratigraphically manifested at the *Vucedol* tell. To the west of the Danube river the **Vucedol** culture was in the Pannonian valley replaced by the earliest Bronze Age **Vinkovci** culture, but at several sites their parallel existence can also be observed (*Grabrovac*, *Rudina*). The final stage of the Eneolithic Age in Macedonia is defined at the site of *Crnobuki* by the late phase of the great *Bubanj - Sălcuta - Krivodol* complex, while in Eastern Serbia, western parts of Rumania and Bulgaria, it can be found as early as the Final Neolithic period.

The comparison of Mesolithic, Neolithic and Eneolithic cultures in the hinterland with those on the Adriatic coast is by no means straightforward, due to the lack of direct overlapping of archeological artifacts. The relative chronology has been established on the basis of the intermediary cultures found in Bosnia, so that indisputable relations can be identified only by means of ^{14}C chronology dating. The only exception is the finding of two Eneolithic cultures – **Lasinja** and **Vucedol** – originally of continental descent, in the stratigraphically interesting *Odmut* cave (Montenegro), where they overlie several Neolithic layers of various Adriatic cultures.

It should be stated that the **Lasinja** culture marks the transition from the Neolithic towards the Eneolithic period. On the other hand, the **Vucedol** culture marks the transition from the Eneolithic into the Early Bronze Age, both in the continent and on the Adriatic coast.

In the period from the N e o l i t h i c till the end of the I r o n A g e the focus of settlement gradually, but evenly spread from the Pannonian and Adriatic regions, traditionally the most attractive settling areas, into their mountainous hinterlands which had previously existed as refuge areas allowing long conservative survival. The dispersion of settlement pattern typical of the B r o n z e A g e period can be observed in the diversity of settlements and abodes : pile dwellings (*Notranje Gorice, Blatna Brezovica*), caves (*Bezdanjaca, Ajdovska jama, Pupicina Pec*), pit houses (*Grabrovac, Podgorac*), while traditional houses can most commonly be found at new types of protected settlements, *i.e.*, hill-forts (*Ljuljaci, Pod, Velika gradina* in Varvara, *Igrišce* in NW Croatia). Innovations in burial ceremony have also been recorded in Bosnia, otherwise conservative region, *e.g.*, in *Grabovica* (grave of **Urnfield** culture) and *Pustopolje* near Kupres (wooden sarcofagus under tumulus). All this bears witness to uncertain times of great changes.

Since the settlement of hill-forts mainly took place during the I r o n A g e period, practically all finds belong exclusively to this period. The most common reasons for the analyses of the finds from that time are, therefore, the unusual circumstances surrounding the finds (*e.g.* caves, boats, wells). Hill-forts typical of the period are *Pod*, *Prozor*, *Libna*, *Most na Soci*, and the excavations on the position of the Zagreb City museum also reveal the remains of the settlements from the older (**Halstatt**) and later (**La Tène**) Iron Age period.

The whole area of South-Eastern Europe was for the first (and single) time culturally unified due to the R o m a n conquest. Apart from the analyses from large Roman settlements, like *Stobi* in Macedonia and *Siscia* (modern Sisak), *Andautonia* and *Aque Iassae*, *Pola* (modern Pula) in Croatia, the research included several Adriatic shipwrecks (*Pelješac*, *Lastovo*, *Nin*, *Zlarin*).

More significant series of analyses of m e d i e v a l and modern material originate from the rescue excavations carried out within the urban cores of several Croatian towns (*Zagreb*, *Cakovec*, *Varazdin*, *Pozega*, *Zadar, Dubrovnik* and *Nin*).

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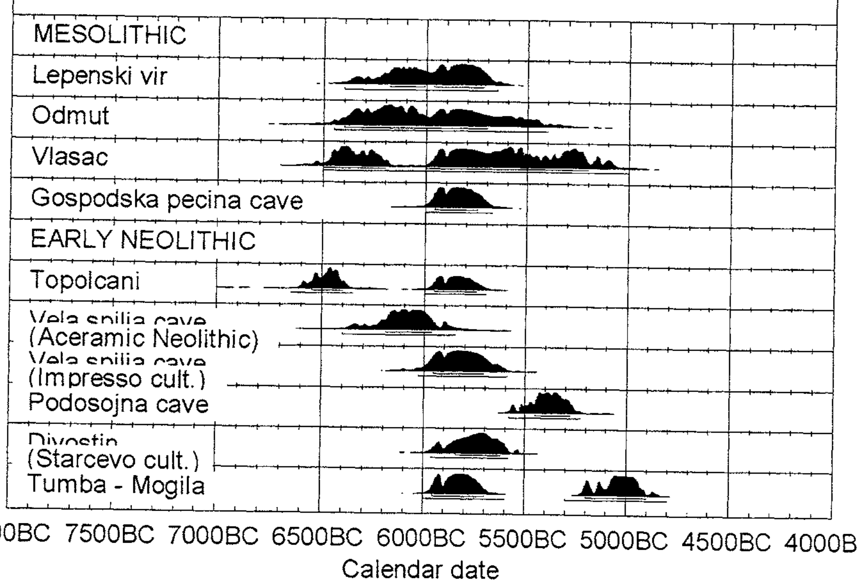
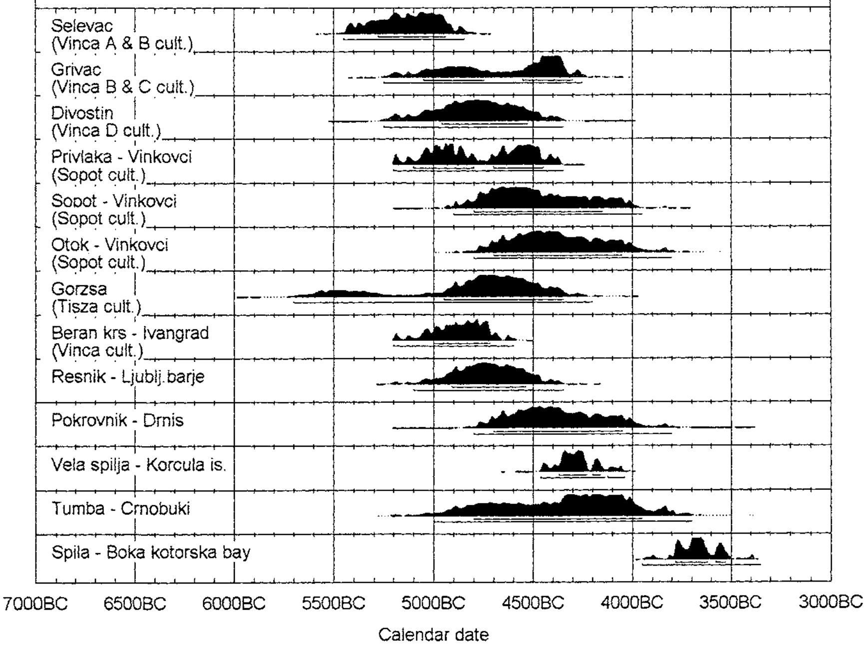
Table 1: Mesolithic & Early Neolithic



Calibration limits (% confidence, 1σ)

BC 6180-5720 BC (1.00)
BC 6400-5700 BC (1.00)
BC 6500-6200 BC (0.22)
BC 6000-5200 BC (0.78)
BC 5950-5750 BC (1.00)
BC 6550-6400 BC (0.50)
BC 5950-5750 BC (0.50)
BC 6190-5960 BC (1.00)
BC 5950-5710 BC (1.00)
BC 5450-5280 BC (1.00)
BC 5960-5580 BC (1.00)
BC 5950-5700 BC (0.54)
BC 5200-4900 BC (0.46)

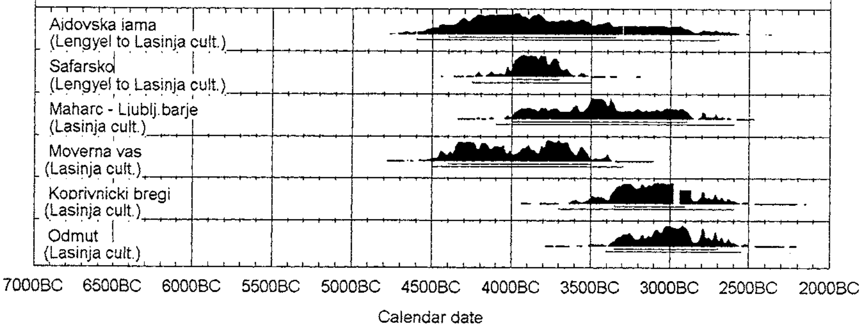
Table 2: Late Neolithic



Calibration limits (% confidence, 1σ)

BC 5280-4940 BC (1.00)
BC 5050-4750 BC (0.43)
BC 4550-4300 BC (0.57)
BC 4960-4530 BC (1.00)
BC 5100-4800 BC (0.50)
BC 4700-4450 BC (0.50)
BC 4800-4150 BC (1.00)
BC 4700-4050 BC (1.00)
BC 4950-4350 BC (1.00)
BC 5000-4720 BC (1.00)
BC 4910-4540 BC (1.00)
BC 5330-5070 BC (1.00)
BC 4370-4230 BC (0.86)
BC 4200-4160 BC (0.14)
BC 4800-3950 BC (1.00)
BC 3780-3620 BC (0.81)
BC 3580-3530 BC (0.19)

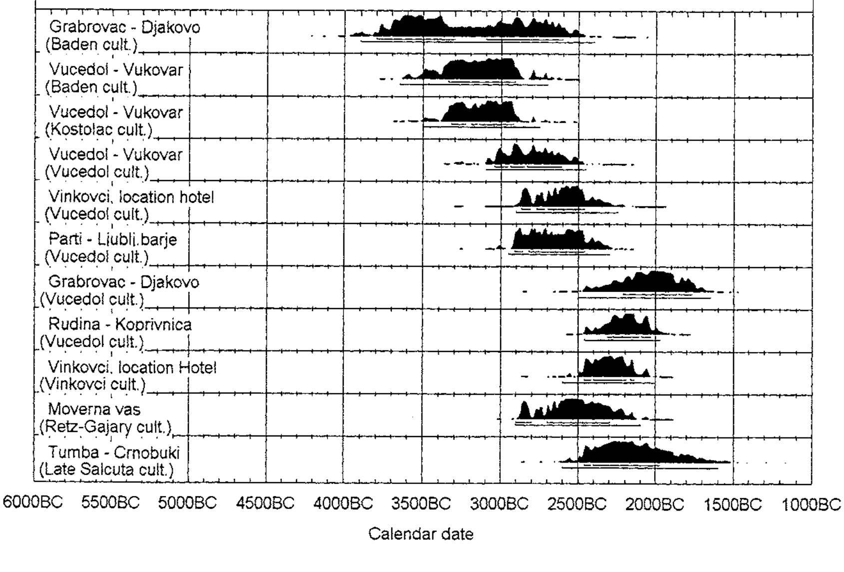
Table 3: Final Neolithic & Early Eneolithic



Calibration limits (% confidence, 1σ)

BC 4400-3350 BC (1.00)
BC 3990-3700 BC (1.00)
BC 4000-2900 BC (1.00)
BC 4400-3500 BC (1.00)
BC 3350-2910 BC (1.00)
BC 3350-2700 BC (1.00)

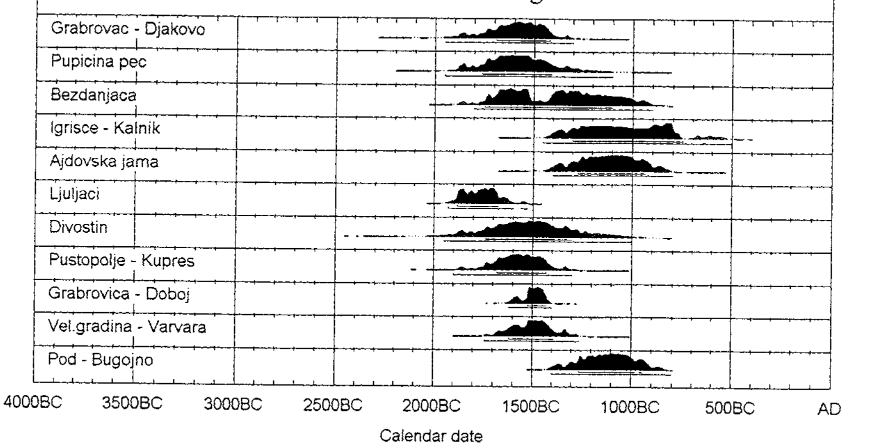
Table 4: Late Eneolithic



Calibration limits (% confidence, 1σ)

BC 3800-3300 BC (0.53)
BC 3100-2600 BC (0.47)
BC 3340-2910 BC (1.00)
BC 3320-3230 BC (0.25)
BC 3140-2920 BC (0.75)
BC 3040-2610 BC (1.00)
BC 2870-2810 BC (0.17)
BC 2770-2460 BC (0.83)
BC 2910-2460 BC (1.00)
BC 2210-1850 BC (1.00)
BC 2910-2030 BC (1.00)
BC 2460-2190 BC (1.00)
BC 2900-2800 BC (0.10)
BC 2700-2300 BC (0.90)
BC 2460-1970 BC (1.00)

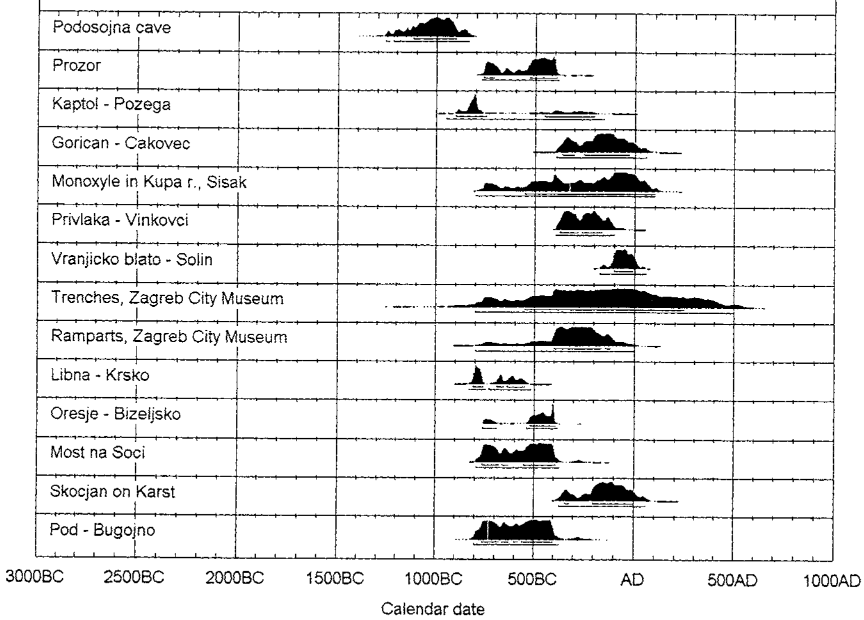
Table 5: Bronze Age



Calibration limits (% confidence, 1σ)

BC 1690-1420 BC (1.00)
BC 1760-1410 BC (1.00)
BC 1750-1100 BC (1.00)
BC 1300- 750 BC (1.00)
BC 1270- 930 BC (1.00)
BC 1880-1680 BC (1.00)
BC 1740-1300 BC (1.00)
BC 1680-1420 BC (1.00)
BC 1525-1425 BC (1.00)
BC 1620-1390 BC (1.00)
BC 1260- 940 BC (1.00)

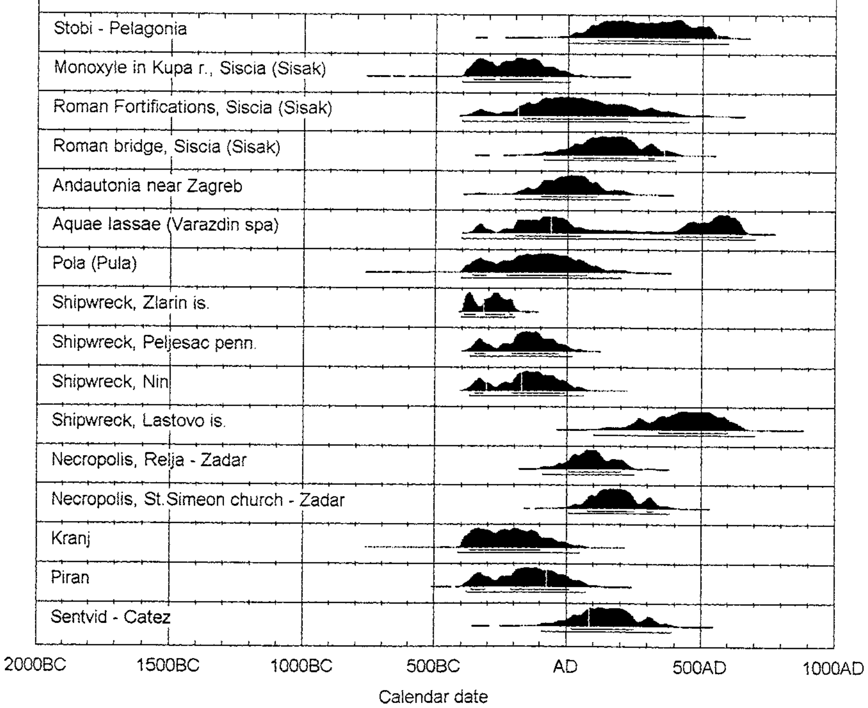
Table 6: Iron Age



Calibration limits (% confidence, 1σ)

BC 1120- 900 BC (1.00)
BC 760- 700 BC (0.20)
BC 530- 390 BC (0.80)
BC 900- 750 BC (0.66)
BC 450- 200 BC (0.44)
BC 360- 300 BC (0.17)
BC 250- 30 BC (0.83)
BC 550- 100 AD (1.00)
BC 370- 160 BC (1.00)
BC 100- 10 BC (1.00)
BC 550- 250 AD (1.00)
BC 400- 120 BC (1.00)
BC 810- 760 BC (0.56)
BC 690- 550 BC (0.44)
BC 520- 390 BC (1.00)
BC 760- 630 BC (0.05)
BC 550- 390 BC (0.95)
BC 340- 320 BC (0.05)
BC 200- 1 AD (0.95)
BC 360- 400 BC (1.00)

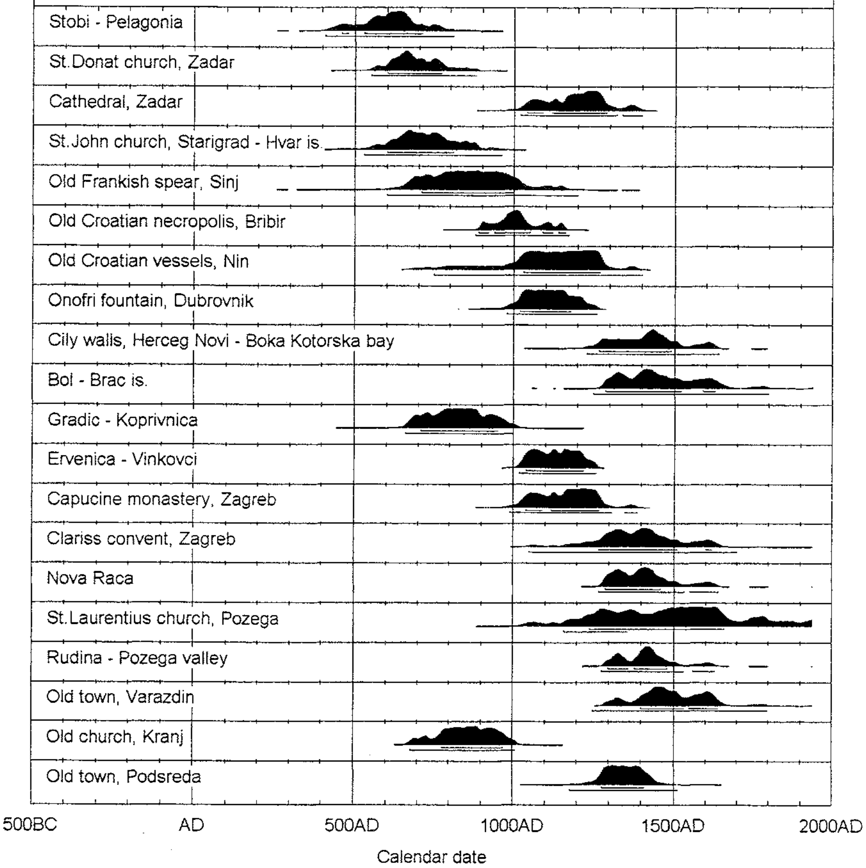
Table 7: Roman period



Calibration limits (% confidence, 1σ)

AD 110- 450 AD (1.00)
BC 360- 280 BC (0.32)
BC 260- 100 BC (0.68)
BC 170- 220 AD (1.00)
AD 20- 260 AD (0.95)
AD 300- 320 AD (0.05)
BC 100- 110 AD (1.00)
BC 200- 50 AD (0.50)
AD 400- 650 AD (0.50)
BC 360- 310 BC (0.11)
BC 230- 70 AD (0.89)
BC 390- 210 BC (1.00)
BC 350- 310 BC (0.12)
BC 210- 30 BC (0.88)
BC 350- 320 BC (0.08)
BC 210- 10 BC (0.92)
AD 340- 600 AD (1.00)
AD 10- 200 AD (1.00)
AD 80- 250 AD (0.98)
AD 300- 320 AD (0.02)
BC 370- 100 BC (1.00)
BC 360- 310 BC (0.11)
BC 210- 10 AD (0.89)
AD 20- 250 AD (1.00)

Table 8: The Middle Ages



Calibration limits (% confidence, 1σ)

AD 460- 480 AD (0.04)
AD 530- 710 AD (0.96)

AD 600- 70 AD (1.00)

AD 1040-1090 AD (0.04)
AD 530- 710 AD (0.96)

AD 600- 810 AD (1.00)

AD 710-1000 AD (1.00)

AD 890-1050 AD (0.88)
AD 1090-1160 AD (0.13)

AD 1030-1270 AD (1.00)

AD 1020-1180 AD (1.00)

AD 1270-1490 AD (1.00)

AD 1290-1520 AD (0.92)
AD 1590-1630 AD (0.08)

AD 610- 790 AD (1.00)

AD 1040-1220 AD (1.00)

AD 1040-1090 AD (0.20)
AD 1120-1270 AD (0.80)

AD 1270-1510 AD (0.99)
AD 1600-1620 AD (0.01)

AD 1290-1460 AD (1.00)

AD 1240-1660 AD (1.00)

AD 1300-1360 AD (0.28)
AD 1380-1480 AD (0.72)

AD 1400-1530 AD (0.68)
AD 1550-1640 AD (0.32)

AD 780- 970 AD (1.00)

AD 1280-1410 AD (1.00)

Actes du colloque « C14 Archéologie », 1998, p. 239-241.

CHRONOLOGY OF CULTURES IN BRONZE AGE IN EASTERN EUROPE AND NEW DATES ACCORDING TO ^{14}C

*Pavel KOUZNETSOV**

Abstract : For the first time, a series of radiocarbon datings was made by A.M.S. on the cultures of the Russian steppe zone. 21 graves were dated and the chronological sequence of these cultures was established as follows : Pit-grave culture→Poltakva culture→Potapovo culture→Timber grave culture→Suskan culture. A chronological hiatus between Eneolithic and Early Bronze Age cultures was evidenced.
The dating of graves with disk cheek-piece, decorated in the «Micenan» style was established.
The choice of significant absolute dates for each culture was based on the top limit of the calibration interval ; in this way, the traditional chronology was better taken into account.
The Bronze cultures from South Russia cover the period from the beginning of the IIIrd millenium BC to the second half of the II millenium BC.

Résumé : Pour la première fois, on a effectué par A.M.S. une série de dates radiocarbone sur les cultures de la steppe de Russie. 21 tombes ont été datées, ce qui permet d'établir la séquence chronologique de ces cultures comme suit : Culture de «Pit-grave» → Culture «Poltkava»→ Culture «Potapovo»→ Culture «Timber»→ Culture «Suskan». On a mis en évidence un hiatus chronologique entre les cultures de l'Enéolithique et celles du Bronze ancien. On a fait aussi la datation de tombeaux contenant des pièces de joue discoïdes décorées dans le style micénien. Le choix des dates absolues significatives pour chaque culture a été basé sur la limite supérieure de l'intervalle de calibration la concernant ; de cette façon la chronologie traditionnelle est mieux prise en compte. Les cultures de l'Age du Bronze du Sud de la Russie occupent une période s'étendant du IIIème millénaire jusqu'à la seconde moitié du IIème milléniare avant J.-C.

Key-words : Radiocarbon dates, Steppe zone, South Russia, Ukrain, Bronze Age.

Mots-clefs : Dates radiocarbone, steppe, Russie méridionale, Ukraine, Age du Bronze.

A series of ^{14}C data are now available for sites located in South Russia and Ukrain. It is a very important geographical region, located in the west of the Eurasian steppe zone in between Caucasus, Ural and Carpathians. On this territory, artefacts from Eneolith sites from the Bronze age have brought evidence of interaction with high civilizations in Front Asia, Near East, Agian World. However, the common scheme on the consequence of cultures in the Eurasian steppe has not been defined yet. The triad of the change of cultures in the Bronze age was preserved, as stated by the Russian archaeologist V.A. Gorodtsov as early as in 1903-1905. It is now identified by three main stages : early, middle and late Bronze age.

The link between different cultures, according to radiocarbon data, will make it possible to establish the degree of interaction between different regions and to create a common scheme for the development and the change of cultures in the whole steppe of Eurasia. The first results of these works from the last decade have now been published (Bochkarev, 1992 ; Anthony & Vinogradov, 1995 ; Trifonov, 1996).

The chronological position of cultures was traditionally defined through artefacts in metal. These are copper implements and armourments but their duration and their modification through time remains problematic. The methods of radiocarbon data become here rather important. The use of ^{14}C data on samples from different regions will make it possible, in my opinion, to find the real correlation between cultures from different territories. It is paradoxal, but the use of radiocarbon data for such purpose seems to be safer than its direct nomination - the definition of absolute age. The samples are representative as there are bones from the burried.

In the last decade, in eastern Europe, and especially in the steppe zone, many diagnostic sites from the Bronze age were studied. Among them, some from the Early

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Bronze age show traces of cultures from Central Europe.

The large territory of the Eurasian steppe zone makes it difficult to create a united chronological scheme, as it was done for Central and Northen Europe. To achieve this aim, it results necessary to create a local, but very precise chronological scheme, where the position of the main archaeological cultures are defined. 21 samples from burial grounds of the Volga river were sent to the radiocarbon laboratory of Oxford University inside the Russian-English archaeological cooperation. All the samples were reliable. As a result of the project, which is carried out by V. Trifonov for Povolzhie, the laboratory of Oxford found 21 samples from the Eneolith - Bronze age.

Bones were selected from the burried Chvalynsk II from the late Eneolithic as well as burial mounds from the Bronze Age, with precise cultural connections. For better reliability, more samples were selected in three burial graves from the same burial mound with direct stratigraphy (N. Orlyanka I, burial mound 1, burial graves 3 → 4 →5 ; excavations carried out by the author in 1993). The results of the dating proved precisely this stratigraphical consequence, which reflects the reliability of new radiocarbon data (see fig. 1).

Two sites from this seria were dated - Potapovka and Utevka VI burial grounds. In these burial grounds, disk cheek-piece were found, made of an ornament in the «Mikeni» style. It seems obvious that only these ornamental elements from the Aegean world entered Eastern Europe in the earliest times. According to this traditional chronology, the significant calibrated date should not be defined according to the arithmetical medium of the whole calendar interval of radiocarbon date, but according to the meaning of the upper interval of the calibrated curve. The results showed that the Potapovka culture existed in the limits 19 - 17 century B.-C. (middle Ellade III according to A. Furumark). Therefore, this method, based on the choice of the upper limit of the calibrated interval, might be the best.

These observations, taking into account the «historical collection», make it possible to relate the upper limits of ^{14}C calibrated intervals for the Maikop culture in the Caucasus to the second half of the IV - beginning of the III melliennium B.-C. (Korenevskiy, 1993).

The given observations make it possible to suggest the method of choosing calibrated intervals, taking into account the traditional chronology.

The result concerning calibrated calendar intervals for the Eneolith - Bronze were defined on the basis of radiocarbon dating of the earliest and the latest burial grave of one culture, which leads to the following chronological scheme (tab.).

A chronological column for the compact territory of the southern region of Middle Volga was established. According to these dates, the duration of the last culture was longer than the previous one and characterized by a greater dynamism. A surprisingly big hiatus appeared between early Bronze and late Eneolithic periods.

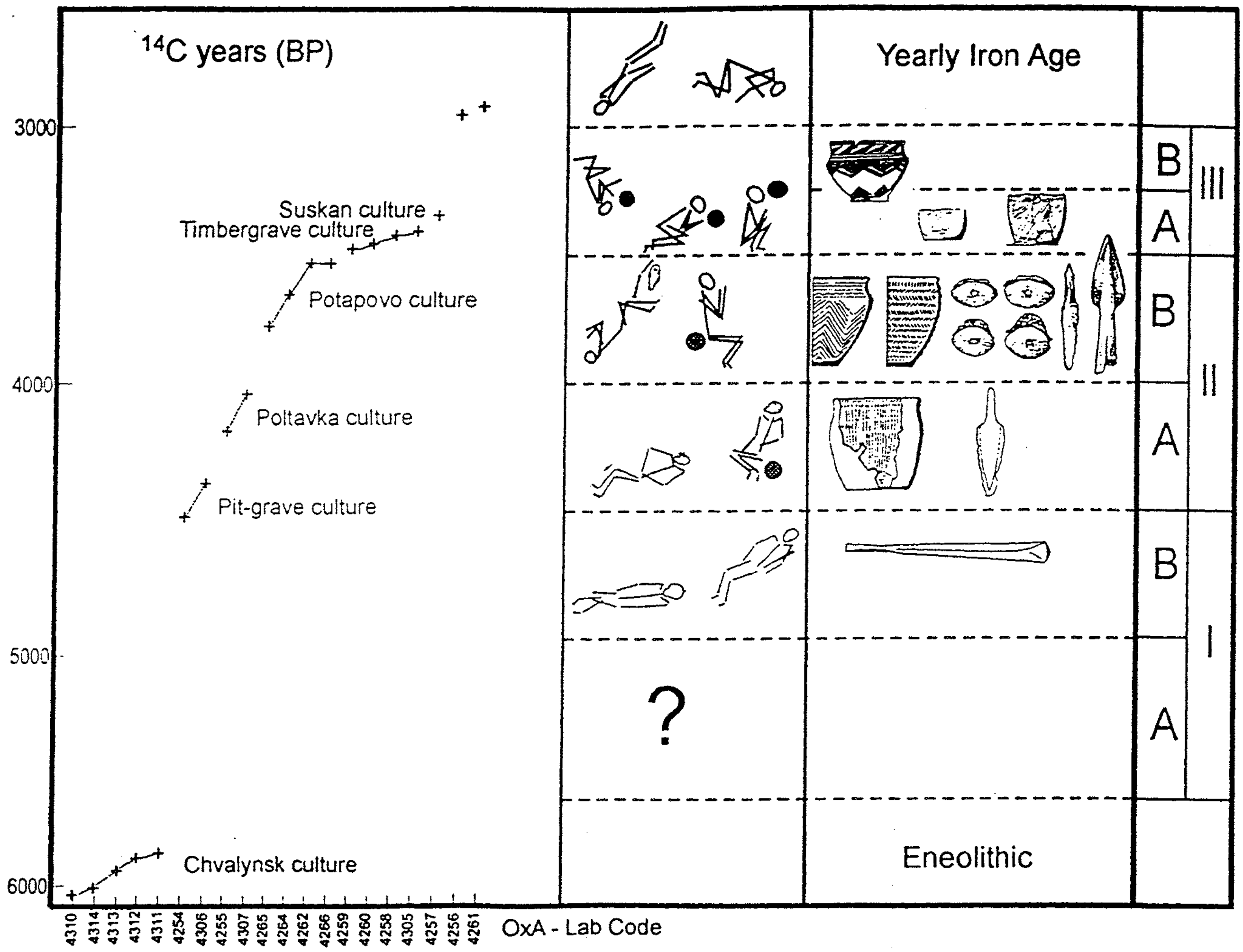

Fig. 1 : Dates of Bronze age cultures from Eastern Europe according to ^{14}C.

	Late Bronze Age	
III B	Suskan culture	1450 y. BC (XV century BC)
III A	Timber grave culture	1622 - 1520 y. BC (XVII-XVII century BC)
	Middle (developed) Bronze Age	
II B	Potapovo culture	1889 - 1622 y. BC XIX - XVII century BC
II A	Poltavka culture	2574 - 2461 y. BC (second half of the III thousandYears BC)
	Early Bronze Age	
I B	Pit-grave culture	3098 - 2887 y. BC (first half of the III thousandYearsBC)
I A	?	?
	Eneolithic	
	Chvalynsk culture	4840 - 4461 y. BC (V thousand BC)

Tab.

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DATING A BURNT MOUND AND ITS BEAKERS AT NORTHWOLD, NORFOLK

Andy CROWSON and Alex BAYLISS***

Abstract : A well-preserved burnt mound at Northwold, Norfolk, offered an ideal opportunity to test the merits of producing a model of the site's chronology based on its stratigraphy and a sequence of high-precision radiocarbon dates. In spite of the flat shape of the calibration curve for the earlier Bronze Age, close dates were achieved for activity around the mound and for an associated assemblage of Beaker pottery. The results will contribute significantly to research into the problematic questions of the morphology and functions of burnt mound and Beaker dating.

Résumé : Un monticule carbonisé, bien conservé et fouillé à Northwold, dans le Norfolk, nous a donné l'occasion de tester les avantages de produire un modèle mathématique de la chronologie du chantier se basant sur la stratigraphie et les datations radiocarbone de précision. Malgré l'absence de changement significatif de calibration pendant l'Age du Bronze ancien, nous avons réussi à obtenir des dates précises de l'activité autour du monticule et de la céramique "Beaker" associée. Les résultats vont contribuer aux recherches des problèmes de morphologie et de fonction du monticule carbonisé et de la datation de la culture "Beaker".

Key-words : High-precision, modelling, taphonomy, burnt mound, Beaker.

Mots-clés : Précision, modèle mathématique, taphonomie, morticule carbonisé, Campaniforme.

INTRODUCTION

Scatters, spreads and mounds of burnt and heat-affected stone are one of the most common elements of prehistoric landscapes. In fact, rarely is a site of any period excavated without producing a few of these artefacts.

Early study of burnt mounds began in Ireland in the last century, with over 4000 examples of 'fulachta fiadh' recorded to date (Buckley, 1990, 9). Work earlier this century in Wales (Cantrill and Jones, 1911, 253-69), and indeed Norfolk (Layard, 1922, 483-98), suggested these sites represent cooking places. This interpretation was not seriously challenged until the mid-1980s, when hypotheses of their use as bathing sites and saunas were put forward (Barfield and Hodder, 1987, 370-79). The scope of suggestions has broadened to include steam and hot water for fulling (Hodder and Barfield, 1991, 97-107) and a range of semi-industrial functions (Lawson, 1983, 95-6).

Over the past 20 years English Heritage has funded a programme of survey work in the former wetland area of the Fens (Hall and Coles, 1994). Several hundred spreads of burnt flint were identified. It is suggested that they date to the late third or second millennium BC (Silvester, 1991, 86). Northwold was excavated as a well-preserved example of this category of site (Crowson forthcoming).

1 - THE SITE

The site at Northwold is situated on the eastern edge of the Fens (fig. 1). Fenland surface deposits are the product of marine transgressions and freshwater flooding episodes during the Flandrian (Waller, 1994, 6-17). Towards the end of the Neolithic, activity shifted from increasingly isolated islands and ridges onto the edge of freshwater fen generated at the limits of marine influence.

Land use in the Fens since the 1940s has seen a concentration on arable farming. This is the single most potent threat to the integrity of archaeological deposits in Fenland, not just through plough damage but also by dewatering which destroys organic remains and environmental data.

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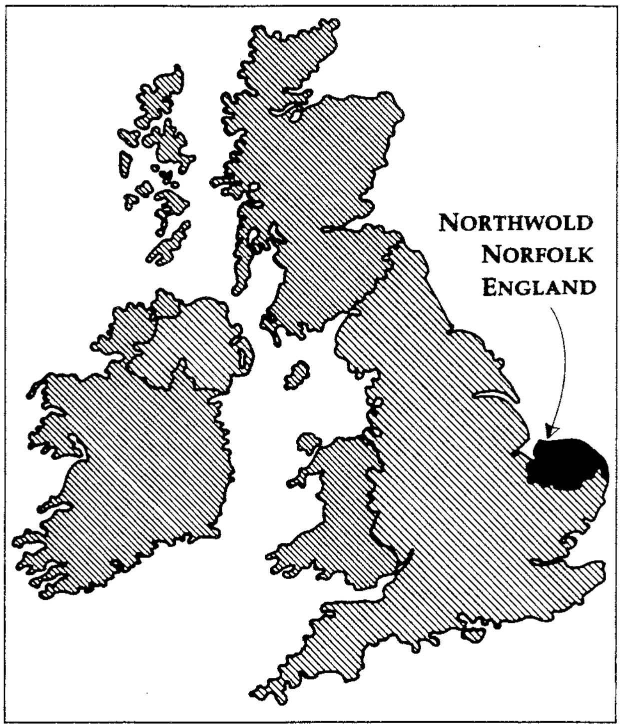

Fig. 1 : Site location.

2 - THE EXCAVATION

The depth and quality of preserved archaeological deposits was remarkable, because the site was partially sealed beneath structured woody peat. The area was mechanically-stripped of ploughsoil, and the revealed burnt mound sub-divided into quadrants, dry-sieved, and sampled for charred plant remains on a 1 m grid.

Pre-mound occupation was represented by a buried soil cut by a number of pits, and a ditch. This activity was provisionally dated to the earlier Neolithic. Charred plant remains were recovered from these features (BS74 and BS94), although the taphonomy of the samples is unclear. They could be residual, but they must provide accurate *termini post quem* for the contexts dated, on the principle that all the material in a deposit must predate its formation. Since these samples are at the bottom of the sequence, this is sufficient.

Activity relating to the burnt mound dates to the early Bronze Age (fig. 2). The focus of this was a 1.40 m deep, sub-circular pit [52] containing organic, waterlogged fills with well-preserved oak leaves and pointed hazel stakes. Upcast form the initial digging of the pit was sealed below the earliest burnt flint deposits. One of the dated samples (BS62) was a fragile waterlogged plant macrofossil from the primary silt of the pit. The character of this layer suggests that it immediately predated the charcoal-rich activity and the fragility of the macrofossil argued against any possibility of residuality. These factors together suggested that this sample would provide an excellent *terminus post quem* for the construction of the mound. The other sample from this pit was a waterlogged stake (176), which we interpreted as functionally related to the primary construction of the feature.

The burnt mound consisted of small, heat-crazed flint fragments in a charcoal-rich peaty matrix. This extended *c* 13 m in diameter, and survived to a maximum of 0.18 m deep. The functions of burnt mounds, and the taphonomy of this material, is unknown. For this reason an initial series of ten samples was submitted for dating. This comprised one sample of bulk charcoal for high-precision dating and four single fragments of charcoal for AMS dating from each of two 1 m squares. One of these squares (BS47) was central to the mound, the other (BS44) was peripheral.

Further features probably related to water management were constructed during the period of use of the mound (eg [23]). The latest feature associated with this activity was a sub-rectangular pit [14], which was lined with alder planks (*Alnus* sp.). These provided two samples (188 and 192), which may be interpreted as post-dating other activity concerned with the mound if we assumed that the timber used to line the pit was not reused. There was no evidence of this, although absence of evidence is not proof.

Completing the structural sequence, two samples were available from the peat deposit which grew over the site once it had been abandoned (123 and 125).

The environmental evidence from plant macrofossils, palynomorphs, insects, and molluscs shows that the site was located in mixed deciduous woodland, with probably damp, grazed, weedy grassland in the immediate vicinity. Local woodland was exploited to supply constructional wood of alder (*Almus* sp.), hazel (*Corylus* sp.) and oak (*Quercus* sp.).

The pottery assemblage recovered from the burnt mound comprised 166 sherds, principally of Beaker form (fig. 3). They are dated *stylistically* towards the end of the period *c.* 2600-1800 cal BC (Clarke, 1970). The Beakers are all decorated, most frequently with rough, plastic, finger-tip rustication. A smaller number feature incised lines in a chevron motif combined with stabbed decoration to the rim. The fabric types and decorative forms fall within the range characteristic of Bronze Age pottery from the region (Bamford, 1982). Fen Beaker is usually said to be 'domestic' in that it is not generally found as a burial accompaniment but was in everyday use.

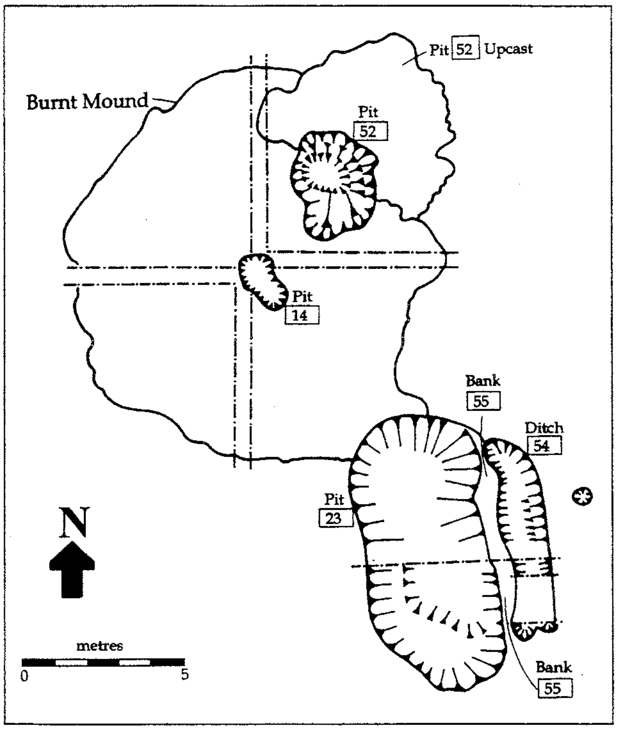

Fig. 2 : Site plan : burnt mound and associated features.

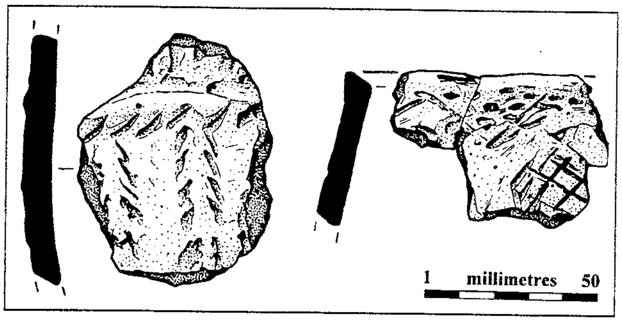

Fig. 3 : Beakers from the mound. Scale 1:2.

3 - OBJECTIVES OF THE DATING PROGRAMME

The radiocarbon dating programme has two major objectives. Firstly we wished to provide precise dates for the period of use of the mound and the associated Beaker pottery. This would allow inter-site comparisons to be made with some knowledge of the relative dating of the sites and assemblages under consideration. Secondly we wished to investigate the chronological make-up of the mound, particularly with reference to possible spatial differences. For this reason bulk samples of charcoal were retrieved on a 1 m grid (see above). The aim was to distinguish reliably between two hypotheses - that the mound represents a very short period of activity, or that it represents a long period of use. If either of these objectives could be successfully achieved, we hoped that the site could contribute to wider archaeological research into the dating of Beaker pottery (Kinnes *et al.*, 1991) and into the morphology of burnt mounds (Hodder and Barfield, 1991).

4 - METHODOLOGY

Although the simple calibrated date ranges of radiocarbon measurements are accurate estimates of the dates of the samples, this is usually not what we really wish to know as archaeologists. It is the dates of the archaeological events which are represented by those samples which are of interest. For this reason we have taken an interpretative, contextual, approach to answering the archaeological objectives for the dating of this site.

Fortunately, explicit methodology is now available which allows us to combine the results of the radiocarbon analyses with other information which we may have, such as stratigraphy, to produce realistic estimates of these dates of archaeological interest. It should be emphasised that these distributions and ranges are not absolute, they are interpretative *estimates*, which can and will change as further dates becomes available and as other researchers choose to model the existing data from different perspectives.

The technique we have used is known as 'Gibbs' sampling' (Gelfand and Smith, 1990) and has been applied using the programme OxCal v2.18 (http://www.oxford.ac.uk/rlaha/). Full details of the algorithms employed by this program are available from the on-line manual or in Bronk Ramsey (1995), and fully worked examples of this approach are given in the series of papers by Buck *et al.*, (1991 ; 1992 ; 1994). The algorithms used in the models described below can be derived from the structure shown in figures 4 and 5.

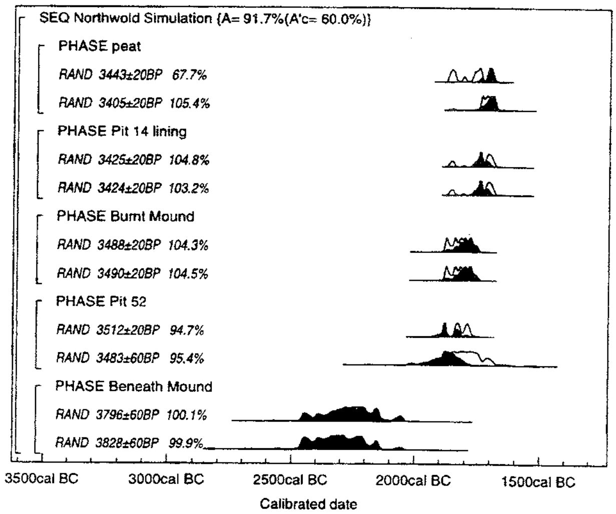

Fig. 4 : Probability distributions of dates from a simulation of the sequence at Northwold : each distribution represents the relative probability that an event occured at a particular time. The distributions plotted in outline are the result of simple radiocarbon calibration. The distributions plotted in black are based on the chronological model used. The radiocarbon results were simulated using the RAND function of OxCal, with error terms estimated from the type of material available from each context. See the text for further discussion. The large square brackets down the left hand side along with the OxCal keywords define the overall model exactly.

Here we concentrate on the archaeology - particularly on the reasoning behind the interpretative choices which we have made in producing the models presented. These archaeological decisions fundamentally underpin our choice of statistical model.

5 - SAMPLING

Fortunately a relatively complete stratigraphic sequence was preserved and recovered from Northwold (see above). By taking this sequence and examining the type of material which was available for dating from each context, we were able to find a series of samples of known relative age. Utilising an archaeological estimate of 1800 BC for the date of the rusticated Beaker which was recovered form part of the sequence, we constructed the simulation shown in figure 4. This suggested that we might be able to date the mound to within a century if high-precision measurements could be obtained.

The desirability of high-precision dates was also shown by estimating how many measurements would be required to distinguish between a short phase of use for the mound and a long one of 200 years or more. For the fairly short phases which we expected in this case, high-precision measurements are extremely cost-effective (Bayliss and Orton, 1994).

Of course, the mathematical approach which we have taken here fundamentally depends on the relationship between the actual date of the formation of the archaeological context and the date of the material sampled (Bayliss, this volume). Because of this the taphonomy of the samples selected for dating has been discussed explicitly as part of the description of the structural sequence above.

All the samples submitted from this site are charcoal or wood. Since the centre of a large tree will have the radiocarbon content of the year in which the tree-ring grew, it is essential that all the material should be identified to age and species before dating (van Strydonk *et al.*, this volume). Otherwise there will be a significant offset between the actual date of the material which has been sampled and the date of the archaeological context, irrespective of how the sample reached the context. Samples of short-lived species or of roundwood or sapwood minimise this age-at-death offset present in samples from tree-rings.

6 - RESULTS

The radiocarbon results and calibrated date ranges are given in table 1. They are quoted in accordance with the international standard known as the Trondheim convention (Stuiver and Kra, 1986). The calibrated date ranges cited in the text are those for 95 % confidence. They are quoted in the form recommended by Mook (1986), with the end points rounded outwards to 5 years. Those in italics are ranges derived from mathematical modelling of archaeological problems (see below). The calibrated ranges in table 1 have been calculated according to the maximum intercept method (Stuiver and Reimer, 1986), all other ranges are derived from the probability method (Stuiver and Reimer, 1993). All the calibrations have been calculated using the data set published by Pearson and Stuiver (1986).

7 - THE INTERPRETATIVE MODEL

The model of the chronology of the site is shown in figure 5. This integrates the radiocarbon evidence with the relative dating which is provided by the stratigraphic sequence. It should be said that two results were not in good agreement with the original stratigraphic position suggested by our archaeological interpretation. It seems likely that BS74 did not really come from a pre-mound feature (A=12.9 % ; Bronk Ramsey, 1995), but was intrusive. It has therefore been excluded from the model shown in figure 5. UB-4099 has been included in the model, although it seems likely that this stake was driven into the pit at a later date than original envisaged.

All the results from the burnt mound are statistically indistinguishable (T'=9.9 ; T'(5 %)=16.9 ; v=9 ; Ward and Wilson, 1978). However, we have decided not to take a weighted mean of all the measurements, since we do not know that all the fragments of wood are of exactly the same date. Instead we have taken a weighted mean for each sampling unit (BS44 : T'=8.1 ; T'(5 %)=9.5 ; v=4 ; BS47 : T'=1.1 ; T'(5 %)=9.5 ; v=4). This approach makes the same assumption as if we had simply taken bulk samples for radiometric dating from the mound (see Ashmore, this volume). The statistical consistency of the results suggests that this is reasonable.

Using this approach and the model shown in figure 5, we can see that the actual burnt mound activity is dated to *cal BC 2195-2155 (at 95 % confidence ; BS44)* or *cal BC 2200-2140 (at 95 % confidence ; BS47)*. The mound and associated activity, such as the construction of pits [52] and [14], started in *cal BC 2265-2165 (at 95 % confidence)* and ended in *cal BC 2140-2065 (at 95 % confidence)*. This activity lasted for *35-165 years (at 95 % confidence* ; fig. 6). By calculating the interval between the lining of pit [14] and the peat which sealed it, it can be shown that this feature was probably used for a relatively short period of time of *0-70 years (at 95 % confidence)*.

8 - ARCHAEOLOGICAL SIGNIFICANCE

The excavation and dating programme of this site can claim to have provided three important pieces of archaeological information :

- high precision dating for the period of use of the burnt mound,
- a close date range for a distinctive Beaker assemblage,
- information on the chronological homogeneity of the charcoal deposit.

Laboratory Number	**Sample Reference**	**Identification**	**Radiocarbon Age (BP)**	**$\delta^{13}C$ (‰)**	**Weighted mean (BP)**	**Calibrated date range (95% confidence)**
UB-4078	123	*Quercus* sp. roundwood	3682±20	-26.8±0.2	-	cal BC 2140–1985
UB-4079	125	*Alnus* sp. roundwood	3692±20	-28.7±0.2	-	cal BC 2185–2030
UB-4080	188	*Alnus* sp. plank	3682±20	-28.9±0.2	-	cal BC 2140–1985
UB-4081	192	*Alnus* sp. plank	3783±24	-28.9±0.2	-	cal BC 2315–2140
UB-4099	176	*Corylus* sp. stake	3692±20	-30.2±0.2	-	cal BC 2185–2035
UB-4102	BS94	*Corylus/Alnus* sp. (50.5g)	3751±22	-27.5±0.2	-	cal BC 2280–2045
OxA-6894	BS62	*Corylus* sp., roundwood	3730±45	-25.2	-	cal BC 2290–2030
OxA-6895	BS74	*Corylus* sp.	3650±45	-28.6	-	cal BC 2190–1895
UB-4100	BS44	*Corylus/Alnus* sp. (48g); *Prunus* sp. (1g); Pomoideae (1g)	3706±21	-27.9±0.2		
OxA-6626	BS44(i)	*Corylus/Alnus* sp., roundwood	3750±55	-26.4		
OxA-6726	BS44(ii)	*Corylus/Alnus* sp., roundwood	3770±55	-26.4	3724±16	cal BC 2195–2040
OxA-6823	BS44(iii)	*Corylus/Alnus* sp., roundwood	3840±55	-26.1		
OxA-6846	BS44(iv)	*Corylus/Alnus* sp., roundwood	3650±55	-26.5		
UB-4101	BS47	*Corylus/Alnus* sp. (50g)	3746±22	-27.7±0.2		
OxA-6847	BS47(i)	*Corylus/Alnus* sp., roundwood	3730±60	-28.0		
OxA-6848	BS47(ii)	*Corylus/Alnus* sp., roundwood	3700±50	-25.8	3743±16	cal BC 2275–2045
OxA-6849	BS47(iii)	*Corylus/Alnus* sp., roundwood	3765±45	-26.3		
OxA-6850	BS47(iv)	*Corylus/Alnus* sp., roundwood	3755±45	-26.3		

Tab. 1 : Sample details and radiocarbon results.

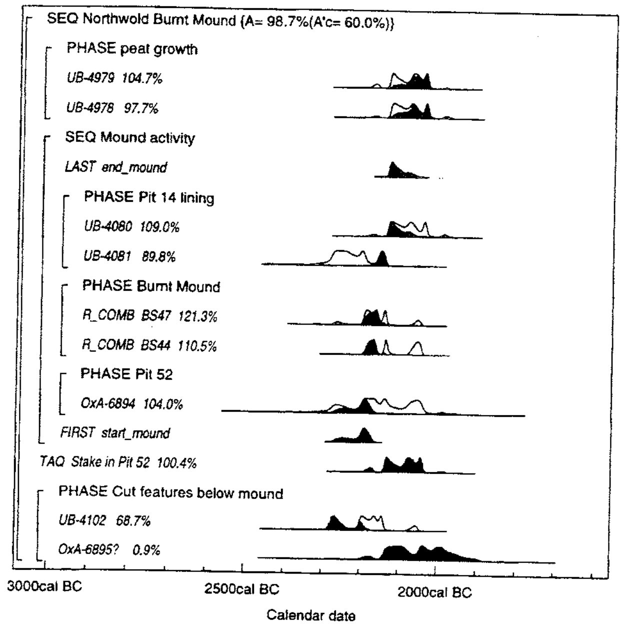

Fig. 5 : Probability distributions of dates from the sequence at Northwold : each distribution represents the relative probability that an event occured at a particular time. The distributions plotted in outline are the result of simple radiocarbon calibration. The distributions plotted in black are based on the chronological model used. Other distributions correspond to aspects of the model : the start of mound activity began at some point defined as 'start_mound' and the last activity at the time 'end_mound'. The large square brackets down the left hand side along with the OxCal keywords define the overall model exactly.

An ambitious programme of burnt mound analysis in tandem with a stratified sequence of radiocarbon dates has not been attempted before in Britain. With burnt mounds characteristically offering little in the way of artefactual information, 'it has long been clear that these sites represented an excellent opportunity for radiocarbon analysis' (Buckley, 1990, 165).

Radiocarbon dates from the current excavation and a neighbouring burnt mound at Feltwell (2460-1900 cal BC ; GU-5573 ; 3720 ± 80 BP and 2290-2130 cal BC ; GU-5574 ; 3770 ± 50 BP) (Crowson and Leah, 1994) are significantly earlier than most other examples (Buckley, 1990, 56). Radiocarbon determinations from sites in the West Midlands and Scotland tend to cluster in the range of *c* cal BC 1700-1000, whilst those from the Irish sites provide a date range of between *c* cal BC 2100-1250 for the majority of mounds (Buckley, 1990, 55-6 ; Hodder and Barfield, 1991, 55). Sweden's skärvstenshögar were deposited principally in the later second millennium cal BC and the first half of the first millennium cal BC (Buckley, 1990, 142-53).

Although further research remains to be undertaken and more dated examples sought, it seems that early Bronze Age communities of Fenland Norfolk were among the front-runners of hot stone technology.

The chronology of Beakers is problematic. Radiocarbon dating has established their currency in Britain between 2600-1800 cal BC. Although some broad aspects of stylistic change through time do hold good for some places, chronology based on stylistic succession cannot be applied to the whole country, with different styles current in different areas at the same time (Kinnes *et al.*, 1991, 35-68). There is a marked lack of comparative data available for sites in eastern England, however, and new distinctive assemblages associated with radiocarbon dates are extremely important to the future study of Beakers.

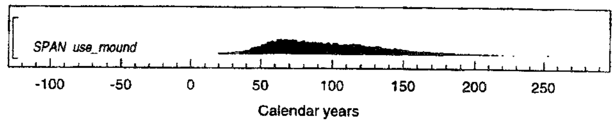

Fig. 6 : Probability distribution of the number of years during which the mound was in use, derived from the model defined in figure 5.

Although greatly varied, Bell-beakers of continental western Europe share the same principal features of British Beakers. Attempts to determine a chronology of development and relationship with Single Grave Beaker groups in Europe have been founded on available radiocarbon determinations from charcoal (Case, 1993). As with the British debate, however, discussion over the origins and typological succession of pan-European Beakers looks set to continue.

The chronological homogeneity of the charcoal from the mound (see above) and the apparently relatively short period of use (*35-165 years*), suggests that the Northwold burnt mound represents short-lived activity with a specialised function, which did not lead to constant or repeated use of the site for many centuries. The succession of cut and re-cut features demonstrates that the site was probably revisited a number of times, although perhaps this should be seen as a seasonal activity rather than sporadic use over an extended period.

9 - LESSONS FOR PROJECT MANAGEMENT

This dating programme has demonstrated the high degree of mutual reliance for quality information between excavation and specialist staff. Constant exchange of detailed information is invaluable, right through to publication. It is also vital to establish specific questions for specialists to answer from their data sets, so that analytical work can be focused. To obtain the necessary samples, this may need to happen on site. But if this not possible, it still costs little to take samples from potentially significant deposits. You can always decide that they are not worth further study. Underpinning this work is the requirement for the identification and inclusion of funding for specialists and scientific dating at the planning stage.

The importance of integrating the selection of radiocarbon samples with the stratigraphic sequence cannot be over-stated. Incorporating stratigraphy into a formal model of the site's chronology increases the precision of the estimated dates of archaeological interest (fig. 7). Using a sequence of only eight radiocarbon measurements, this figure also shows the benefits of obtaining precise measurements. We feel that the submission of fewer than eight samples to address a problem of this type would be unwise, simply because the archaeological and scientific hazards of sample retrieval, selection, and measurement are such that a degree of replication is desirable.

CONCLUSIONS

We have been pleased with the success of this dating programme, which for us acted as a test-bed for the application of the methodology used here to the chronological problems of burnt mounds and the Beaker period. We hope our results demonstrate that the unhelpful shape of the calibration curve in this period can be tackled by exploiting the relative dating information provided by stratigraphy. This should enable wider

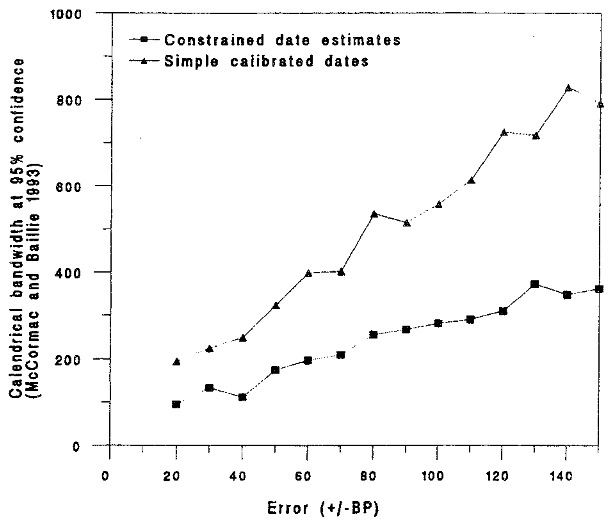

Fig. 7 : Graph to show a simulation of the calendrical bandwidth which may be expected for the estimated date of a burnt mound, such as Northwold which actually dates to *c* 2100 cal BC (1) when samples are measured and simply calibrated (2) when using a model which includes the stratigraphic information shown in the upper part of figure 5. All errors on the radiocarbon measurements in a particular model are the same.

questions of the earlier Bronze Age to be addressed using radiocarbon. The relatively low cost of such a strategy, at least for smaller monuments of this type, should enable these techniques to be adopted widely.

ACKNOWLEDGEMENTS

This research was funded by English Heritage. We would like to thank all our colleagues who worked on material from the site, particularly Rowena Gale and Peter Murphy for botanical identifications, Sarah Percival for studying the pottery and the staff of the Oxford Radiocarbon Accelerator Unit and the Queen's University, Belfast, Radiocarbon Laboratory for measuring the radiocarbon samples.

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STONE AGE STUDIES IN THE BRITISH ISLES : THE IMPACT OF ACCELERATOR DATING

Christopher TOLAN-SMITH and Clive BONSALL***

Résumé : Une des contributions les plus significatives de la datation radiocarbone par accélérateur c'est le fait qu'elle permet la datation directe de l'activité humaine, soit sous la forme des restes de squelettes, soit sous celle de matériaux organiques modifiés par l'homme. Ceci est la conséquence de la quantité très réduite de charbon nécessaire - on peut obtenir des dates à partir d'échantillons auparavant considérés trop petits ou trop précieux pour être sacrifiés pour la datation radiocarbone conventionelle. En datant les êtres humains ou leurs actions directement on peut obtenir une structure temporelle plus rigoureuse que celle qui était disponible jusqu'ici. Dès le début des années 1980 un certain nombre de programmes de datation directe concernant le Paléolithique supérieur et le Mésolithique britanniques ont été développés en utilisant surtout la facilité AMS ^{14}C de l'université d'Oxford. Ces programmes ont compris la datation de restes humains, d'os d'animaux qui montraient des traces de dépeçage ou d'abattage, et des objets d'os et de bois de cerf. Cet article passe en revue les résultats des divers projets de datation et le nouvel élan qu'ils ont donné aux études concernant l'Age de la Pierre dans les Iles Britanniques. Sont soulignés ces aspects de la recherche qui nous ont le plus directement intéressés - à savoir l'élucidation du développement de l'industrie de l'os et bois de cerf pendant le Paléolithique terminal et le Mésolithique, et la reconstruction de la démographie des sociétés des chasseurs-cueilleurs de l'Age de la Pierre.

Abstract : One of the most significant contributions of the AMS ^{14}C technique is that it enables human activity to be dated directly, either in the form of human skeletal remains or organic materials modified by man. This stems from the very small amount of carbon required - dates can therefore be obtained on samples previously considered too small or too valuable to sacrifice to conventional ^{14}C dating. By dating humans or their actions directly a more rigorous temporal framework is achieved than was available hitherto. Since the early 1980s a number of programmes of direct dating relating to the British Upper Palaeolithic and Mesolithic have been developed primarily using the AMS ^{14}C facility at the University of Oxford. These have included the dating of hominid remains, animal bones exhibiting butchery traces, and artefacts made from bone and antler. Our paper reviews the results of the various dating projects and the new impetus they have given to Stone Age studies in the British Isles. Emphasis is placed on those aspects of research with which we have been most directly concerned - namely, elucidating the development of antler/bone technology in the Late Palaeolithic and Mesolithic, and reconstructing the demography of Stone Age hunter-gatherer societies.

Mots-clés : Iles Britanniques, datation radiocarbone, accélérateur, Paléolithique supérieur, Mésolithique, bois de cerf, os, outils, Tardiglaciaire, Postglaciaire, recolonisation, paléodémographie.

Key-words : British Isles, radiocarbon dating, AMS, Upper Palaeolithic, Mesolithic, antler, bone, artefacts, Lateglacial, Postglacial, resettlement, palaeodemography.

INTRODUCTION

The overwhelming advantage of AMS over conventional radiocarbon dating techniques is the very small sample size needed - measurable in milligrams rather than grams. This gives archaeologists much greater flexibility in their choice of samples for dating, since dates can be obtained on samples formerly considered too small or too valuable to sacrifice to conventional ^{14}C dating. More importantly, it enables human activity to be dated *directly*, either in the form of human skeletal remains or organic materials modified by man.

Since 1983 a number of programmes of direct dating relating to the Late Upper Palaeolithic and Mesolithic of Great Britain have been developed using the AMS ^{14}C dating facility at the University of Oxford. These have included the dating of hominid remains, animal bones exhibiting butchery traces, and artefacts made from bone or antler.

In the course of our own research we have concentrated on the dating of antler/bone artefacts. When we first reviewed the evidence - at the *Second ^{14}C and Archaeology Symposium* held in Groningen in 1987 - dates were available for only 10 items from Great Britain

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(Smith and Bonsall, 1990). Since then, the number of directly dated specimens has increased substantially. In the first part of this paper we consider the implications of dates obtained on three numerically important classes of artefacts : (i) barbed projectile points ; (ii) bevel-ended tools ; and (iii) antler mattocks (fig. 1). In the second part of the paper we examine the role that AMS dating has played in documenting the recolonization of Britain following the Last Glacial Maximum and its potential for addressing wider issues of palaeogeography and palaeodemography.

1 - PREVIOUS IDEAS ON THE DEVELOPMENT OF BONE AND ANTLER TECHNOLOGY

Prior to the use of the Oxford accelerator, evidence relating to the development of bone and antler technology in the British Late Upper Palaeolithic and Mesolithic was limited. The only well-documented assemblages were those from Star Carr and Thatcham, dated to the early/mid-10th millennium BP, and the assemblages from the 'Obanian' sites of western Scotland which on various lines of evidence were assigned a time-range from c. 6500–5400 BP. Attempts to date the very large number of unassociated finds of bone and antler artefacts from Britain by seeking typological parallels in either the Star Carr or 'Obanian' series, or in the Mesolithic/Early Neolithic of the North European mainland, led to conflicting interpretations of the absolute and relative chronology of the different types.

The few isolated examples of flat bilaterally-barbed points, such as those from Shewalton in Ayrshire (Lacaille, 1954) and Whitburn in Co. Durham (Mellars, 1970), were linked with the 'Obanian' series. The majority, however, being slender unilaterally-barbed forms, were compared to those from Star Carr or to early

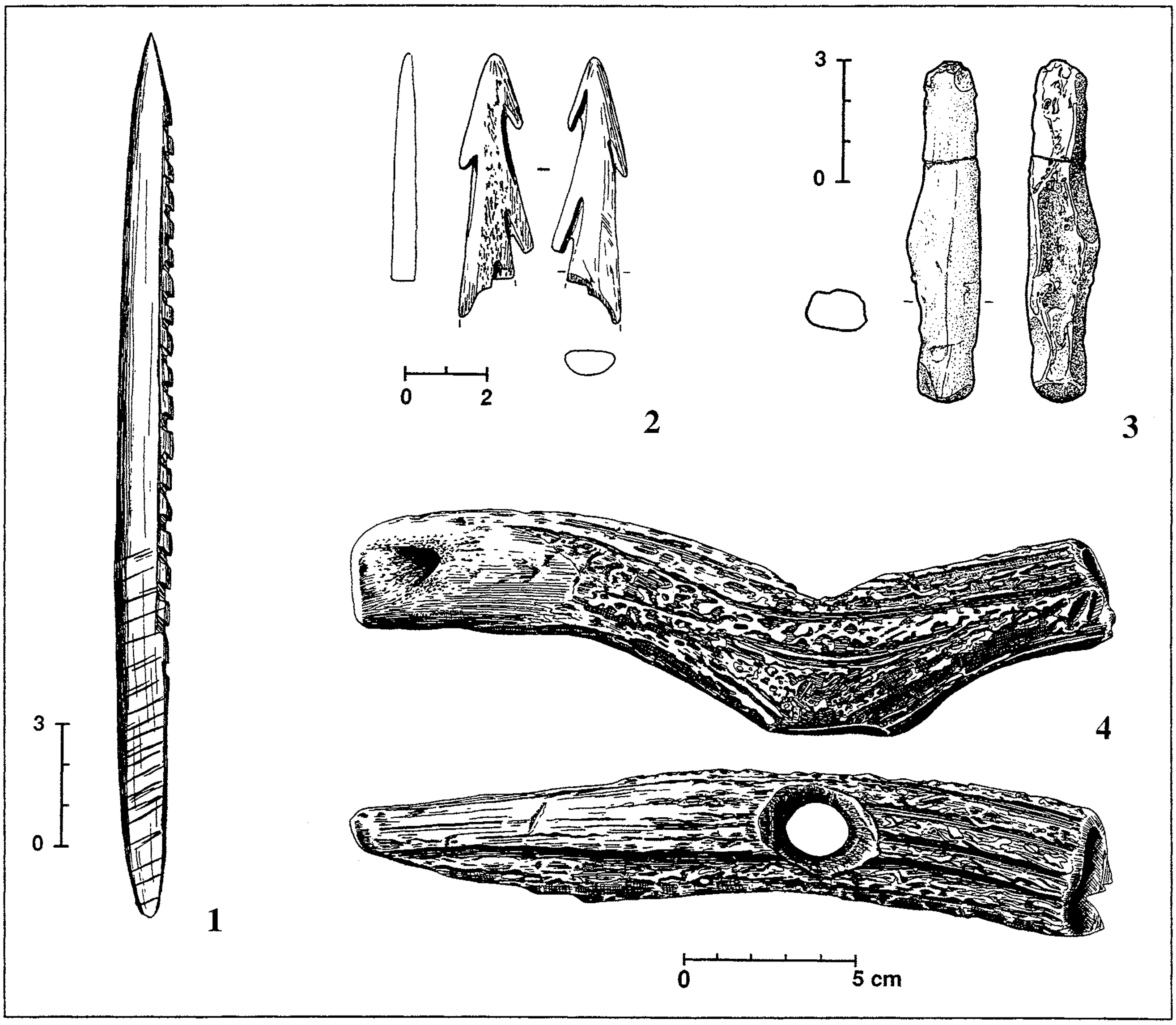

Fig. 1 : Directly dated specimens of numerically important types of Late Upper Palaeolithic and Mesolithic antler and bone artefacts from Great Britain. 1. 'Maglemosean' style barbed point from the Leman and Ower Banks, North Sea (11,740±150 BP : OxA-1950) ; 2. Forepart of an 'Obanian' style barbed point from MacArthur's Cave, Oban (6700±80 BP : OxA-1949) ; 3. Bevel-ended tool from Ulva Cave, Argyll (5750±70 BP : OxA-3738) ; 4. Red deer antler-beam mattock from Meiklewood, Stirling (5920±80 BP : OxA-1159). *Acknowledgements* : No. 1, reproduced with permission from Clark, J.G.D. (1932) *The Mesolithic Age in Britain*, p. 115. London : Cambridge University Press ; Nos 2–4, after Bonsall and Smith (1990).

Fig. 1 : Pièces directement datées renvoyant à des types fréquents d'objets en os et bois de Cerf du Paléolithique final et du Mésolithique britanniques. 1. Harpon de type 'maglemosien' de Leman et Ower Banks, Mer du Nord (11,740±150 BP : OxA-1950) ; 2. Extrémité distale de harpon de type 'obanien' de la grotte de MacArthur, Oban (6700±80 BP : Oxa-1949) ; 3. Outil à extrémité biseautée de la grotte d'Ulva, Argyll (5750±70 BP : OxA-3738) ; 4. Pioche façonnée dans un merrain de Cerf élaphe provenant de Meiklewood, Stiling (5920±80 BP : OxA-1159). *Origine des illustrations* : No. 1 reproduit avec l'autorisation de Clark, J.G.D. (1932) *The Mesolithic Age in Britain*, p. 115. London : Cambridge University Press ; No 2-4, d'après Bonsall and Smith (1990).

Maglemosian finds from Denmark and northern Germany. As a result, this latter group came to be regarded as characteristic of the Early Mesolithic and attributed to the early stages of the Holocene (Godwin Zones IV–VI). Not all authors accepted this interpretation. Wymer *et al.* (1975, 238–240), for example, argued for a Lateglacial age for some of the finds of 'Maglemosian' type.

The dating of red deer antler mattocks posed similar problems. Nearly a hundred examples have been recorded from Britain, most of them as unassociated finds. They were usually attributed to the Mesolithic on the basis of similarities to late Maglemosian and Ertebølle finds in Denmark, and the presence of at least one type in some of the 'Obanian' shell middens. Smith and Bonsall (1985 ; Smith, 1989) regarded these as part of a range of heavy-duty tools which also includes the Star Carr elk antler mattocks. They drew a basic distinction between *antler-base mattocks,* made from the basal portion of a red deer antler, and *antler-beam mattocks,* made from a mid-section of the antler beam. They also proposed a chronological scheme in which the antler-base mattocks replaced forms made out of elk antler c. 9000 BP and were in turn superseded by the antler-beam type towards the end of the Mesolithic. Subsequently, Smith (1989, 275–279) proposed a further subdivision of antler-base and antler-beam mattocks according to whether the shaft hole is in the same plane as the tines (Types A, C) or at right angles to them (Types B, D).

A different interpretation was put forward by Jacobi (1982) who maintained that red deer antler mattocks and certain other kinds of artefacts traditionally assigned to the Mesolithic were in fact of post-Mesolithic date. On this hypothesis the 'gap' in the archaeological record between the Star Carr and 'Obanian'-type assemblages would represent a genuine hiatus in the development of bone and antler technology in Britain. Jacobi argued that as Britain became progressively isolated by the Holocene marine transgression, social contact with the European mainland effectively ceased and the bone and antler technology of the indigenous population went into decline. It was suggested that after c. 8500 BP the range of tool forms decreased, with implements such as barbed points and antler mattocks disappearing altogether from the Mesolithic toolkit, to be re-introduced by an immigrant farming population in the sixth millennium BP. The corollary of Jacobi's hypothesis is that the barbed harpoon heads and antler-beam mattocks found in 'Obanian' middens were acquired through contact with agricultural communities (Jacobi, 1982, 20–21), or that the 'Obanian' is a post-Mesolithic phenomenon.

2 - AMS DATING OF ANTLER AND BONE ARTEFACTS

At the time of writing, direct AMS dates are available for 67 antler/bone artefacts from Great Britain previously assumed to belong to the Late Upper Palaeolithic and Mesolithic. The dates for the numerically important categories of barbed points, bevel-ended tools and red deer antler mattocks are listed in tables 1–3, and those for other artefacts in table 4. Tables 5 and 6 list examples of barbed points and antler mattocks that have not been dated directly but are from contexts for which conventional or AMS ^{14}C dates are available. Figure 2 summarizes graphically the information contained in the tables. Columns 1–5 of this figure show the respective minimum time-ranges of 'Maglemosian'-style barbed points, 'Obanian'-style barbed points, bevel-ended tools, antler-base mattocks, and antler-beam mattocks. Plotted in column 6 are the 'mean' ages for all other directly

Site	Type	Material	Context	Lab. No.	^{14}C Age BP	cal BC age range (2σ)
Leman and Ower Banks (North Sea)	Uniserial (M)	Antler	Unassociated find from North Sea bed	OxA-1950	11,740±150	12200–11350
Porth-y-Waen (Shropshire)	Uniserial (M)	Antler	Unassociated find	OxA-1946	11,390±120	11700–11050
Sproughton 1 (Suffolk)	Uniserial (M)	Bone	Unassociated find	OxA-517	10,910±150	11200–10550
Victoria Cave (North Yorkshire)	Biserial	Antler	Excavated from breccia containing Late Pleistocene fauna and human artefacts	OxA-2607	10,810±100	11010–10550
Sproughton 2 (Suffolk)	Uniserial (M)	Antler	Unassociated find	OxA-518	10,700±160	11050–10250
Waltham Abbey (Essex)	Uniserial (M)	Antler	Unassociated find	OxA-1427	9790±100	9700–8500
Earl's Barton (Northamptonshire)	Uniserial (M)	Antler	Unassociated find	OxA-500	9240±160	8950–7950
Wandsworth (Thames, London)	Uniserial (M)	Antler	Unassociated find	OxA-3736	9050±85	8340–7940
Druimvargie Rockshelter (Oban, Argyll)	Uniserial (O)	Bone	Artefact excavated from 'Obanian' shell midden	OxA-1948	7810±90	7000–6400
MacArthur's Cave (Oban, Argyll)	Biserial (O)	Antler	Artefact excavated from 'Obanian' shell midden	OxA-1949	6700±80	5690–5440
Cumstoun (Kirkcudbrightshire)	Biserial (O)	Antler	Unassociated find	OxA-3735	6665±70	5660–5430
Shewalton (Ayrshire)	Biserial (O)	Antler	Unassociated find	OxA-1947	5840±80	4910–4500

Table 1 : Direct dates for barbed points. *Key* : M – points of 'Maglemosian' type ; O – points of 'Obanian' type.
Tab. 1 : Dates directement obtenues sur les harpons. M - harpons de type 'maglemoisien' ; O - harpons de type 'obanien'.

Site	Material	Lab. No.	^{14}C age BP	cal BC age range (2σ)
Druimvargie (Oban, Argyll)	Bone	OxA-4608	8340±80	7540–7090
Druimvargie (Oban, Argyll)	Bone	OxA-4609	7890±80	7050–6450
An Corran (Skye)	Bone	OxA-4994	7590±90	6560–6180
Isle of Risga (Argyll)	Antler	OxA-3737	5875±65	4810–4550
Morton B (Fife)	Bone	OxA-4612	5790±80	4830–4460
Ulva Cave (Mull, Argyll)	Antler	OxA-3738	5750±70	4780–4460
Morton B (Fife)	Bone	OxA-4611	5475±60	4460–4160
Carding Mill Bay I (Oban, Argyll)	Antler	OxA-3740	5190±85	4230–3790
Morton B (Fife)	Bone	OxA-4610	5180±70	4230–3790
Carding Mill Bay I (Oban, Argyll)	Bone	OxA-3739	4765±65	3660–3370

Table 2 : Direct dates for bevel-ended tools from Mesolithic shell middens in Scotland.
Tab. 2 : Dates directement obtenues sur les outils à extrémité biseautée provenant d'amas coquillier d'Ecosse.

Site	Type	Sub-type	Context	Lab. No.	^{14}C Age BP	cal BC age range (2σ)
Kew Bridge (Thames, London)	Antler-base	B	Unassociated find	OxA-1160	8820±100	8030–7590
Finsbury Circus (London)	Antler-base	A	Unassociated find	OxA-2024	4140±70	2890–2490
Willington Quay (River Tyne)	Antler-base	A	Unassociated find	OxA-1157	3880±80	2600–2000
County Hall 3 (Thames, London)	Antler-base	A	Unassociated find	OxA-2020	3850±70	2480–2040
County Hall 2 (Thames, London)	Antler-base	A	Unassociated find	OxA-2021	3800±80	2460–1980
Southery Fen (Norfolk)	Antler-base	A	Unassociated find	OxA-3745	3460±70	1940–1530
Peterborough 2 (Huntingdonshire)	Antler-base	B	Unassociated find	OxA-3742	3430±75	1900–1520
Kew 2 (Thames, London)	Antler-base	B	Unassociated find	OxA-2022	3300±80	1750–1410
Brentford (Thames, Middlesex)	Antler-base	B	Unassociated find	OxA-3744	3245±75	1690–1320
Putney 2 (Thames, London)	Antler-base	B	Unassociated find	OxA-3743	3155±70	1610–1210
Feltwell (Norfolk)	Antler-base	B	Unassociated find	OxA-3741	3000±75	1410–1010
Alton Longville (Huntingdonshire)	Antler-beam	D	Unassociated find	OxA-4606	8005±80	7250–6600
Splash Point (North Wales)	Antler-beam	D	Unassociated find	OxA-1009	6560±80	5590–5320
Hutton (Lancashire)	Antler-beam	D	Unassociated find	OxA-4800	6520±60	5570–5310
Uskmouth (Gwent)	Antler-beam	D	Unassociated find	OxA-4547	6180±80	5270–4920
Meiklewood (Carse of Stirling)	Antler-beam	C	Unassociated find	OxA-1159	5920±80	4990–4550
Staines (Thames, Middlesex)	Antler-beam	D	Unassociated find	OxA-1158	5350±100	4340–3990
Isle of Risga (Argyll)	?	?	Possible fragment of the blade of a mattock, associated with bone and lithic artefacts in 'Obanian' shell midden	OxA-2023	6000±90	5250–4650
Crantit Farm (Orkney)	?	?	Associated with Bronze Age burial in a stone cist. At one time erroneously reported to be from a Mesolithic shell midden on Oronsay	OxA-4606	3385±55	1870–1520
Hammersmith (Thames, London)	?	?	Unassociated find	OxA-1156	2240±100	550–AD

Table 3 : Direct dates for red deer antler mattocks. Sub-type classification follows Smith (1989, 275–279). ? – classification uncertain.
Tab. 3 : Dates directement obtenues sur les pioches en bois de Cerf. Classification en sous-type d'après Smith (1989, 275-279). ? - classification incertaine.

Site	Artefact description	Lab. No.	^{14}C Age BP	cal BC age range (2σ)	*Archlist* reference
Robin Hood Cave (Creswell, Derbyshire)	'Awl' made on tibia of mountain hare (*Lepus timidus*)	OxA-3416	12580±110	13250–12400	A 18, 340
Gough's Cave (Cheddar, Somerset)	'Awl' made on tibia of mountain hare (*Lepus timidus*)	OxA-4107	12550±130	13300–12300	A 18, 341
Kent's Cavern (Devon)	Bone 'piercer' from the layer known as the 'black band'	OxA-1789	12320±130	12950–12000	A 9, 215
Church Hole (Creswell, Derbyshire)	Fragment of reindeer antler rod with 'scooped' end	OxA-3718	12250±90	12750–12000	A 18, 339
Gough's Cave (Cheddar, Somerset)	Worked mammoth ivory rod or 'point'	OxA-1890	12170±130	12750–11850	A 10, 104
Church Hole (Creswell, Derbyshire)	Fragment of reindeer antler rod with 'scooped' end	OxA-3717	12020±100	12450–11750	A 18, 339
Fox Hole Cave (Derbyshire)	Fragment of antler rod or point lacking both extremities	OxA-1494	12000±120	12450–11650	A 9, 214
Fox Hole Cave (Derbyshire)	Reindeer antler rod 'scooped' at one end and bevelled at the other	OxA-1493	11970±120	12450–11650	A 9, 214
Gough's Cave (Cheddar, Somerset)	Reindeer antler baton	OxA-2797	11870±110	12250–11550	A 13, 283
Victoria Cave (North Yorkshire)	Broken double-bevelled artefact of antler	OxA-2455	11750±120	12150–11400	A 14, 141
Kent's Cavern (Devon) [1]	Worked mammoth ivory rod from the layer known as the 'black band'	OxA-2155	11650±130	12050–11300	A 13, 284
Kinsey Cave (North Yorkshire)	Broken antler artefact	OxA-2456	11270±110	11550–10950	A 14, 142
Coniston Dib (Yorkshire)	Bone point	OxA-2847	11210±90	11400–10960	A 14, 142
Dowel Cave (Derbyshire)	Broken antler tang	OxA-1463	11200±120	11450–10900	A 9, 214
Earl's Barton (Northamptonshire)	Reindeer antler club ('Lyngby axe')	OxA-803	10320±150	10700–9100	A 4, 209
Victoria Cave (North Yorkshire)	Grooved double-bevelled point of antler	OxA-2453	10220±110	10400–9100	A 14, 141
Kendrick's Cave (North Wales)	Horse mandible with engraved chevron decoration	OxA-111	10000±200	10400–8600	A 2, 238
Thatcham IV (Berkshire)	Red deer antler beam with bevelled end	OxA-732	9760±120	9700–8400	A 5, 127
Seamer (North Yorkshire)	Worked antler	OxA-1176	9700±160	9700–8300	A 9, 216
Seamer (North Yorkshire)	Red deer antler frontlet	OxA-1154	9500±120	9050–8250	A 9, 216
Greenham Dairy Farm (Berkshire) [2]	Red deer antler 'chisel'	OxA-956	8160±100	7500–6750	A 8, 294
Borth, Ynys-las (Dyfed)	Artefact made from base of red deer antler, perforated near lower end and hollowed out at the truncated end	OxA-3816	3890±100	2650–2000	A 21, 195
Distillery Cave (Oban, Argyll)	Antler 'spatula'	OxA-4509	3780±60	2450–1980	A 20, 424
Mochras (Harlech, Gwynnedd)	Artefact made from base of red deer antler, perforated near lower end and hollowed out at the truncated end	OxA-3813	3600±90	2200–1650	A 21, 195
Beddington (Surrey)	Red deer antler 'mattock'	OxA-1161	3450±80	1940–1520	A 7, 160

Notes: 1. This date may be 'too young' as a result of contamination by a collagen-based adhesive used in its restoration.
2. This date is later than expected from associated Early Mesolithic artefacts, possibly attributable to a low collagen content.

Table 4 : Direct dates for other artefacts previously assumed to be of Late Upper Palaeolithic or Mesolithic age. References are to entries in the *Archaeometry* datelists, e.g. A 18, 340 = *Archaeometry* vol. 18, p. 340.
Tab. 4 : Dates directement obtenues sur d'autres artefacts antérieurement attribués au Paléolithique final ou au Mésolithique. Les références renvoient à des entrées dans les listes de dates publiées *Archaeometry*, e.g. A 18, 340 = *Archaeometry* vol. 18, p. 340.

dated artefacts. The large number of determinations for 'other' artefacts corresponding to the LUP is explained by the fact that they derive mainly from LUP levels of cave sites and, in most cases, were obtained in an attempt to establish the chronology of Lateglacial settlement in Britain. Taken together, these dates on antler/bone artefacts - all from the Oxford Radiocarbon Accelerator Unit - contribute to the resolution of the issues discussed above.

2.1 - BARBED POINTS

Twelve barbed points have so far been directly dated by the Oxford accelerator (table 1). With the exception of the piece from Victoria Cave, North Yorkshire, these can be grouped into two loosely-defined types : (i) 'Maglemosian' - typically slender, uniserial points with small barbs and a long tang (fig. 1, no. 1) ; and (ii) 'Obanian' - often biserial in form and relatively broad and flat with large barbs and a short tang (fig. 1, no. 2). To

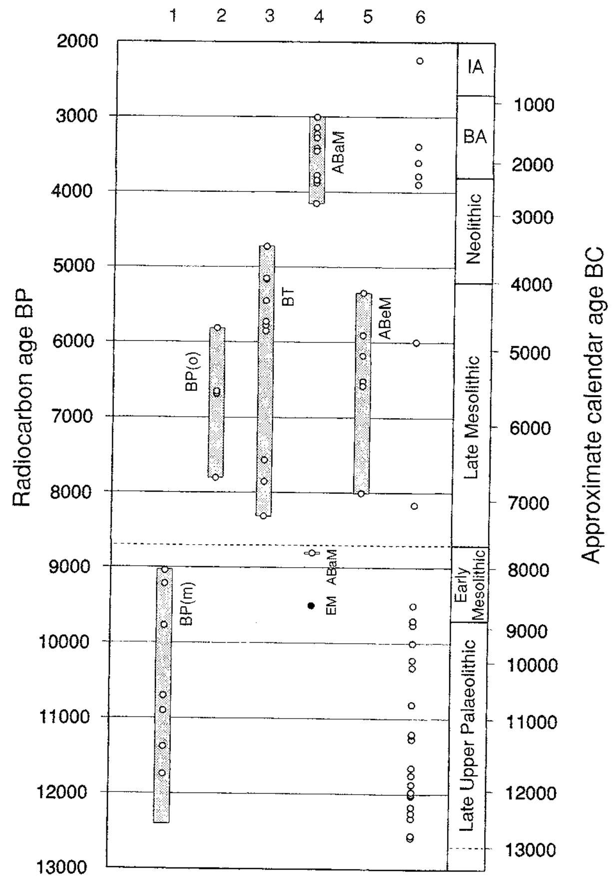

Fig. 2 : Dating of Late Upper Palaeolithic and Mesolithic antler and bone artefacts from Great Britain. 1. **BP(m)** – 'Maglemosean' style barbed points ; 2. **BP(o)** – 'Obanian' style barbed points ; 3. **BT** – bevel-ended tools ; 4. **ABaM** – red deer antler-base mattocks ; **EM** – elk antler mattocks ; 5. **ABeM** – red deer antler-beam mattocks ; 6 – other artefacts. Open circles = mean AMS ages. Bars = indicate minimum time-ranges of the principal artefact types based on a combination of direct AMS measurements and indirect AMS/conventional ^{14}C dates.

Fig. 2 : Datations des artefacts en os et bois de cerf du Paléolithique final et du Mésolithique de Grande-Bretagne. 1. **BP(m)** - Harpons de type 'maglemosien' ; 2. **BP(o)** - harpons de type 'obanien' ; 3. **BT** - outils à extrémité biseautée ; 4. **ABaM** - pioches façonnées dans des bases de ramures de Cerf élaphe ; **EM** - pioches en bois d'Elan ; 5. **ABeM** - pioches façonnées dans des merrains de Cerf élaphe ; 6 - autres objets. Cercles vides = moyenne des dates AMS. Les barres indiquent les durées de vie minimales des principaux artefacts basées sur une combinaison des dates AMS directement obtenues sur ces derniers et de dates conventionnelles et AMS obtenues sur des témoins associés.

these may be added a number of examples of both 'types' recovered from contexts for which conventional or AMS ^{14}C dates are available (table 5). Taken together, these dates effectively increase the time-ranges previously assigned to the 'Maglemosian' and 'Obanian' types. The 'Maglemosian' forms, at one time considered to belong exclusively to the Early Mesolithic, can now be assigned a minimum time-range of c. 12,400–9050 BP (c. 12,600–8150 cal BC), which is more in accord with the considerable variability they exhibit in both form and technique (Smith and Bonsall, 1991). The dates on the 'Obanian' series indicate that barbed points of this type were being manufactured at a much earlier date than was previously thought to be the case. It is also interesting to note that whereas the barbed points from the earliest dated site, Druimvargie Rockshelter, are of *uniserial* type, those from MacArthur's Cave, dated to c. 6700 BP, Risga,

Site	Number	Type	Dated material/Context	Lab. No.	^{14}C Age BP
Poulton-le-Fylde (Lancashire)	2	Uniserial (M)	Amino acids from elk skeleton associated with barbed points	OxA-150	12,400±300
Aveline's Hole (Somerset)	1	Biserial (Ma)	Bone. Bovine 2nd phalanx with cut marks from same 'Red Cave Earth' deposit that produced the barbed point as well as lithic artefacts of 'Creswellian' type	OxA-1 121	12,380±130
Kent's Cavern (Devon)	1	Uniserial	Bone piercer from 'Black Band' containing barbed point and lithic artefacts of 'Creswellian' type	OxA-1789	12,320±130
	1	Uniserial	From same general area of cave, but not actually within the 'Black Band'		
	1	Biserial(Ma)			
Gransmoor (East Yorkshire)	1	Uniserial (M)	Barbed point was found embedded in a tree trunk stratified in Lateglacial deposits infilling a kettle hole. Age of artefact is bracketed by ^{14}C dates on wood (SRR-4920) and 'sedimentation rate' date (c. 11,100 BP) for sediments draping the log, based on large series of AMS dates for terrestrial plant remains from sequence.	SRR-4920	11475±50
Star Carr (North Yorkshire)	191	Uniserial(M)	Wood. 'Brushwood platform' associated with Early Mesolithic flint and bone/antler industries	Q-14	9557±210
				C-353	9488±350
Caisteal nan Gillean I (Oronsay)	11	Biserial(O)	Charcoal from shell midden containing lithic and bone/antler artefacts	Q-3008	6190±80
				Q-3007	6120±80
				Q-3009	6035±70
				Q-3010	5485±50
				Q-3011	5450±50
Risga (Argyll) [1]	2	Biserial(O)	Antler artefacts from same shell midden deposit that produced the barbed points	OxA-2023	6000±90
				OxA-3737	5875±65
Cnoc Sligeach (Oronsay)	1	Biserial(O)	Marine shell (*Pecten maximus*, inner fraction), associated with barbed point in redeposited midden material	Birm-465	5605±155
Cnoc Sligeach (Oronsay)	7	Biserial(O)	Charcoal from shell midden containing lithic and bone/antler artefacts.	BM-670	5426±159

Note: 1. Fragments of at least two barbed points were recovered from the Risga shell midden (Lacaille 1954, 232–233, fig. 104)

Table 5 : Barbed points dated by association with conventional or AMS ^{14}C dates. *Key* : M – points of 'Maglemosian' type ; O – points of 'Obanian' type.
Tab. 5 : Harpons datés par association avec des dates radiocarbone conventionnelle ou AMS. M - harpon de type 'maglemosien' ; O - harpon de type 'obanien'.

Site	Number	Type	Material/Context	Lab. No.	^{14}C Age BP
Star Carr (North Yorkshire)	6	Elk antler mattock (E)	Wood. 'Brushwood platform' associated with Early Mesolithic flint and antler/bone assemblages	Q-14	9557±210
				C-353	9488±350
Druimvargie Rockshelter (Oban, Argyll)	1	Red deer antler-beam mattock (?C/D)	Bone artefacts from shell midden containing antle/bone lithic artefacts	OxA-4608	8340±80
				OxA-4609	7890±80
				OxA-1948	7810±90
Caisteal nan Gillean I (Oronsay)	8+	Red deer antler-beam mattock (?C)	Charcoal from shell midden containing lithic and antler/bone artefacts	Q-3008	6190±80
				Q-3007	6120±80
				Q-3009	6035±70
				Q-3010	5485±50
				Q-3011	5450±50
Isle of Risga (Argyll)	1	Red deer antler-beam mattock (C)	Antler artefacts from shell midden containing lithic and antler/bone artefacts	OxA-2023	6000±90
				OxA-3737	5875±65
Priory Midden (Oronsay)	1	Red deer antler-beam mattock (C)	Charcoal from shell midden containing lithic and antler/bone artefacts	Q-3001	5870±50
				Q-3000	5825±50
				Q-3002	5717±50
				Q-3003	5510±50
				Q-3004	5470±50
Cnoc Coig (Oronsay)	1	Red deer antler-beam mattock (?C/D)	Charcoal from shell midden containing lithic and antler/bone artefacts	Q-1353	5645±80
				Q-1354	5535±140
				Q-1351	5495±75
				Q-1352	5430±130
Cnoc Sligeach (Oronsay)	3+	Red deer antler-beam mattock (?C/D)	Charcoal from shell midden containing lithic and antler/bone artefacts	BM-670	5426±159

Table 6 : Antler mattocks dated by association with conventional or AMS ^{14}C dates. The typological classification follows Smith (1989). ? – classification uncertain.
Tab. 6 : Pioches en bois de Cervidés datés par association avec des dates radiocarbone conventionnelles ou AMS. Classification typologique d'après Smith (1989). ? - classification incertaine.

dated to c. 6000–5875 BP by association with other directly dated artefacts, and the Oronsay middens, with radiocarbon dates in the range c. 6200–5400 BP (Mellars, 1987), are exclusively of *biserial* form. Whether this apparent typological trend can be shown to have general chronological significance will depend on the acquisition of further dates for both types of 'Obanian' barbed point.

The anomalous Victoria Cave specimen, which has sometimes been compared with barbed points of the 'Obanian' series, is more reminiscent of the biserial points with angular projecting barbs and pointed spade-shaped bases from the Final Palaeolithic of the North European Plain (*cf.* Clark, 1975, 71).

2.2 - BEVEL-ENDED TOOLS

All of the directly dated specimens of bevel-ended tools (table 2) were excavated from Mesolithic shell middens in Scotland. They are the most common antler/bone artefact type found in the 'Obanian' middens of the Atlantic seaboard ; unlike barbed points and antler mattocks, they occur in all known 'Obanian' sites (fig. 1, no. 3).

Together, the dates for bevel-ended tools and other artefacts from the middens indicate a minimum time-range for the 'Obanian' sites of c. 8350–4750 BP (c. 7300–3500 cal BC). Not only do these dates demonstrate that the 'Obanian' had considerable time depth, they provide clear evidence for a substantial chronological overlap in the west of Scotland between 'Obanian' and 'narrow blade' microlithic assemblages. This in turn negates the hypothesis that the 'Obanian' is a post-Mesolithic phenomenon, and also seriously weakens the position taken up by some workers (e.g. Jacobi, 1982 ; Woodman, 1989) who have suggested that the 'Obanian' sites represent a discrete phase at the end of the local Mesolithic characterized by the loss of the microlithic component of the toolkit. The fact that a very substantial chronological overlap can now be demonstrated between 'Obanian' and narrow blade microlithic assemblages demands consideration of other explanations (Bonsall and Smith, 1990). From various other lines of evidence, it is becoming increasingly clear that the 'Obanian' sites represent a particular aspect of the Late Mesolithic maritime adaptation in western Scotland (Bonsall, 1996). The direct dates on artefacts from Carding Mill Bay I, which are supported by conventional ^{14}C age measurements on charcoal and marine shells from the same deposits, overlap those for the earliest dated Neolithic sites in western Scotland and suggest that the subsistence practices represented by the 'Obanian' shell middens persisted into the period when farming became established in the region.

2.3 - ANTLER MATTOCKS

Direct dates are now available for 17 red deer antler mattocks (table 3). From these dates it is evident that previous ideas on their chronology are in need of revision.

The temporal range indicated for the antler-base mattocks is broad (c. 8820–3000 BP), but clearly falls into two non-overlapping spans - one during the early 9th millennium BP, and another coinciding with the Late Neolithic and Bronze Age from c. 4200–3000 BP (c. 2750–1200 cal BC). The dating of this type exclusively to the Mesolithic (Smith and Bonsall, 1985 ; Smith, 1989) therefore is shown to be incorrect. The dates for the *later* series of antler-base mattocks show an interesting pattern. Of the 10 dates available, the five oldest dates are for mattocks of Smith's sub-type A (Smith, 1989) ; whereas all later dates are for specimens belonging to Smith's sub-type B. This pattern suggests a small, but significant, change in the form of antler-base mattocks during the earlier part of the Bronze Age.

Dates are also available for heavy-duty red deer antler implements from Borth and Mochras (Wales), and Beddington (Surrey) (table 4). These specimens all possess a circular or oval shaft-hole, but lack the distal oblique facet, and therefore fall outside our definition of antler *mattocks*. They are all made from the basal portion of the antler, and it is interesting that the AMS dates fall within the time-range indicated for the later series of *antler-base* mattocks.

The six typical antler-beam mattocks assayed (fig. 1, no. 4) have produced dates in the range c. 8000–5350 BP (c. 6900–4200 cal BC), and there are a number of indirectly dated specimens from 'Obanian' shell middens that may be assigned to the same period (table 6). These dates suggest that antler-beam mattocks were primarily, if not exclusively, a Late Mesolithic type ; more importantly, their known period of use spans the greater part of the time-range of narrow blade microlithic assemblages. The unclassified fragment from Risga also fits into this time-range. Two other specimens listed in table 3 as 'unclassified mattocks' have given much younger dates, but neither can be regarded as of 'typical' antler-beam form - the artefact recovered from the Thames at Hammersmith is exceptionally long and its AMS date of 2240±100 BP places it significantly later in time than either the typical antler-beam mattocks or the later series of antler-base mattocks ; while the specimen associated with a Bronze Age burial at Crantit Farm, Orkney, and dated to 3385±55 BP, is unusual in being made from an antler tine and may never have been intended as a 'functional' item.

Taken together, the available dates for all types of antler mattocks provide broad confirmation of the relative chronology proposed by Smith and Bonsall (1985 ; Smith, 1989), namely a replacement of elk antler mattocks by implements made from basal sections of red deer antlers early in the Mesolithic, which in turn were superseded by antler-beam mattocks. The later series of dates for antler-base mattocks indicates that implements of this type were also popular in Southeast England in post-Mesolithic times. Re-invention, or re-adoption, of such a simple form is a better explanation of the dates than supposing a continuity between the 9th and 5th millennia BP for which there is no evidence.

2.4 - GENERAL OBSERVATIONS

It is clear from the large number of direct AMS dates now available that various kinds of bone and antler artefacts were in use at all stages of the LUP and Mesolithic. Contrary to the hypothesis advanced by Jacobi (1982), there is no major hiatus or period of decline in the use of antler or bone for tool-making corresponding to the Later Mesolithic, nor at any time during the period c. 12,700–5200 BP (c. 13,000–4000 cal BC).

However, there is a clear distinction between the artefact forms characteristic of the major stages of the Mesolithic. 'Maglemosian'-style barbed points, elk antler mattocks and, possibly, red deer antler-base mattocks were confined to the early part of the Mesolithic characterized by broad blade microlithic assemblages. By contrast, the main types in use during the Later Mesolithic when narrow blade microlithic technology is found throughout Britain were antler-beam mattocks, 'Obanian'-style barbed points, and bevel-ended tools. Moreover, no individual artefact type can be shown to span the transition from broad blade to narrow blade lithic technology. It is worth noting that the only certainly Mesolithic example of a red deer antler-base mattock - an unassociated find from the River Thames at Kew Bridge in London (table 3) - gave a date of 8820±100 BP (OxA-1160). This is similar to the date usually placed on the change over from broad blade to narrow blade lithic technology. Thus, it is conceivable that red deer antler-base mattocks are not an Early Mesolithic type in Britain, but belong instead to the later, narrow blade phase. Regardless of the chronological/cultural status of the red deer antler-base mattocks, it may be argued that the advent of narrow blade technology at c. 8700 BP was accompanied by the appearance of new forms of antler/bone artefacts. In fact, the changes that occur in the archaeological record between the Early and Late Mesolithic appear more fundamental than those that characterize the LUP/Early Mesolithic boundary and, it may be suggested, mark a major cultural discontinuity in British prehistory.

3 - AMS DATING AND THE LATEGLACIAL–EARLY POSTGLACIAL RE-SETTLEMENT OF THE BRITISH ISLES

Although artefacts made of bone and antler, and therefore suitable for direct dating, are rare compared with those made from inorganic materials they are an important source of evidence for the presence of humans. When combined with similar evidence from human remains and humanly modified faunal assemblages the technique can make an important contribution to the study of the ages and rates at which the various regions were reoccupied during the Lateglacial and Early Postglacial. Over the decade that has passed since our 1987 review of the impact of the technique (Smith and Bonsall, 1991, 266) AMS radiocarbon dating has begun to place the palaeogeography and palaeodemography of Europe north of latitude 50°N during the millennia spanning the Pleistocene–Holocene transition on a more secure footing. Several hundred AMS radiocarbon dates are now available and any detailed consideration of this work is beyond the scope of this brief contribution. We would, nonetheless, like to draw attention to what we consider to have been the major developments. These developments have proceeded at two scales of analysis, the mapping of broad trends on a regional, or even sub-continental, scale and finer resolution analyses of developments within regions.

Syntheses encompassing much of northwest Europe have been published by Gob (1991) and Housley *et al.* (1997). The more recent of these studies, which is based largely on an analysis of AMS radiocarbon dates, proposes that the resettlement of northwest Europe after the Pleniglacial took place in two distinct phases : a 'pioneer' phase which proposes an initial human presence in the Low Countries by 13,400 BP, Southern Scandinavia by 13,200 BP and Southern Britain by 13,000 BP, and a 'residential' phase which can be documented in the same areas about 600 years later in each case. Another aspect of this study is the proposal that the radiocarbon dates can be used to suggest hypothetical rates of colonization. For example, the expansion of the 'pioneer' phase into the British Isles and Southern Scandinavia from 'residential' centres in the Upper Rhine region is estimated to have progressed at rates of 1.54 and 2.04

kilometres per year, respectively. Studies of data from the British Isles and Scandinavia provide an opportunity to test the validity of this proposition.

In a series of publications the first author (Smith and Openshaw, 1990; Smith, 1992, 1997; Tolan-Smith, 1998, in press) has sought to integrate AMS radiocarbon dates from the British Isles with a suite of critically evaluated conventional radiometric dates. The spatial and temporal distribution of radiocarbon dated records of an initial human presence allows three broad phases of settlement to be proposed. The first, the phase of initial colonization, which began around 12,500 BP, towards the end of the Lateglacial Interstadial (Dryas Ib, Ic and II), was marked by the rapid and widespread dispersal of human groups into the lowlands of central, southern and eastern England. This corresponds to the 'residential' phase of Housley *et al.* (1997), and their preceding 'pioneer' phase has not been recognized. Tolan-Smith's second phase, corresponding to the Loch Lomond Stadial (Dryas III) and the Preboreal (Godwin Zone IV) and dating from c. 11,000–9000 BP, was an episode of consolidation with little further spread of settlement. The third phase, from c. 9000–7000 BP witnessed a rapid expansion of settlement which involved most of the rest of the British Isles, including Ireland, but appears not to have extended to the northeast of Scotland or the far southwest of England. This analysis of the data documents a human presence well established at about latitude 54°N by 12,500 BP. Using Housley *et al.*'s rate of expansion the most northerly parts of mainland Britain should have been occupied within a further 350 years, or 650 years if we take the rate they propose for the establishment of 'residential' as opposed to 'pioneer' settlement. Present radiocarbon evidence suggests that these northerly regions were not occupied, in any form, until the eighth millennium BP, a span of 5000 years for humans to cover a distance of 500 kilometres, a rate of 0.1 km per year. Clearly there is a massive discrepancy between the picture presented by the evidence available and that which would be predicted by the application of Housley *et al.*'s rates of expansion.

Several papers published in the volume edited by Larsson (1996) provide opportunities to test the Housley *et al.* expansion rates in a Scandinavian context. In particular, Thommessen gives details of a number of radiocarbon dated records of a human presence in the far north of Norway in the centuries either side of 10,000 BP (Thommessen, 1996, 237). Housley *et al.* have their 'residential' phase of settlement established in southern Scandinavia by 12,600 BP. A human presence 2000 km to the north 2600 years later requires an expansion rate of 0.8 km per year which compares well with the estimated rate published by Housley *et al.* of 0.68 km per year for the establishment of residential settlement (Housley *et al.*, 1997, 49). The differing scenarios presented by the British and Scandinavian data offer a challenging area for further research, such as the absolute dating of typologically 'early' lithic assemblages (*cf.* Morrison and Bonsall, 1989) from Northern Britain.

Examples of the use of AMS radiocarbon dating at finer scales of temporal and spatial analysis are proved by papers by Barton and Roberts (1996), Reynier (1994) and the present authors (Bonsall and Smith, 1989). Barton and Roberts have proposed a subdivision of the British Late Upper Palaeolithic, on both typological and chronological grounds, into two phases, a 'Creswellian' phase of Late Magdalenian affinities dating to the earlier part of the Lateglacial Interstadial (Dryas Ib, Ic and II) and a British Final Palaeolithic, dating from the latter part of the Interstadial and the succeeding Loch Lomond Stadial (Dryas III), with affinities with the *Federmessergruppen* of the North European Plain. For the Mesolithic period Reynier has used a similar approach to suggest a subdivision of the British Early Mesolithic in three 'stages', while Bonsall and Smith have proposed a revision of the temporal status of the Late Mesolithic so-called 'Obanian' assemblages of western Scotland. These studies also comment on the palaeogeographical implications of their findings. In this paper we draw attention to the distinction between the antler/bone technologies of the LUP/Early Mesolithic and those of the Late Mesolithic. The fact that these periods may now be defined in terms of their antler/bone technologies as well as lithics is a significant development. This distinction may also have palaeogeographic and palaeodemographic implications, and it may not be a coincidence that the Late Mesolithic in Great Britain corresponds to the third phase of Tolan-Smith's (1998, in press) resettlement model, the 'phase of expansion'.

As Housley *et al.* (1997, 43–44) point out the use of radiocarbon dates, both radiometric and AMS, as data in themselves is a relatively new approach (Rick, 1987 ; Smith, 1992, 1997 ; Holdaway and Porch, 1995 ; Housley *et al.*, 1997 ; Tolan-Smith, 1998, in press) to issues of palaeogeography and palaeodemography. The increasing number of such dates is likely to mean that they will play an even greater part in our attempts to understand the manner and rate at which *Homo sapiens* has so successfully managed to occupy so much of the face of the globe.

CONCLUSION

The application of radiocarbon dating to archaeological problems since the early 1960s has had a revolutionary effect on our understanding of the past. The calibration of radiocarbon and calendrical time-scales has had a similar effect and has been referred to as the 'Second Radiocarbon Revolution'. AMS radiocarbon dating, with its capacity to date very small samples with a high degree of precision, has greatly extended the range of items considered suitable for absolute dating. In the context of Upper Palaeolithic and Mesolithic archaeology, the fact that we can now routinely obtain direct dates for the humans themselves or their actions as represented by anthropogenically-modified organic materials, is having a significant impact on research. After a decade, during which the technique has been systematically applied to a series of archaeological problems, the impact of AMS dating can now be evaluated and recognized as the 'Third Radiocarbon Revolution'.

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ESQUISSE CHRONOLOGIQUE DE LA PRÉHISTOIRE POST-PALÉOLITHIQUE DE LA RÉGION CANTABRIQUE (Espagne)

*Pablo ARIAS-CABAL**

Résumé : Le but de cet article est la mise à jour de la chronologie des complexes archéologiques qui se développent dans la région cantabrique (côte septentrionale espagnole) depuis le Mésolithique jusqu'à l'Age du Fer. On essaiera aussi d'établir une représentation graphique significative du schéma proposé et on discutera des procédures de représentation graphique des séries de dates absolues.
Dans la région Cantabrique, environ deux cents datations absolues sont connues pour les périodes étudiées ici, la plupart ayant été obtenues par la méthode du ^{14}C, et le reste par thermoluminescence ou, occasionnellement, par d'autres méthodes. Cependant, la distribution de ces dates par période est très irrégulière, et leur qualité et degré de fiabilité sont très variables. Il faudra donc faire un bilan critique des séries de dates avant leur étude statistique.

Abstract : The aim of this paper is to discuss the chronology of the archaeological complexes developed in the Cantabrian region (Spanish northern coast) from the Mesolithic to the Iron Age. The methods for the graphic representation of series of radiocarbon dates are also discussed.
Nearly two hundred absolute dates (most of them radiocarbon dates) are currently known for the periods under study. The distribution among periods, though, is quite uneven, and the quality and degree of reliability of the determinations is very variable. Therefore, a critical reexamination of the series of dates is needed before their statistical analysis.

Mots-clés : Mésolithique, Néolithique, Chalcolithique, Age du Bronze, Age du Fer, Mégalithisme, chronologie, représentation graphique.

Key-words : Mesolithic, Neolithic, Chalcolithic, Bronze Age, Iron Age, Megalithic tombs, chronology, graphic representation.

INTRODUCTION

La région cantabrique est un rectangle de 350 sur 40 km, compris entre le golfe de Biscaye et les Monts Cantabriques, sur la côte nord de l'Espagne. Elle comprend les actuelles provinces espagnoles des Asturies, la Cantabrie, la Biscaye et Guipúzcoa. Celle-ci est l'un des territoires classiques pour l'étude de la Préhistoire de l'Europe occidentale. La découverte des peintures d'Altamira en 1879, et la polémique subséquente concernant leur authenticité, ont contribué au développement d'une intense activité de recherche dans cette région, notamment dans le premier tiers du XX^{ème} siècle, et à lui donner un grand rayonnement international. De grands savants d'origine étrangère, comme E. Cartailhac, H. Breuil, H. Obermaier ou P. Wernert ont fait des fouilles et des relevés d'art rupestre dans la région, et les résultats de leur recherches, ainsi que celles des archéologues espagnols comme E. Hernández-Pacheco, le comte de la Vega del Sella, T. de Aranzadi ou J.M. de Barandiarán, ont joué un rôle très remarqué dans la systématisation du Paléolithique Supérieur européen et de l'art paléolithique, aussi bien pariétal que mobilier.

Néanmoins, pendant ces premières années, un inconvénient est apparu dans la recherche de la Préhistoire cantabrique : l'excessive spécialisation dans l'étude du Paléolithique. Ceci est justifé si l'on tient compte de la richesse en témoignages de cette époque dans cette région et de l'importance des sites comme Altamira, El Castillo, Cueto de la Mina ou Santimamiñe, mais cela s'est traduit aussi par un constant manque d'attention pour les autres périodes du passé régional. Bien que dans la région Cantabrique il y ait un nombre important de datations absolues (autour de 450), la plupart correspondent au Paléolithique Supérieur. C'est seulement dans les dix dernières années que l'on a commencé à construire un corpus de dates radiocarbone pour le Néolithique et les âges des

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Métaux, corpus qu'on peut juger suffisant pour aborder avec un minimum d'objectivité la chronologie de ces périodes : c'est le but de la présente étude.

L'évolution de la recherche régionale peut être observée dans la fig. 1. C'est seulement à partir de 1970 que s'est généralisé l'utilisation de la méthode ^{14}C, avec une importante concentration de dates pour le Paléolithique Supérieur, notamment dans le Magdalénien et un grand nombre des datations pour le Paléolithique Supérieur ancien à cause d'un remarquable programme de recherche (celui de Cueva Morín) centré dans cette partie de la Préhistoire. Entre 1980 et 1990, le nombre de dates a augmenté de 208 %. Celles du Magdalénien se sont multipliées presque par quatre, et, on observe une augmentation importante pour les périodes antérieures au Néolithique. Depuis 1990, le nombre de dates a continué à augmenter de façon considérable (131 %) jusqu'aux 449 qui ont été cataloguées en avril 1998. Dans cette dernière période, trois nouveautés doivent être soulignées. En premier lieu, la soudaine parution de dates pour l'art rupestre paléolithique. En second lieu, l'emploi régulier des méthodes alternatives de datation absolue, en particulier la thermoluminescence. Finalement, et c'est ce qui nous intéresse ici particulièrement, une importante augmentation des datations pour le Néolithique et les âges des Métaux, dont le nombre absolu s'est équilibré avec celles de la Préhistoire ancienne (à l'exception, encore une fois, du Magdalénien, qui est toujours la période la mieux datée).

La fiabilité des datations n'est pas toujours comparable, car une partie importante des couches et des structures holocènes présentent des problèmes de contamination et des difficultés pour établir le rapport entre l'échantillon et son contexte archéologique beaucoup plus aigüs que pour le Paléolithique. Toutefois il semble que nous sommes maintenant en mesure d'affronter avec un minimum d'objectivité l'étude de la chronologie de la Préhistoire postazilienne de la région Cantabrique.

REPRÉSENTATION GRAPHIQUE DES DATES

La représentation graphique des datations est fondamentale pour l'étude de la chronologie des sites ou des phénomènes archéologiques. A vrai dire, depuis les début de la méthode de datation par ^{14}C, on a employé, d'une façon plus ou moins occasionnelle, la représentation imagée de chaque date par un point ou, dans le meilleur des cas, par un segment de droite, dont les extrémités correspondent aux valeurs de la moyenne plus ou moins l'écart-type (simple ou double). Cependant, ces méthodes, acceptables pour de petits groupes de dates, sont devenus insuffisantes pour affronter des grands ensembles de dizaines, ou même de centaines des datations, qu'on a commencé à pouvoir étudier depuis les années quatre-vingt. Ces ensembles exigent un traitement systématique des séries de dates, afin de permettre d'évaluer d'une façon rapide et facile la localisation dans le temps des phénomènes qu'on étudie, ainsi que leur rapport avec d'autres phénomènes, et la distribution des probabilités dans la période concernée.

Une sorte de représentation graphique très efficace (et très souvent utilisée chez les archéologues de langue française) est sous la forme d'histogrammes dans lesquels la hauteur de chaque segment représentant une certaine période est proportionnelle au nombre des dates comprises dans cette période (en prenant les dates avec une ou deux déviations standards : $x \pm \sigma$ ou $x \pm 2\sigma$). Ce genre de représentation a été proposé par des auteurs comme W. Pape (1979) et J. Gasco (1985). Cependant, les histogrammes

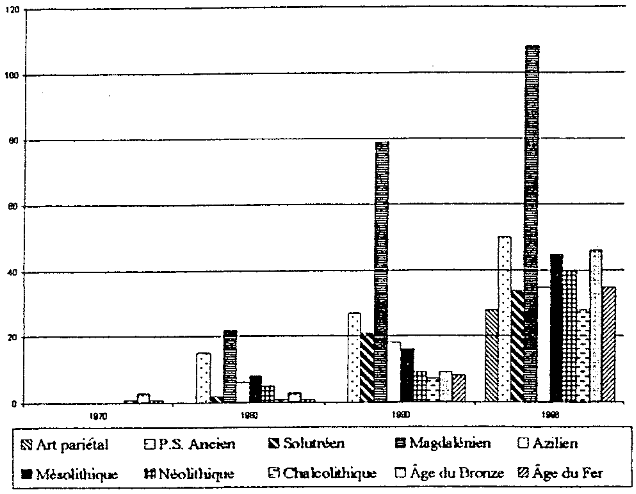

Fig. 1 : Distribution par période des dates absolues publiées jusqu'aux années indiquées.

simples présentent des inconvénients, car ils donnent lieu à la surreprésentation des dates les moins précises (parce qu'elles se retrouvent dans plus de segments temporels que celles avec un écart-type court). La solution proposée par Gasco est une pondération graphique, en donnant la même surface à chaque datation, de façon que celles ayant un écart-type plus long aient moins de poids dans chaque classe temporelle. Un apport intéressant, du point de vue de l'interprétation graphique, est la transformation des histogrammes en fuseaux (souvent appelés « chroniques ») où l'on ajoute à l'histogramme sa représentation symétrique en lissant les barres de l'histogramme. Ceci est très fréquent dans des travaux de nombreux chercheurs français (Gasco et Binder 1983 ; Evin *et al.*, 1995). La symétrie bilatérale des fuseaux facilite la comparaison entre plusieurs ensembles, même quand il y a, des recouvrements partiels, ce qui est fréquent (fig. 2).

Un autre problème des systèmes de répresentation des années quatre-vingt était qu'ils donnaient la même probabilité à tout l'intervalle ou bien que l'on considérait que celle-ci était distribuée suivant une courbe normale. C'était une conséquence logique de l'emploi des dates non calibrées, ou de celles calibrées avec des tables du « Groupe de Tucson », dans lesquelles on pouvait uniquement obtenir les intervalles maximaux. Cependant, on sait bien que, quand on fait la projection de la probabilité gaussienne de la détermination vers la courbe de calibration, comme celle-ci comprend de nombreuses oscillations, le résultat conduit souvent à de grandes et très irrégulières variations de probabilité. pour cela, ces dernières années, avec la diffusion des courbes de haute précision, on a actualisé les méthodes de représentation graphique, qui, de façon générale, incorporent ce facteur (Stuiver et Reimer, 1989 ; Van der Plicht et Mook, 1989 ; Michczynska *et al.*, 1990), en faisant une pondération de l'apport de chaque date dans l'ensemble, selon la distribution des probabilités.

La méthode employée pour construire la figure 2 a été la suivante : on a fait un catalogue exhaustif des dates absolues publiées jusqu'au mois d'avril 1998 pour les périodes étudiées. La fiabilité de chaque datation a été soigneusement critiquée. Ont été éliminées quelques dates jugées non-représentatives ou peu fiables à cause de problèmes tels que l'incohérence avec la stratigraphie, le manque d'un contexte clair (par exemple des échantillons pris en surface ou non intégrés dans des couches ou des structures préhistoriques) et finalement, des dates évidemment aberrantes (par exemple, des chronologies du Moyen Age pour des monuments mégalithiques). Une fois établi, de cette

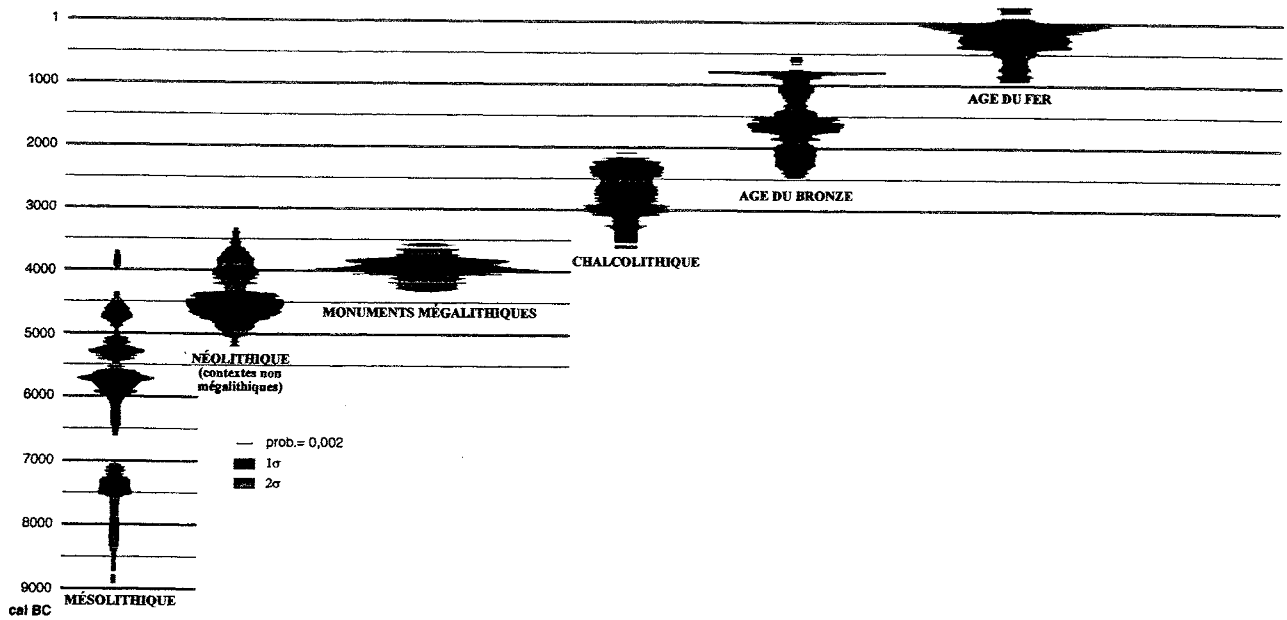

Fig. 2 : Distribution de probabilités des dates Radiocarbone pour les périodes de la Préhistoire postazilienne de la région Cantabrique.

façon, l'inventaire des dates, on a essayé d'éviter un autre problème : la surreprésentation des contextes les mieux datés. D'après les propositions de J. Mestres (Mestres et Martín, 1996) on a utilisé la moyenne pondérée au lieu des datations individuelles quand il y avait plus d'une date pour le même contexte. Evidemment, on a suivi ce procédé uniquement dans les cas pour lesquels les dates correspondaient au même événement radiocarbone (par exemple, plusieurs datations du même squelette) et si elles étaient homogènes d'un point de vue statistique (si elles ont passé le test χ^2 avec un niveau de signification de 0,05). A partir de là, le procédé suivi a été très simple : on a calibré les datations selectionnées avec la méthode B du logiciel Calib 3.0.3 (Stuiver et Reimer, 1993), les probabilités résultantes ont été additionnées, et on a traité graphiquement les données numériques, dans les intervalles 1σ et 2σ, avec le logiciel Adobe Illustrator 7.0.

Dans la figure 3 on a représenté les mêmes entités archéologiques, mais en appliquant le concept de *floruit,* défini comme la période comprise dans le 50 % de probabilité autour de la médiane, c'est-à-dire, entre le premier et le troisième quartile de la probabilité (Aitchinson, Ottaway et Al-Ruzaiza, 1991).

LA CHRONOLOGIE DE LA PRÉHISTOIRE POSTAZILIENNE DE LA RÉGION CANTABRIQUE D'APRÈS LE RADIOCARBONE

Dans la figure 2, la période Mésolithique présente une distribution atypique, polymodale, avec une partie de très faible probabilité dans le VII[ème] millénaire av. J.-C. A notre avis, les causes sont liées en grande partie à des problèmes de préservation des couches de cette époque et aux stratégies de la recherche. Dans quelques gisements

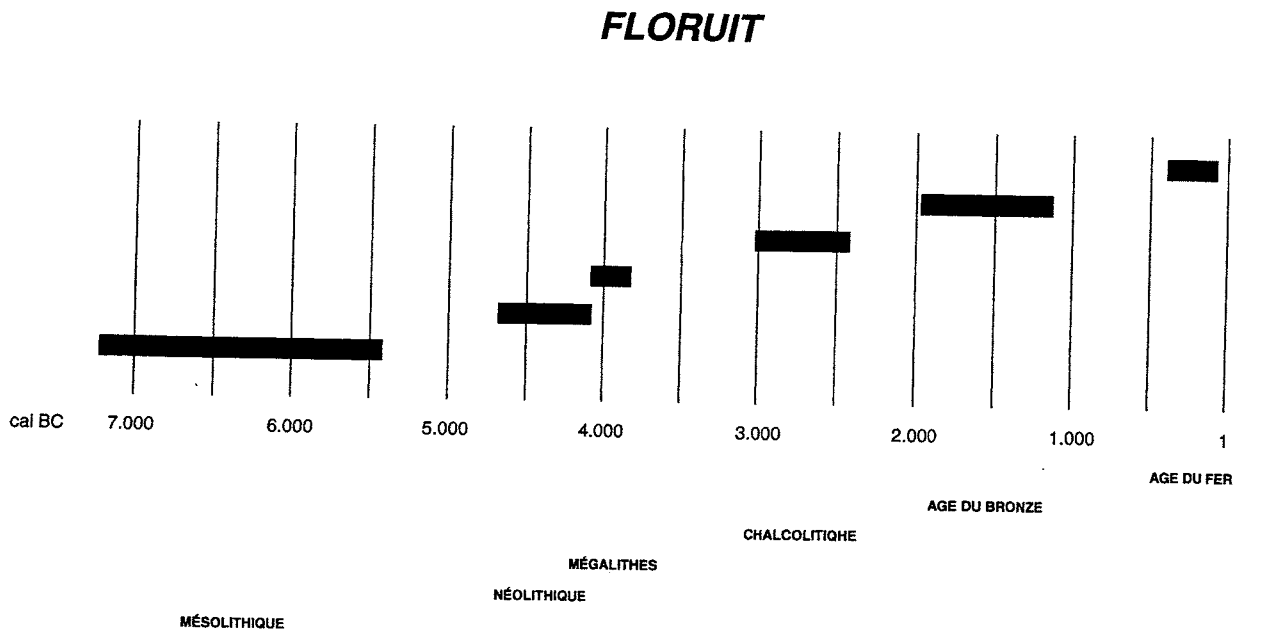

Fig. 3 : Intervalles compris dans le 50 % de probabilité autour de la médiane (*floruit*) pour les périodes de la Préhistoire postazilienne de la région Cantabrique.

les échantillons datés ont été pris dans les couches basales des amas coquilliers dont la partie supérieure a été préservée seulement dans des petites brèches cimentées dans les parois des abris, trop réduites pour être fouillées. D'un autre côté, l'intérêt des chercheurs pour le processus de néolithisation a concentré un bon nombre de datations dans des contextes de la fin du Mésolithique, dans les VI^{ème} et V^{ème} millénaires. Cependant, Il faudra enquêter si la basse probabilité qu'on atteint entre 7000 et 6000 av. J.-C. peut être mise en rapport avec un phénomène historique significatif (chute dans la densité démographique ou changement dans des types d'habitat). Somme toute, le Mésolithique cantabrique se situe fondamentalement entre 7500 et 4500 av. J.-C. avec des probabilités plus hautes dans la deuxième moitié du VIII^{ème} millénaire et dans le VI^{ème}. La localisation du *floruit* (7220-5420) est, dans ce cas, très peu significative, car le 50 % central est composé avec les sommets de probabilité de la fin du VIII^{ème} millénaire et la première motié du VI^{ème}, la « vallée » du VII^{ème} millénaire étant aussi y comprise.

Quoique la courbe soit bimodale, la distribution des dates pour les contextes non mégalithiques du Néolithique s'approche beaucoup plus d'une distribution normale. La probabilité maximale est concentrée dans le deuxième tiers du V^{ème} millénaire, avec une petite superposition avec les dernières datations mésolithiques entre 5000 et 4500 av. J.-C. Ceci suggère que le processus de néolithisation a eu lieu dans la région à cette période et plus probablement entre 5000 et 4700 av. J.-C., quelques siècles plus tard que dans des régions voisines, comme la haute vallée de l'Èbre (Arias, 1997). Le *floruit,* bien plus significatif que pour le Mésolithique, se situe entre 4680 et 4080 av. J.-C.

La courbe des datations pour le phénomène mégalithique est un peu surprenante. La forme est très proche de la distribution normale, mais elle est extrêmement courte. Cela met en évidence une extraordinaire concentration de 17 datations jugées valides dans une période de temps très réduite, autour de 4000 av. J.-C. Logiquement, la période du *floruit* est aussi très courte : 4082-3827 av. J.-C. Ceci suggère quelques réflexions de grand intérêt. En premier lieu, le contraste est étonnant entre un ensemble de dates aussi concentré dans le temps et la longue durée suggérée par les matériaux récupérés dans les fouilles, matériaux distribués depuis un Néolithique assez archaïque, à haches polies et microlithes géométriques, jusqu'au commencement de l'Age du Bronze, ayant livré beaucoup de monuments avec des matériaux chalcolithiques. Il est vrai que les archéologues responsables des fouilles ont, presque toujours, tenté de dater la chronologie des bâtiments, et que, en conséquence, une partie importante des échantillons datés ont été pris dans des paléosols. On a beaucoup discuté sur les problèmes liés à cette stratégie de recherche pour le mégalithisme, qui peut être responsable d'un vieillissement des monuments (Boujot et Cassen, 1992), les datations des paléosols représentant des termes *post quem* dont le rapport avec la chronologie du bâtiment est difficile à établir. Cependant, dans le cas de la région cantabrique, la plupart des datations sont trop cohérentes pour qu'on puisse les attribuer à des datations aléatoires des contextes, sans rapport avec les monuments. D'autre part, les dates provenant des paléosols sont semblables à celles de la masse tumulaire. Ceci nous entraîne obligatoirement vers l'hypothèse, qu'il faudra, dans le futur, tenter de savoir si la construction des monuments mégalithiques s'est concentrée pendant une période assez courte, entre la fin du V^{ème} millénaire et le commencement du IV^{ème}, et si l'ampleur chronoculturelle des offrandes funéraires pourrait être mieux expliquée par les réemplois successifs de ces tombes que par leur construction pendant de longues périodes. D'un autre point de vue, il semble clair qu'il y a un certain décalage entre la chronologie du commencement de la néolithisation et celle des premières tombes mégalithiques ; cela viendrait à l'appui de l'hypothèse que nous avons émise il y a quelques années de l'existence dans la région Cantabrique d'un Néolithique initial prémégalithique (Arias, 1991). Le rapport entre la chronologie du Mégalithisme cantabrique et celle des régions voisines permet d'avancer une autre perspective intéressante. Si les mégalithes cantabriques sont à peu près contemporains de ceux de la haute vallée de l'Èbre, la Meseta septentrionale, les Pyrénées et la Galice, comme les dates radiocarbone le suggèrent, il semble difficile de maintenir un schéma diffusionniste simple qui a été très à la mode parmi les préhistoriens de la région jusqu'à nos jours : des bergers venus des lieux hors la région, colonisant les monts cantabriques et y introduisant le rituel mégalithique. Les données chronologiques sont plus compatibles avec un modèle de transmission d'une idée entre des communautés néolithiques (ou en voie de lente néolithisation) distinctes et fondamentalement indigènes. L'expansion du mégalithisme n'aurait pas eu lieu en suivant des groupes d'envahisseurs, mais à travers des réseaux de relations sociales, sans doute existants depuis le Mésolithique.

Les dates du Chalcolithique s'étalent tout au long du III^{ème} millénaire, avec une densité plus haute dans la première moitié, où la probabilité la plus élevée est bien centrée (*floruit* : 3020-2420 av. J.-C.). Nous voudrions souligner deux particularités des datations pour cette période. En premier lieu, les graves problèmes de contexte pour beaucoup de dates, les échantillons étant pris dans des couches très proches de la surface, souvent remaniées (la plupart viennent de sépultures collectives en surface des grottes). Le deuxième est l'existence d'un vide dans la séquence chronologique entre le Néolithique et le Chalcolithique, dans le IV^{ème} millénaire. Pourquoi y a-t-il aussi peu de datations pendant cette époque ? A notre avis, il est possible que nous nous trouvions devant un simple problème de visibilité archéologique. Pendant le Néolithique, il y a encore de nombreux amas coquilliers et d'autres habitats en grotte, tandis que depuis le Chalcolithique, il semble que les grottes soient utilisées surtout comme des lieux funéraires. Il est possible que le manque de dates pour le IV^{ème} millénaire représente le temps pendant lequel les grottes (et peut être aussi l'exploitation systématique des coquillages) sont en voie d'abandon, et l'inhumation collective dans le milieu de l'hypogée n'est pas encore fréquent, le rituel le plus étendu étant le mégalithisme, ce qui donne la partie la plus importante des datations pour ce segment temporel.

Le fuseau de l'Age du Bronze est assez irrégulier. Sa structure a une tendance bimodale, avec deux maximums de probabilité, l'un autour de 1600 av. J.-C. et l'autre déjà dans le premier millénaire, en 820 av. J.-C. Evidemment, le *floruit* est, comme celui du Mésolitique, peu représentatif, puisque la période de 50 % de probabilité centrale (1970-1130 av. J.-C.) inclut le pic ancien ainsi qu'une période avec peu de probabilité : la deuxième moitié du II^{ème} millénaire. A notre avis, nous sommes encore devant des problèmes de représentativité de l'échantillon par rapport au contexte daté. Les datations se concentrent dans deux parties de l'Age du Bronze dans lesquelles des couches archéologiques (souvent des contextes funéraires) ont été fouillées : le Bronze ancien, dans le dernier tiers du III^{ème} millénaire et la première moitié du II^{ème}millénaire, et la partie récente du Bronze Final, surtout le IX[ème] siècle av. J.-C. Le Bronze Moyen et le commencement du Bronze Final sont des phases représentées dans le registre archéologique par des objets métalliques, mais pendant lesquelles peu des contextes sont datables.

Enfin, pendant l'Age du Fer on trouve encore le même problème, mais aggravé : l'Age du Fer ancien est presque complètement inconnu : très peu d'objets, et presque aucun contexte ne peuvent être attribués à cette partie de la Préhistoire, d'où le vide de probabilité pendant les siècles V[ème] à II[ème] av. J.-C., et la concentration des dates dans le temps immédiatement antérieur à la conquête romaine des années 29-19 av. J.-C. (*floruit* : 393-72 av. J.-C). La forme du fuseau est aussi un peu atypique, avec de grandes sauts, sans transition, entre une partie centrale à haute probabilité et des queues à très faible probabilité. Cela pourrait être justifié par les particularités de la courbe de calibration pendant ce temps : la célèbre « catastrophe de l'Age du Fer ». Le plateau de la courbe à l'époque où le plus grand nombre de dates se concentre (*ca.* 2200-2050 BP) a transformé la plupart des déterminations en des périodes très étendues, et aussi très similaires, d'où la tendance rectangulaire du fuseau.

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LES CASTEDDI DE CUCURUZZU (LÉVIE) ET DE TUSIU (ALTAGÈNE) EN CORSE MÉRIDIONALE : CHRONOLOGIE ET PHASES ÉVOLUTIVES

*François de LANFRANCHI**

Résumé : Les études archéologiques de longue durée, conduites sur les sites de Cucuruzzu (commune de Levie) et de Tusiu (commune d'Altagène), individualisaient, dans l'habitat protohistorique, un ensemble de constructions diachroniques dont le nom générique est casteddu. Nous nous sommes efforcés de valider (en acceptant également une éventuelle invalidation), par un programme de mesures d'âge radiométrique, la chronologie relative fondée sur la stratigraphie et sur le mobilier, mais également sur la palynologie et l'anthracologie. A Cucuruzzu, le village se structure dès le Bronze ancien ; la torre se construit au Bronze moyen et le complexe monumental émerge au Bronze récent. A Tusiu le village (non étudié) jouxte la torre du Bronze moyen qui fut partiellement détruite au Bronze récent. Point de complexe monumental mais, au contraire, des informations évoquant un déclin du groupe. La torre ruinée continue néanmoins à être fréquentée sporadiquement à partir du Bronze récent et des structures d'habitat s'implantent sur les éboulis. Ces deux agglomérations protohistoriques montrent que chaque site a sa propre histoire qui s'inscrit cependant dans un cadre historique commun.

Abstract : The archaeological studies carried out on the sites of Cucuruzzu (Levie municipality) and Tusiu (Altagène municipality) showed, in the protohistoric housing, a group of diachronic constructions called casteddu. We tried to validate the relative chronology based on the stratigraphy and the furniture, as well as on the palynology and anthracology, with the help of radiometric measures. In Cucuruzzu, the structured village appears as early as in the ancient Bronze age and the torre in the medium Bronze age ; the monumental construction emerges in the recent Bronze age. In Tusiu, the village (not studied here) is located near the medium Bronze age torre which was partly destroyed in the recent Bronze age. There is no monumental construction but rather information on a decline of the group. Nevertheless, the ruined torre keeps being sporadically occupied from the recent Bronze age and housing structures are set up on the fallen earth. These two protohistoric agglomerations show that each site has its own history but that they both have a common historical frame.

Mots-clés : Datations radiocarbone, Age du Bronze, Corse.

Key-words : Radiocarbon dating, Bronze Age, Corsica.

INTRODUCTION

Les fouilles archéologiques conduites sur le casteddu de Cucuruzzu permirent d'individualiser trois composantes majeures (fig. 1, n°l) - le village protohistorique, d'une superficie d'un hectare environ, la torre tronconique à deux étages, d'une dizaine de mètres de diamètre et le complexe monumental cernant une aire d'une superficie d'un hectare. Malgré l'ubiquité du mot casteddu (de Lanfranchi, 1982), nous l'avons retenu pour désigner les trois composantes (l'agglomération, le monument monotorre et le complexe monumental). La torre et le complexe furent étudiés en 1963 (Grosjean, 1961, 1966 et 1971), le village, de 1977 à 1984 (de Lanfranchi, 1981, 1982, 1997). Les derniers travaux mirent en évidence la diachronie des structures qui nous a conduit à mettre en oeuvre, pour chacune d'elles, un programme de mesures d'âge radiométrique. L'individualisation d'états successifs et d'états simultanés constitue la première partie de la problématique ; la détermination de leur durée en est la seconde.

LE SITE DE CUCURUZZU (Lévie)

1 - LES STRUCTURES D'HABITAT DU VILLAGE DE CUCURUZZU

1.1 - La cabane

La cabane (fig. 2, n°1) fut mise au jour dans le chantier 1 (fig. 1, n°l) implanté sur une terrasse du village de Cucuruzzu, de 1977 à 1978. Sur un versant en forte déclivité, l'ancrage de l'agglomération protohistorique se fit sur des terrasses retenues par des soutènements mégalithiques. La ceinture de pierres en gros appareil donne à l'ensemble l'allure d'une fortification. En fait, il ne s'agit que d'une technique de construction en usage durant tout le Bronze ancien. Elle est fondée sur la juxtaposition et la superposition de gros blocs de pierre (technique mise au point au Néolithique et qui est aussi celle des constructions mégalithiques). La datation absolue (tab. I) conforte la chronologie relative fondée sur le mobilier céramique et métallique (la hache plate en

* *Centre d'étude archéologique, 20170 LEVIE.*

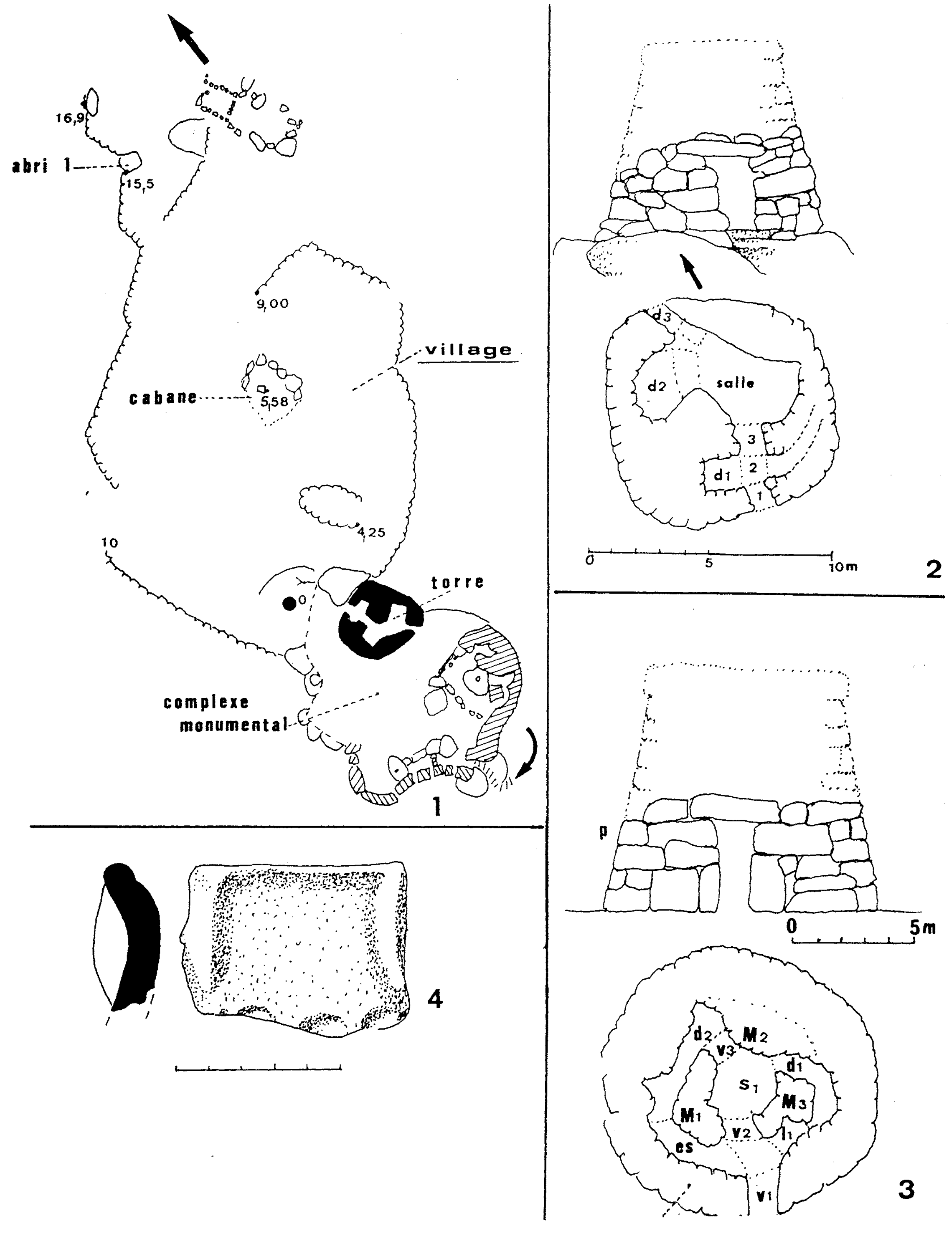

Fig. 1 : Le site de Cucuruzzu : 1 - planimétrie du village de Cucuruzzu ; 2 - planimétrie et restitution graphique du profil de la tour de Cucuruzzu ; 3 - planimétrie et restitution graphique du profil de la tour de Tusiu ; 4 - céramique décorée de la torre de Cucuruzzu, datée du Bronze moyen.

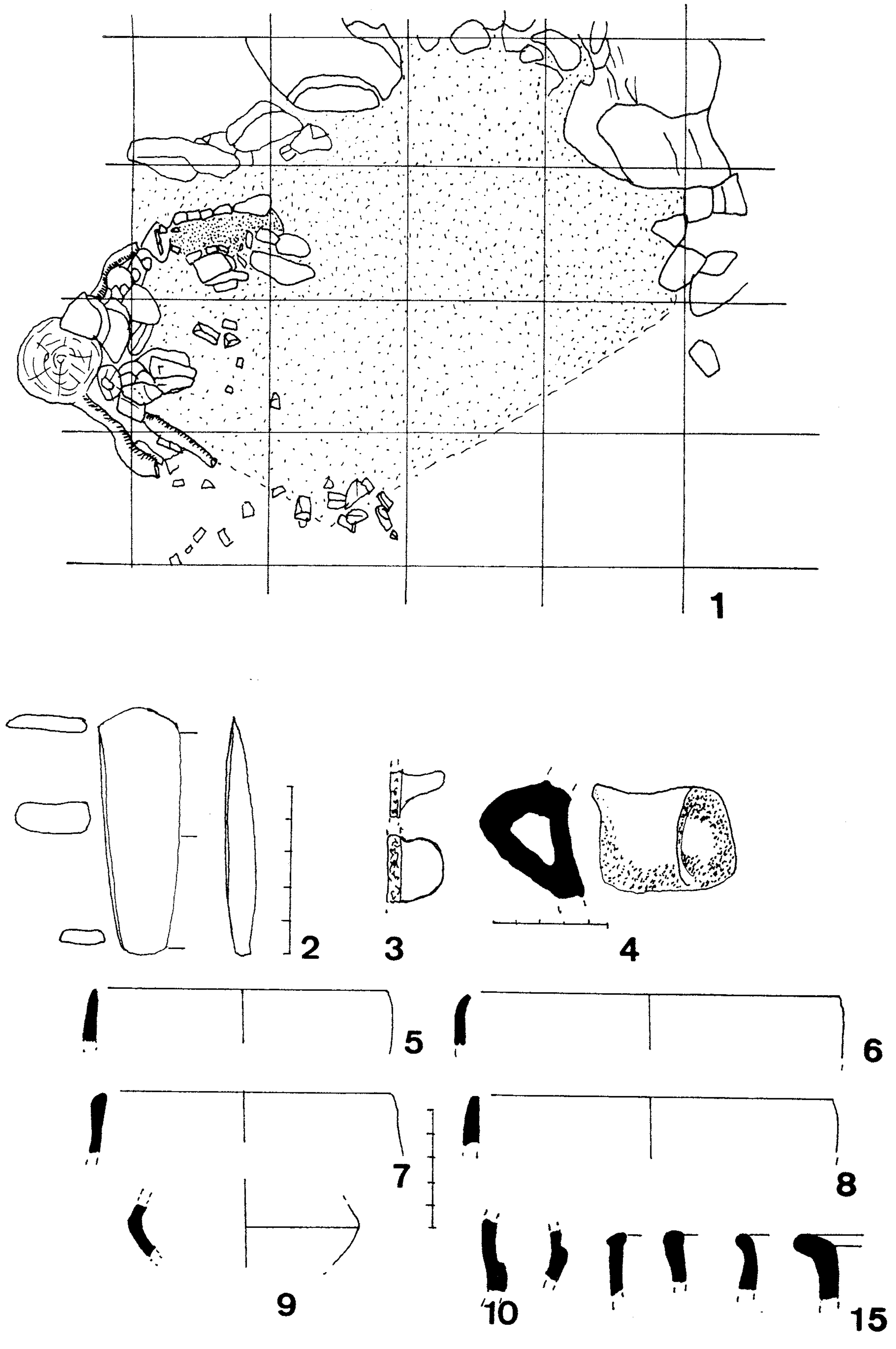

Fig. 2 : La cabane du Bronze ancien du village de Cucuruzzu (chantier 1) : - 1 : planimétrie de la cabane ; - 2 à 15 mobilier de la cabane ; 2 : hache de bronze ; 3 et 4 : prises ; 5 à 9 : quelques formes de vases modelés ; 10 à 15 : épaulements et bords.

Laboratoire	Localisation	Profondeur en cm	Datation BP	Datation av. J.-C.	Culture
Gif-4615	Cucuruzzu, village: cabane, couche 2	couche 2	3580 ± 70	-2116, -1740	**Bronze ancien**
Ly-3238	Cucuruzzu, abri 1 couche 4	-295	3700 ± 190	-2665, -1305	**Bronze ancien**
Ly-3200	Cucuruzzu, abri 1 couche 3	-275	3140 ± 120	-1680, -1070	**Bronze moyen**
Ly-3198	Cucuruzzu, abri 1 couche 3	-275	3140 ± 110	-1665, -1100	**Bronze moyen**
Ly-3199	Cucuruzzu, abri 1 couche 2c	-210	3370 ± 140	-2040, -1375	**Bronze moyen**
Ly-3297	Cucuruzzu, abri 1 couche 2b, F2	-190	2980 ± 110	-1460, -930	**Bronze récent**
Gif-5660	Cucuruzzu, abri 1 couche 2a	-185	3220 ± 90	-1715, -1305	**Bronze récent**
Gif-5658	Cucuruzzu, abri 1 couche 2a	-180	2990 ± 90	-1425, -975	**Bronze récent**
Gif-5657	Cucuruzzu, abri 1 couche 1c	-160	2830 ± 60	-1205, -855	**Bronze final / Premier Age du Fer**
Gif-5461	Cucuruzzu, abri 1 couche 1b	-155	2680 ± 100	-1100, -540	**Bronze final / Premier Age du Fer**
Gif-5462	Cucuruzzu, abri 2 couche 1b	-100	2200 ± 100		**Deuxième Age du Fer**

Tab. I : Mesures d'âge radiométrique de la cabane du village et de l'abri sous roche n°l de Cucuruzzu (Fouilles de Lanfranchi 1980-1984).

bronze notamment). A partir de l'organisation spatiale de la cabane, de sa datation absolue et de son mobilier, il est possible d'affirmer que ce village date du Bronze ancien. Ces structures reposant sur le substratum, la cabane est donc la plus ancienne construction du village.

1.2 - L'abri sous roche n°l

Le chantier 3 (fig. 1, n°1) fut ouvert de 1980 à 1984 dans un abri sous-roche situé à -1,5m par rapport au niveau 0. Le mur d'enceinte du village prend appui sur le niveau du Bronze ancien de l'abri. L'objectif de la fouille dans ce site était double :
- mettre au jour un dépôt sédimentaire suffisamment important pour pouvoir restituer l'histoire de ce village à partir d'une approche chrono-stratigraphique,
- définir les complexes céramiques du casteddu à ses diverses époques. La connaissance de la succession des évènements était à ce prix.

En bordure du village, au pied du mur d'enceinte, l'abri sous roche n°l permit d'établir une échelle de référence à partir de la séquence stratigraphique. Sa couche 4, la plus ancienne, fut datée du Bronze ancien (tab. 1) et la couche correspondant à la dernière occupation de l'abri, se situe à l'Age du Fer. Une fréquentation sporadique au Moyen Age (une petite structure de combustion) marque la dernière présence humaine dans cet abri. Les datations radiométriques, les analyses polliniques (Bui Thi Mai, 1982) et les complexes céramiques permirent de restituer l'histoire du site. Les données chronologiques proposées dans les années quatre-vingts (Camps, 1988) pour Cucuruzzu et limitées à deux seules dates (Gif-5461 pour la couche lb et Gif-4615 pour la cabane), traduisirent fort imparfaitement une réalité beaucoup plus complexe.

2 - UNE STRUCTURE ORIGINALE : LA TORRE

2.1 - Définition

La torre de Cucuruzzu (fig. 1, n°2) a un plan subcirculaire et une forme tronconique en élévation. Cette construction monotorre à deux étages, proche des nuraghi de Sardaigne, fut fouillée par R. Grosjean en 1963. Une autre lecture de son architecture nous permis de voir, à droite en entrant, que ce qui fut retenu comme étant une loge, est en fait le départ d'un escalier conduisant à l'étage. Ce monument comprenait donc deux niveaux : un rez-de-chaussée et un étage.

2.2 - Chronologie

Aucune mesure d'âge n'a été réalisée à partir des charbons des foyers de cette construction. Faute de mieux, nous avons repris les documents afin de tenter de proposer une datation relative fondée sur une céramique ornée (fig. 1, n°4), caractéristique d'une phase moyenne de l'Age du Bronze. Il s'agit de parties supérieures de vases ornés de courts cordons en relief, perpendiculaires au bord, associés à d'autres impressions digitées, parallèles au plan de l'ouverture du vase. Ce type d'ornementation se rencontre en Sardaigne dans le complexe céramique du Bronze moyen de Bonnanaro. Cette datation relative trouve sa confirmation dans les résultats obtenus lors de l'étude de la torre de Tusiu, située à quatre kilomètres à vol d'oiseau de la première.

3 - LE COMPLEXE MONUMENTAL

3.1 - Définition

A l'opposé du village, dominé par la torre du Bronze moyen, une immense construction émerge du chaos granitique au Bronze récent. Le concept architectonique reste celui de la Torre, mais l'expression diffère. Un large mur, mesurant plus de cinq mètres de large par endroits (fig. 1, n°1), comporte des parties concaves et d'autres convexes. Par ce mouvement, le haut mur (de cinq à six mètres de hauteur) génère à l'intérieur des loges éclairées par des baies (deux par loge). Chaque loge était le centre d'un travail artisanal (fabrication de poterie, tissage, dépeçage des bêtes). Des diverticules aménagés dans l'épaisseur du mur s'ouvrent sur des constructions circulaires qui n'étaient autre que des centres de meunerie.

3.2 - Les mesures d'âge

Dans cette partie du casteddu, R. Grosjean avait obtenu, en 1963, trois mesures d'âge radiométriques (tab. II). Toutes sont centrées sur le Bronze récent et le Premier Age du Fer. A partir de ces données et du mobilier qui fut mis au jour, on peut affirmer que Cucuruzzu est un habitat de l'Age du Bronze élaboré durant chacune des trois grandes phases évolutives, l'ancienne, la moyenne, la récente.

4 - L'HISTOIRE DU CASTEDDU

Si l'on excepte la fréquentation du site naturel (avant toute construction) par des groupes du Néolithique final-Chalcolithique, prouvée par l'utilisation des taffoni à des fins funéraires, il est possible de prendre en considération ces trois grandes époques de la vie du casteddu de Cucuruzzu (fig. 3).

4.1 - L'implantation humaine

La première époque, au Bronze ancien, se caractérise par une implantation humaine dans une partie en forte déclivité du site où sera construit un village en terrasses cernées par une enceinte. Ce village sera occupé sans interruption jusqu'au Bronze récent.

4.2 - Le développement du village

La seconde époque, jusqu'au Bronze moyen concerne le développement du village. C'est le moment de la construction de la torre. Cette période du Bronze moyen semble avoir été relativement courte.

4.3 - L'abandon de la torre

La troisième époque se caractérise par l'abandon de la Torre, marquée par la destruction de son étage. Loin d'être déserté, le site, non seulement survit, mais se développe considérablement. La construction du complexe monumental, qui reprend les composantes architecturales de la torre en les reproduisant sur un espace beaucoup plus grand (fig. 1, n°1), l'atteste. Dans l'étage mésoméditerranéen inférieur, le site d'Araghju a une histoire très proche de celle de Cucuruzzu.

LE SITE DE TUSIU (Altagène)

1 - LE CASTEDDU DE TUSIU

Tusiu est un casteddu jouxtant le village néolithique de Presa (Ve millénaire avant J.-C.), archétype de ce que seront plus tard les agglomérations de l'Age du Bronze de la Corse méridionale. Il comprend une torre dont l'entrée s'ouvre sur un village protohistorique découvert en 1997, mais non encore exploré scientifiquement. Seule la torre fit l'objet d'une étude archéologique commencée en 1992. Le site ne comprend pas de complexe monumental. Les mesures d'âge radiométriques (tab. III) mettent en évidence deux phases : l'une primaire, du Bronze moyen, faisant suite à la construction et caractérisant la première occupation de l'édifice ; l'autre, secondaire, annoncée par la destruction de l'étage sur voûtes et par une occupation non fonctionnelle d'un monument ruiné. Effectivement, des structures de combustion sont construites sur les marches de l'escalier conduisant à l'étage et également sur les éboulis des vestibules. Ceci prouve que la fonctionnalité des diverses parties du nuraghe de Tusiu est ignorée des gens du Bronze récent. L'absence de complexe monumental tendrait à prouver qu'à la fin du Bronze moyen, Tusiu entre dans une phase de déclin, contrairement à Cucuruzzu où le Bronze récent devient comme en Sardaigne, «le bel âge des nuraghi». La séquence stratigraphique confirme ce déclin.

2 - LES MESURES D'AGE DU DIVERTICULE DL

Le diverticule est un boyau coudé très étroit dans lequel ont été trouvé plusieurs foyers qui ont été daté (tab. IV). La couche correspondant à l'occupation primaire a livré de très gros fragments de grands vases modelés à la main, ainsi que des structures de combustion non appareillées, contrairement à celles qu'offrait la salle S 1.

Laboratoire	Localisation	Profondeur en cm	Datation BP	Datation av. J.-C.	Culture
Gif-239-1965	Secteur A	Couche II	2610±150		Age duFer I
Gif-241-1965	Secteur B	Couche II	2830±150	-1380, -610 (986, 955, 943)	Age duFer I
Gif-240-1965	Secteur C	Couche I	2775±150	-1342, -530 (969, 907, 809)	Age duFer I

Tab. II : Casteddu de Cucuruzzu (fouilles R. Grosjean).

CONCLUSION : UN CADRE CHRONOLOGIQUE POUR L'AGE DU BRONZE

Un cadre chronologique de l'Age du Bronze se dessine (tab. V). Les mesures d'âge proposées valident les orientations fournies par les datations relatives en confirmant, à Cucurruzzu, pour l'apparition du village, le Bronze ancien, pour la torre, le Bronze moyen et pour le complexe monumental, le Bronze récent. Ces dates font donc proposer le Bronze moyen comme limite entre l'art de bâtir mégalithique et l'architecture véritable et les datations absolues établissent avec certitude le synchronisme entre les sites de montagne et ceux de la piaghja, c'est-à-dire l'étage mésoméditerranéen inférieur.

Localisation et Laboratoire	**Mesures d'âge BP et mesures d'âge calibrées avant J.-C.**	**Culture avant J.-C.**
Foyer, couche 1a, -20cm, salle S1	Datation relative (céramique d'importation)	Moyen Age
Foyer, couche 1b, -40cm, salle S1	Datation relative (céramique d'importation)	Moyen Age
Foyer, couche 1c, -50 cm, salle S1	Datation relative (céramique d'importation)	Moyen Age
Foyer -60cm, sur l'escalier, LGQ-969, année 1993	2350 ± 130, cal. -799, -130	II Fe
		I Fe 1 800 à 660 / 420
Foyer F6, -80cm, entrée S1, Ly-7087, année 1994	2750 ± 130, cal. 960, 808, pics -835, -889	BF 1110 à 980
Entrée de la salle S1, -50/-60 cm, LGQ-969, année 1993	2820, ± 160, cal. -1410, -559	BF 1110 à 980
Entrée de la salle S1, -50/-60 cm, LGQ-970, année 1993	± 100, cal. 1523, -765	BF 1110 à 980
Foyer F5, -65 /-90, salle S1, Ly-7086, année 1994	2800 ± 45, cal. -1049, -842 pics, -921, -969, -869.	BF 1110 à 980
Foyer F9, -78 cm, entrée du couloir, Ly-7085, année 1994	2805 ± 80, cal. -1196, -863 pics -969, -925, -869	BF 1110 à 980
Foyer F10, -80/-90 cm, couloir, Ly-7088, année 1994	2860 ± 35, cal. -1116, -923, pics -1004, -949, -1109	BR 1430-1410 / 1370-1260 à 1110-980
Foyer F12, -97 cm, couloir, Ly-7090, année 1994	3045 ± 40, cal. -1393, -1153, pics -1268, -1274, -1300, -1369	BR 1430-1410 / 1370-1260 à 1110-980
Foyer F8 -80 cm, entrée de la salle S1, Ly-7091, année 1994	3030 ± 45, cal. -1388, -1125, pics -1264, -1289, -1229, -1369	BM 1760-1690 à 1430-1410 / 1370-1260
Foyer F11, -80 cm, couloir sous F7 et F9, Ly-7089, année 1994	3210 ± 50, cal. 1592, -1395 pics, -1450, -1484, -1494	BM 1760-1690 à 1430-1410 / 1370-1260
Echantillon 1-9108, couche 3a -116 cm, diverticule D1, Ly-7927	3361 ± 46, Intervalle de confiance (IC) 95%, cal. -1414, -1204. Pics -1670, -1661, -1637	BM 1760-1690 à 1430-1410 / 1370-1260

Tab. III : La chronologie du nuraghe de Tusiu (fouilles de Lanfranchi, 1992-1998).

Laboratoire	Localisation	Profondeur en cm	Datation BP	Datation av. J.-C.	Culture
Fiche 9108 Ly-7927	couche 3a	-116 cm	3361±46	-1670, -1661, -1637 (-1735, -1528)	Bronze moyen
Fiche 9109 Ly-7928	couche 3b	-124 cm	3079±45	-1379, -1342, -1319 (-1414, -1204)	Bronze moyen
Fiche 9110 Ly-7929	couche 3b	-140 cm	3258±44	-1589, -1516-1469 (-1632, -1431)	Bronze moyen

Tab. IV : Datation des foyers du diverticule D1 de Tusiu (fouilles de Lanfranchi, 1997).

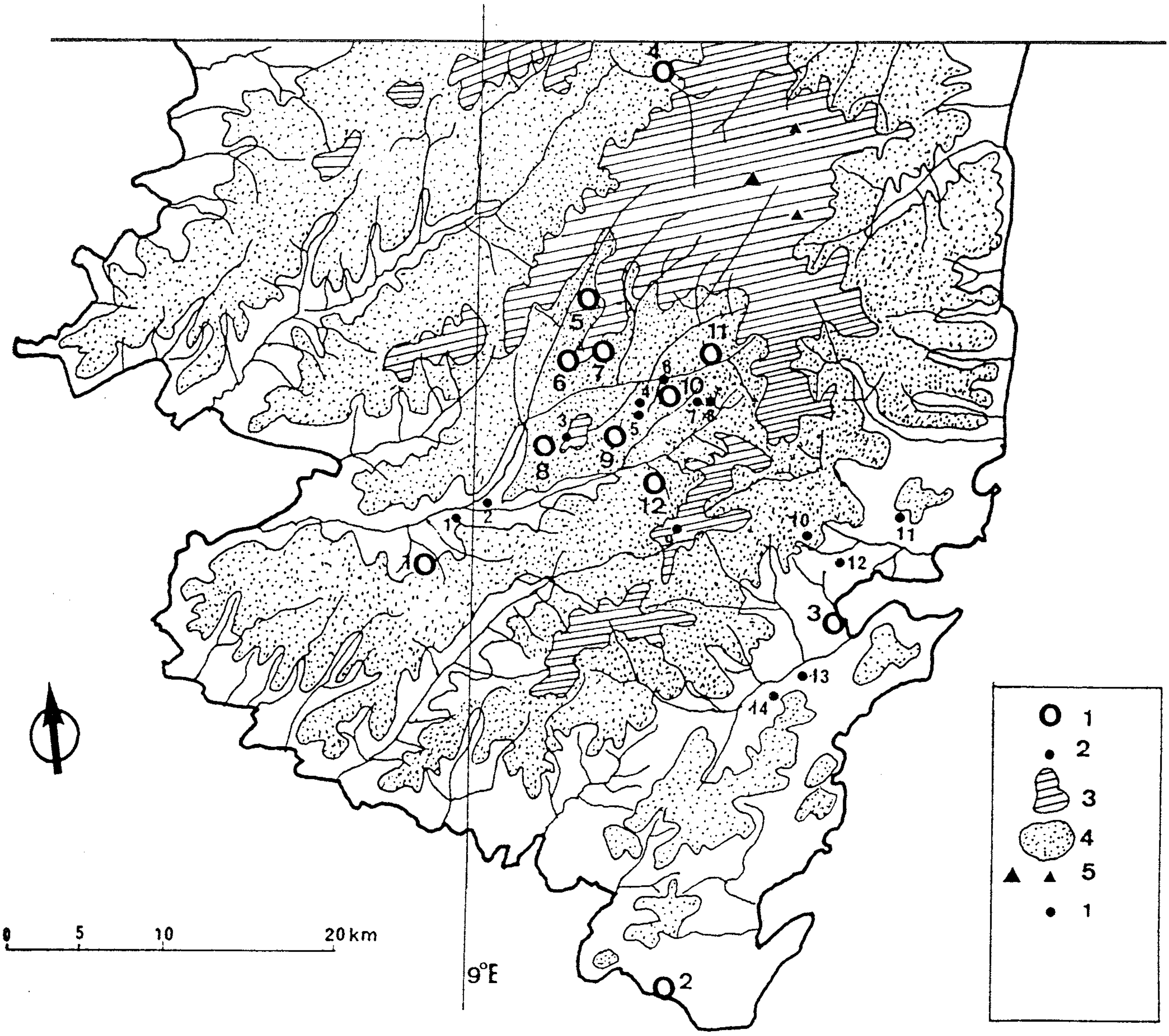

Fig. 3 : Connexions des nuraghi de la région de l'Alta Rocca : - 1 : agglomérations actuelles ; - 2 : casteddi et torre ; - 3 : au-dessus de 600 m ; - 4 : de 200 à 600 m - 5 : Les agglomérations : 1- Sartène ; 2- Bonifacio ; 3- Porto-Vecchio ; 4- Zicavo ; 5-Aullène ; 6- Zirubia ; 7- Serra-di- Scopamena ; 8- Santa-Lucia-di-Tallà-, 8- Levie ; 10- San-Gavino-di-Carbini ; 11- Zonza ; 12- Carbini. Les casteddi : 1- Pozzone ; 2- Furcina ; 3- Tusiu ; 4- Cucuruzzu ; 5- Capula ; 6- Sadisè ; 7-Evini ; 8- Milaonu ; 9- Meda ; 10- Araghju ; 11 - Valle ; 12- Torre ; 13- Ceccia ; 14- Tappa.

Chronologie BP	Date de l'émergence de la culture (av. J.-C.)	Date des premiers témoignages du déclin de la culture (av. J.-C.)	Cultures
3700	2080	1740-1690	Bronze ancien
3450 à 3150 / 3050	1740-1690	1430-1410 / 1370-1260	Bronze moyen
3150 / 3050 à 2850	1430-1410 / 1370-1260	1110 / 980	Bronze récent
2850 à 2650	1110-980	800	Bronze final
2650 à 2100	800	660-420	Age du Fer

Tab. V : Le cadre chronologique de l'Age du Bronze de Cucuruzzu.

Ainsi la restitution de l'histoire de chaque torre repose sur des assises relativement solides accompagnées de datations confirmant la rupture sociale qui se produit à la charnière Bronze moyen-Bronze récent. S'ouvre alors un nouveau chapitre, celui de la recherche que vient d'ouvrir l'ensemble des confirmations radiométriques.

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TOWARDS UNDERSTANDING THE LATE NEOLITHIC AND THE CHALCOLITHIC IN THE IONIAN ISLANDS, WESTERN GREECE : ^{14}C evidence from the "Cave of Drakaina", Poros, Cephalonia

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Abstract : Recent archaeological investigations, still in progress, of the prehistoric deposits of the "Cave of Drakaina" at Poros on Cephalonia has contributed significantly to the enrichment of our data concerning the prehistory in this region. These data combined with the radiocarbon results of stratigraphically controlled charcoal samples, actually permit the establishment of a safe chronological framework for the early phases of the Late Prehistory in the Ionian region, more precisely for the periods belonging, according to the conventional archaeological terminology, to the Late Neolithic (or Late Neolithic I) and Chalcolithic (or Late Neolithic II or Final Neolithic). In this way, more knowledge is acquired concerning the late phases of the Neolithic in Western Greece, which are still rather unknown.

Résumé : Les recherches en cours sur les dépôts préhistoriques de la "Grotte de Drakaina" de la commune de Poros, île de Cephalonia, ont contribué considérablement à l'enrichissement de nos données concernant la préhistoire de la region. Les résultats de datations par le radiocarbone des échantillons de charbon contrôlés stratigraphiquement, permettent actuellement l'établissement d'un cadre chronologique bien déterminé pour les phases initiales de la Préhistoire Récente dans la région des îles Ioniennes, plus précisement pour les périodes qui appartiennent, selon la terminologie archéologique traditionnelle, au Néolithique Récent (ou Néolithique Récent I) et au Chalcolithique (ou Néolithique Récent II ou Néolithique Final). De cette façon, on précise ainsi les connaissances sur les dernières phases du Néolithique à l'Ouest de la Grèce, phases qui sont mal connues jusqu'à présent.

Key-words : Late Neolithic, Chalcolithic, Ionian islands, Cave of Drakaina, Poros, Cephalonia, Greece, Radiocarbon dating.

Mots-cles : Néolithique Récent, Chalcolithique, Iles Ioniènnes, Grotte de Drakaina, Poros, Cephalonia, Grèce, datations par le radiocarbone.

INTRODUCTION

Our knowledge about the prehistory of the Ionian islands remained, till recently, relatively unknown (Sordinas, 1969 ; Demoule, 1994 ; Dousougli 1996a ; 1996b). The revival of interest in locating the Homeric Ithaca at the beginnings of 1990's resulted in a certain number of new archaeological investigations being undertaken by various institutions, mainly on the central complex of the Ionian islands (Cephalonia, Ithaca and Lefkas). Their results seem to shape a new archaeological landscape for the Prehistory of that region. The "Cave of Drakaina" will play an important role in promoting the knowledge and research concerning the early phases of Late Prehistory in the Ionian Sea, and W. Greece in general (Chatziotou *et al.*, 1995 ; Chatziotou and Stratouli, in press ; Stratouli, in press). The recent interdisciplinary research of its prehistoric deposits and especially the radiocarbon dating results progressively establish a secure chronological framework for the Late Neolithic, the Chalcolithic and the early phases of the Bronze Age (^{14}C dates ca. 5500 - 2400 BC ; table 1 ; fig. 6).

THE SITE

The "Cave of Drakaina", being out of sight and with difficult access nowadays, became known to the scientific community in 1992. Since then, the site is being excavated systematically under the responsibility of the Ephory of Palaeoanthropology-Speleology, Greek Ministry of Culture. The cave is located at an altitude of 70 m on the southern steep side of the gorge named "Steno" in the municipality of Poros (38° 9' N Lat, 20° 46' Long), on the south-eastern coast of the island of Cephalonia (fig. 1). Today it has developed into the form of a rock shelter, whereas during its geological past it might have been a

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LAB CODE	TRENCH	DATE OF SAMPLING	$\delta^{13}C$ (‰)	AGE (yr BP)	CALIBRATED AGE
DEM-285	Square C4, Layer 5 Depth 1.23 m	2/10/1992	-25.00	4067 ± 181	2883 - 2344 BC (68.3%) 3075 - 2043 BC (95.4%)
DEM-284	Square C4, Layer 5 Depth 1.02 m	2/10/1992	-25.00	4533 ± 94	3366 - 3043 BC (68.3%) 3508 - 2918 BC (95.4%)
DEM-526	Square F4, Layer 6, Pass 4, Depth 1.22 m	9/6/1994	-25.00	5323 ± 55	4237 - 4042 BC (68.3%) 4326 - 3990 BC (95.4%)
DEM-630	Square F4, Layer 7, Pass 2 Depth 1.23 m	1/6/95	-25.00	6173 ± 33	5210 - 5058 BC (68.3%) 5221 - 4995 BC (95.4%)
DEM-629	Square F4, Layer 7, Pass 1 Depth 1.23 m	31/5/1995	-25.00	6298 ± 28	5266 - 5228 BC (68.3%) 5279 - 5148 BC (95.4%)
DEM-631	Square G3, Layer 3, Pass 1 Depth 0.76 m	23/5/1995	-25.00	5065 ± 74	3961 - 3777 BC (68.3%) 3992 - 3697 BC (95.4%)
DEM-632	Square G3, Layer 3, Pass 2 Depth 0.86 m	24/5/1995	-25.00	5822 ± 102	4797 - 4540 BC (68.3%) 4925 - 4459 BC (95.4%)
DEM-527	Square G4, Layer 5, Pass 1, Depth 0.82-0.83 m	8/6/1994	-25.00	4951 ± 45	3781 - 3693 BC (68.3%) 3900 - 3646 BC (95.4%)
DEM-628	Square G4 Layer, 6, Pass 1 Depth 0.99 m	10/6/1994	-25.00	6499 ± 66	5472 - 5329 BC (68.3%) 5563 - 5287 BC (95.4%)
DEM-633	Square G5, Layer 6, Pass 1 Depth 0.84 m	7/6/1995	-25.00	6388 ± 53	5417 - 5267 BC (68.3%) 5435 - 5242 BC (95.4%)

Table 1 : Summary of radiocarbon dates. The layers and depths of each sample are associated only with the corresponding square.

Fig. 1 : The map of Greece and the position of Poros on Cephalonia.

closed cave with a relatively narrow entrance. In its present condition it extends over an area of ca. 200 m^2 consisting of one open and two roofed areas (fig. 2), which have rich cultural deposits. During the recent fieldwork a surface of 64 m^2 has been excavated ranging to a depth between 0.50 to 1.70 m. The bedrock has not been reached yet on any side of the cave.

The archaeological fill consists of layers belonging to prehistoric and historical times (Chatziotou *et al.*, 1995 ; Stratouli, in press). They are separated by a distinct, archaeologically sterile thick layer consisting of red angular stones (fig. 3 : layer 3). This layer is the result of natural depositional processes which occurred during the extended period between the last prehistoric use of the cave, i.e. EBA II, and the beginning of its re-use in the historical period, i.e. from the end of the 7th - beginning of the 6th century BC, this time as a sanctuary.

THE DEPOSITS OF LATE NEOLITHIC AND CHALCOLITHIC

Most of the excavated prehistoric remains originate from deposits 80 cm thick in the western roofed area of the cave (fig. 2 : squares F3, F4, G3, G4, G5 ; fig. 3 : square F4). Their age span, based at present on 9 radiocarbon dated charcoal samples, which represent the majority of the different layers of the fill under discussion (fig. 3 : layers 4 - 7), ranges between 5510 and 3660 BC - according to the stratigraphy and the archaeological material the mentioned age limits are expected to expand in the future – (table 1). Using terms of conventional dating, the Late Neolithic (or LN I ; fig. 3 : layers 6 and 7), to which layers of relatively greater thickness are attributed, and the Chalcolithic (or LN II or Final Neolithic ; fig. 3 : layers 4 and 5), are represented. During this extended period of ca. 2000 yr the use of the cave was not continuous, according to stratigraphic observations. In the near future we have scheduled a re-examination of the stratigraphy aided by micromorphological studies and a parallel selective sampling for radiocarbon dating. We believe that this will contribute substantially to the establishment of a more secure chronological framework for the use of the cave and subsequently for the analysis and the synthesis of its archaeological record.

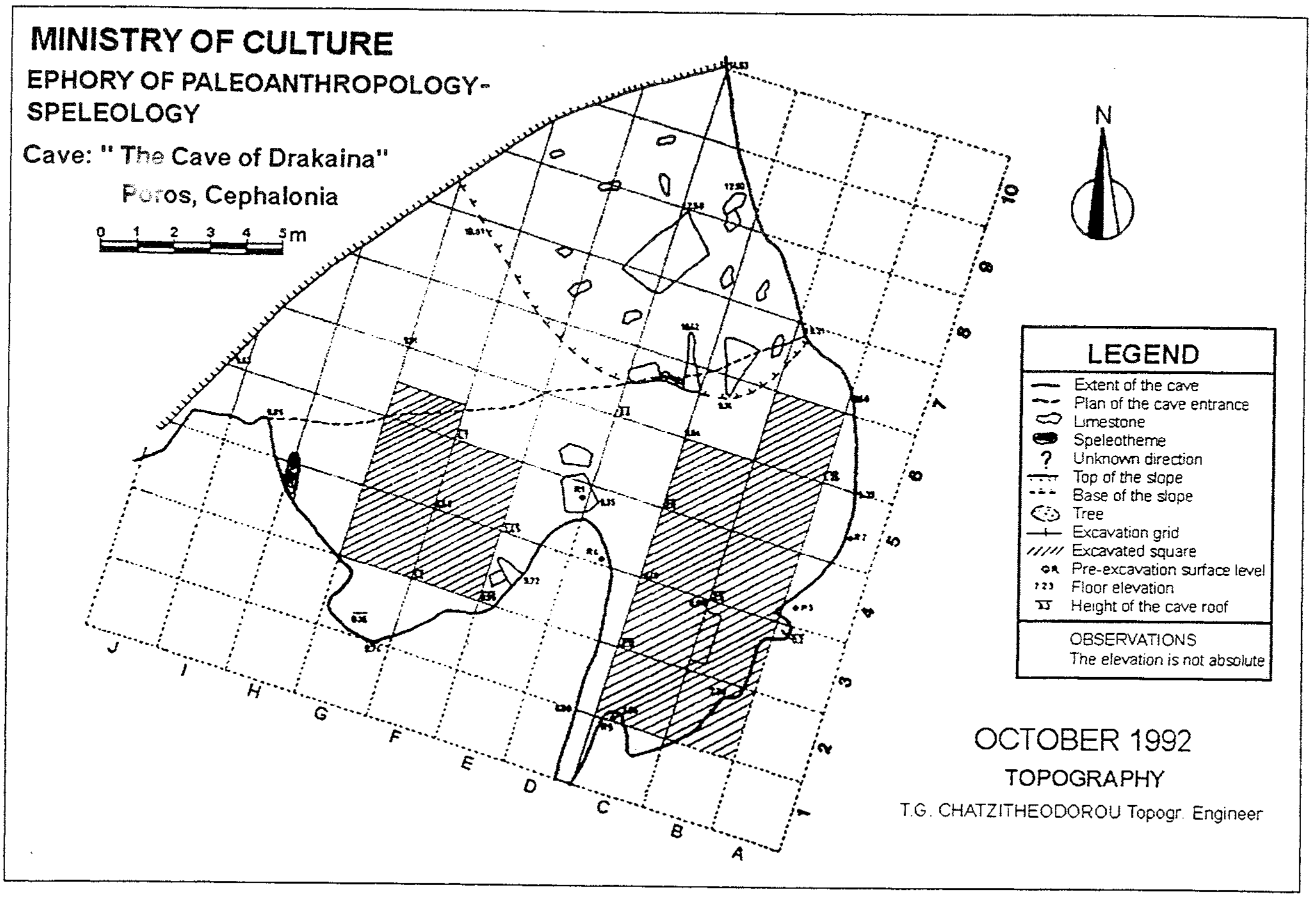
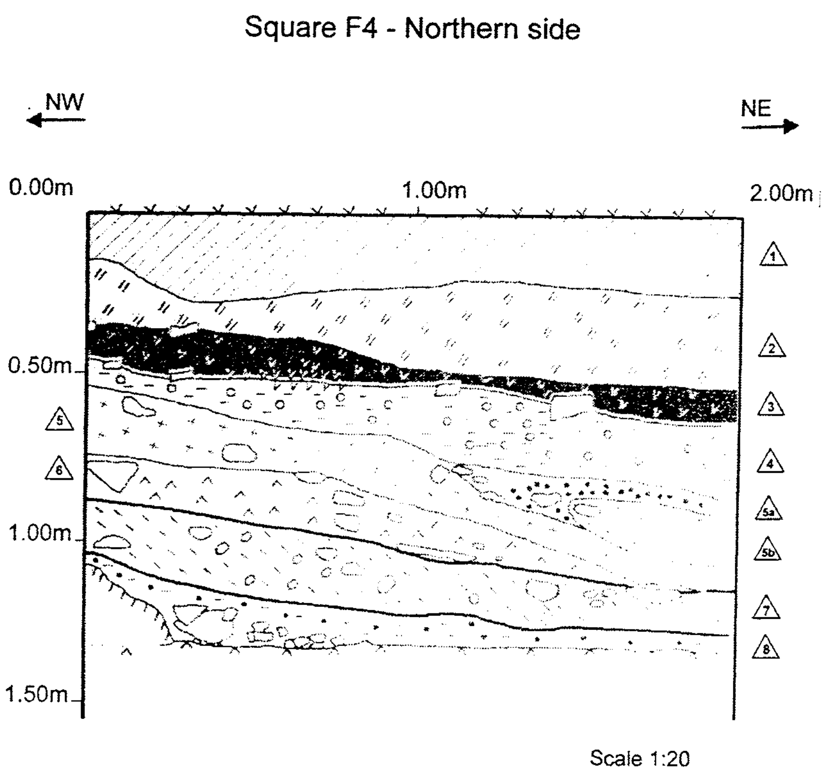


Fig. 2 : Plan of the "Cave of Drakaina", Poros, Cephalonia. The excavated areas are shown as hatched squares.



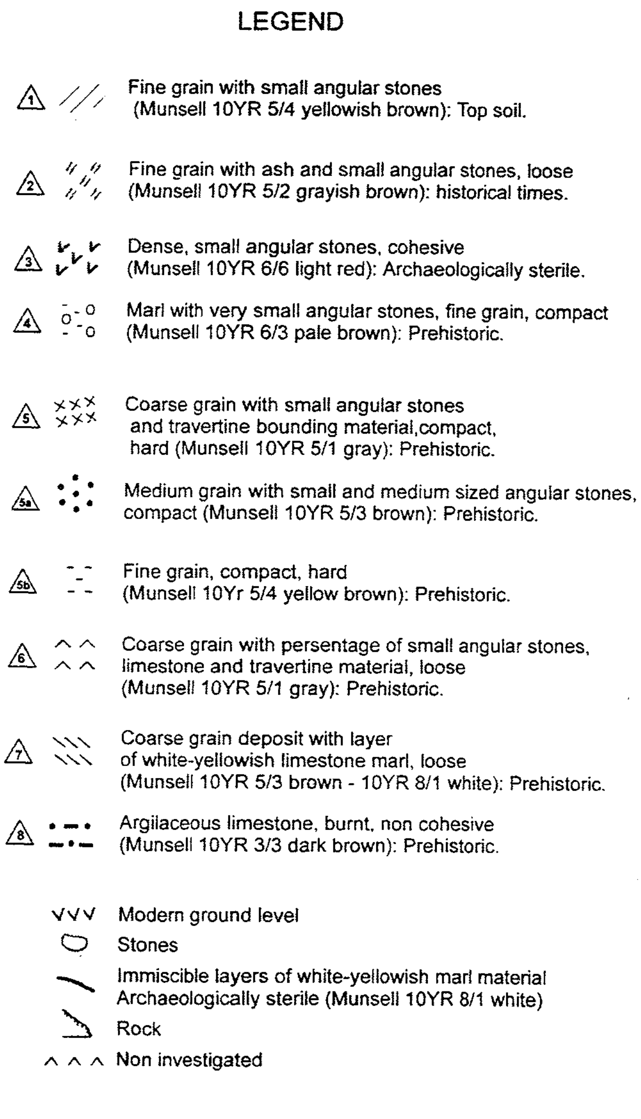


Fig. 3 : "Cave of Drakaina", Poros, Cephalonia. Stratigraphy of the square F4.

THE ARCHAEOLOGICAL MATERIAL

The deposits under discussion consist of successive "surfaces of use" with signs of anthropogenic activity of different intensity and/or diversified use. Small pits dated to the Chalcolithic (fig. 3 : layer 5) and hearths from the deposits of both Chalcolithic (fig. 3 : layers 4 and 5) and Late Neolithic period (fig. 3 : layer 6) have been unearthed, while remains of as yet unidentified wood and clay structures dated to the Late Neolithic are present (fig. 3 : layer 6). The deposits also contain palaeobotanic material (of which the study is still in progress) and dietary remains of domestic animals (sheep/goats, pigs and cattle), as well as of other species of hunted or collected animals (hares, deer, fishes and shells ; Chatziotou *and al.*, 1995, 58). They even contain great amounts of sherds, which belong mainly to utilitarian pottery (figs. 4-5) for the preparation and the consumption of food (e.g. coarse and semicoarse wares, monochrome, smoothed and burnished open and closed bowls in a variety of forms and sizes), as well as to storage vessels for solids and/or liquids in small quantities (e.g. pithoid vases with or without plastic decoration dated mostly to the Chalcolithic). Special categories of decorated pottery for other uses, such as fruitstands or bowls of the LN polychrome ware, bowls and "scoops" with incised and pointillé decoration dated to the Chalcolithic, are also represented in small quantities. The processing of the local flint in-situ was also established, while small quantities of flint (figs 4:1 ; 5:1) and obsidian tools have been discovered (e.g. blades, arrowheads). The obsidian artefacts were found mainly in layers belonging to the early phases of the Late Neolithic ; their diagnosed origin is Melos, an island of the Cyclades in the Aegean Sea. Finally, a few jewels made of stone and shells were also found.

Further systematic interdisciplinary research is still needed for the understanding of the character of the cave's use. However the available data indicate that the cave was used periodically or seasonally probably for short time intervals by small social groups aimed most likely at the promotion of specialized productive activities.

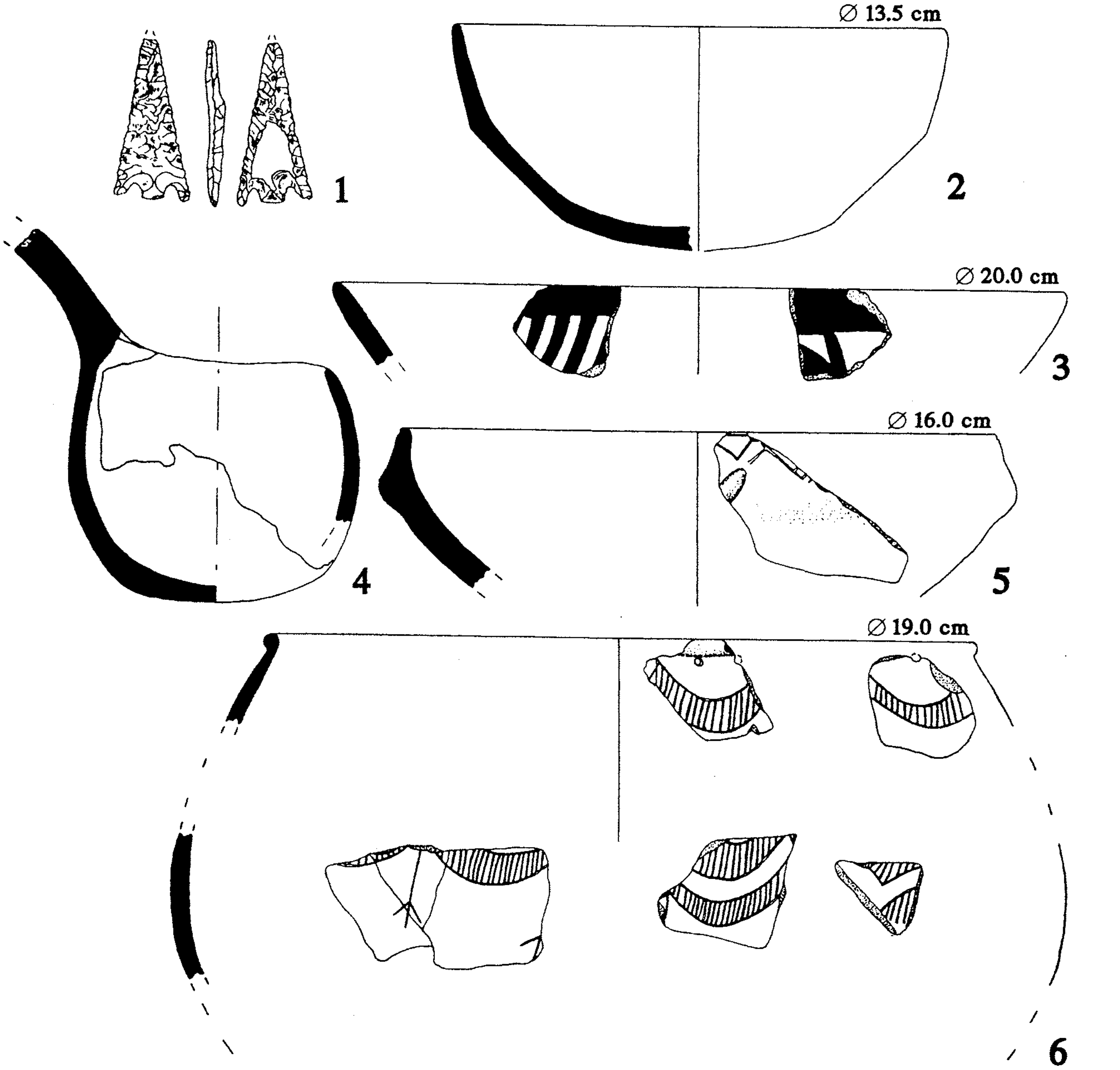


Fig. 4 : "Cave of Drakaina", Poros, Cephalonia. Late Neolithic. 1. Flint arrowhead from the square G4. 2-6. Pottery from the layers 6 and 7 of the square F4 : bowls (2-3, 5-6), scoop (4), burnished (2), painted (3), incised (6), with incised and plastic decoration (5).

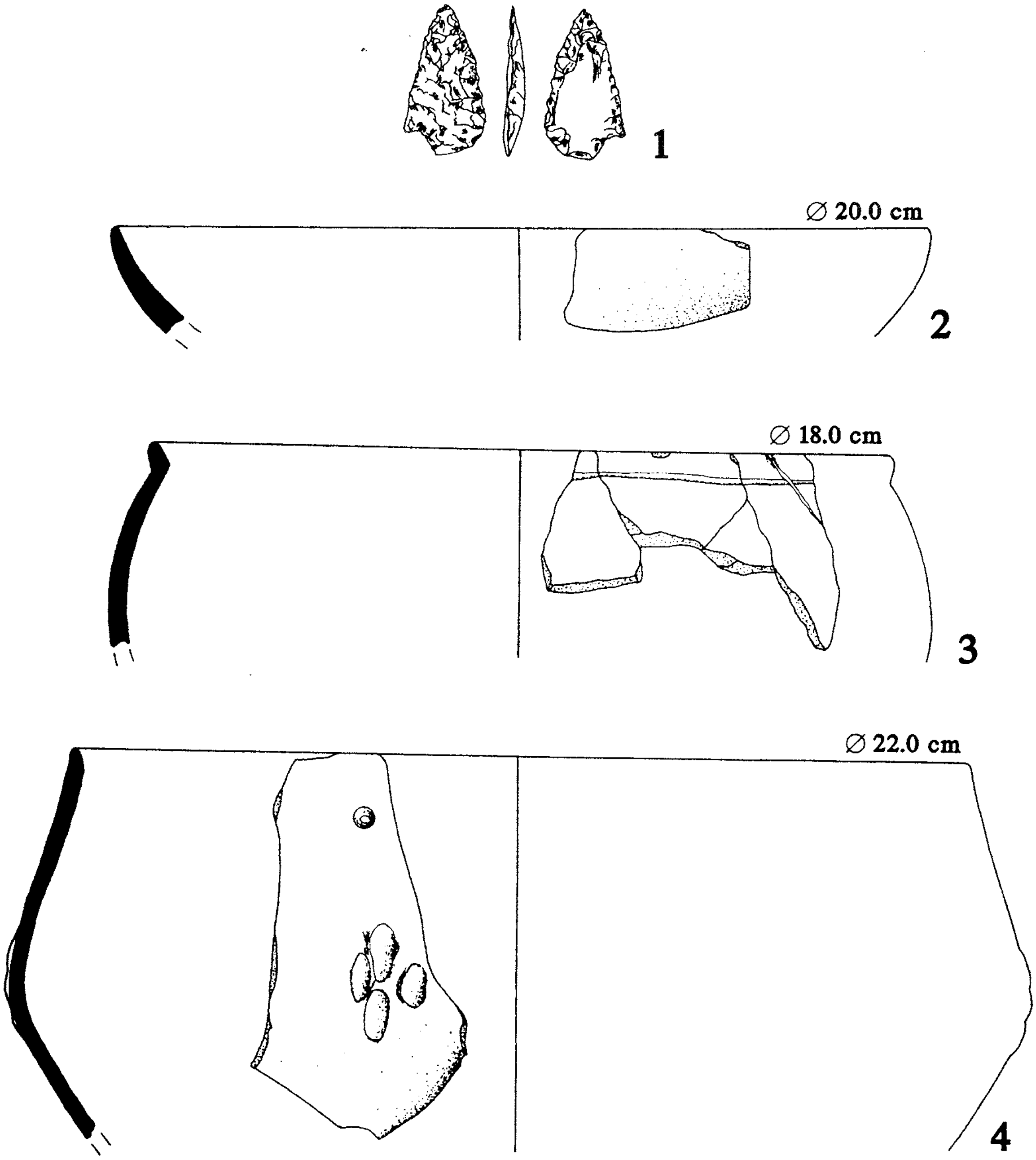


Fig. 5 : "Cave of Drakaina", Poros, Cephalonia. Chalcolithic. 1. Flint arrowhead from the layer 5 of the square F4. 2-4. Pottery from the layer 5 of the square F4 : bowls ; monochrome (2), incised (3), with plastic decoration (4).

WHAT'S NEW ABOUT THE "CAVE OF DRAKAINA" ?

The archaeological research in the "Cave of Drakaina" has produced for the first time absolute dates concerning the Late Neolithic and Chalcolithic in the region of the Ionian islands, spanning the range from ca. 5500 to 2400 BC (fig. 6). The securely stratified and dated remains of the cave deposits constitute a dynamic framework for the re-examination, chronological evaluation and the cultural accession of known, but still insufficiently documented, archaeological material of sites from the Ionian insular complex (e.g. Choirospilia in Lefkas : Velde, 1912 ; Goessler, 1927), as well as from the neighboring W. Greece (e.g. Agios Nikolaos Cave in Akarnania : Benton, 1947), but also of the remote S. Adriatic in the North and the coasts of the Patraic and Corinthian Gulf in the East (Chatziotou *et al.,* 1995 ; Chatziotou and Stratouli, in press). This way, new possibilities for the creation of work hypotheses and approaches are expected to result concerning the settlement patterns in the Ionian islands during the late phases of the Neolithic ; the potential productivity of their ecosystems : the communication networks and the character of the exchange between the islands and the mainland ; the time ; the causes and the form of movement of social groups ; their specific social symbolism ; and the socio-economic procedures at the end of the Stone Age and the dawn of the Bronze Age.

ACKNOWLEDGEMENTS

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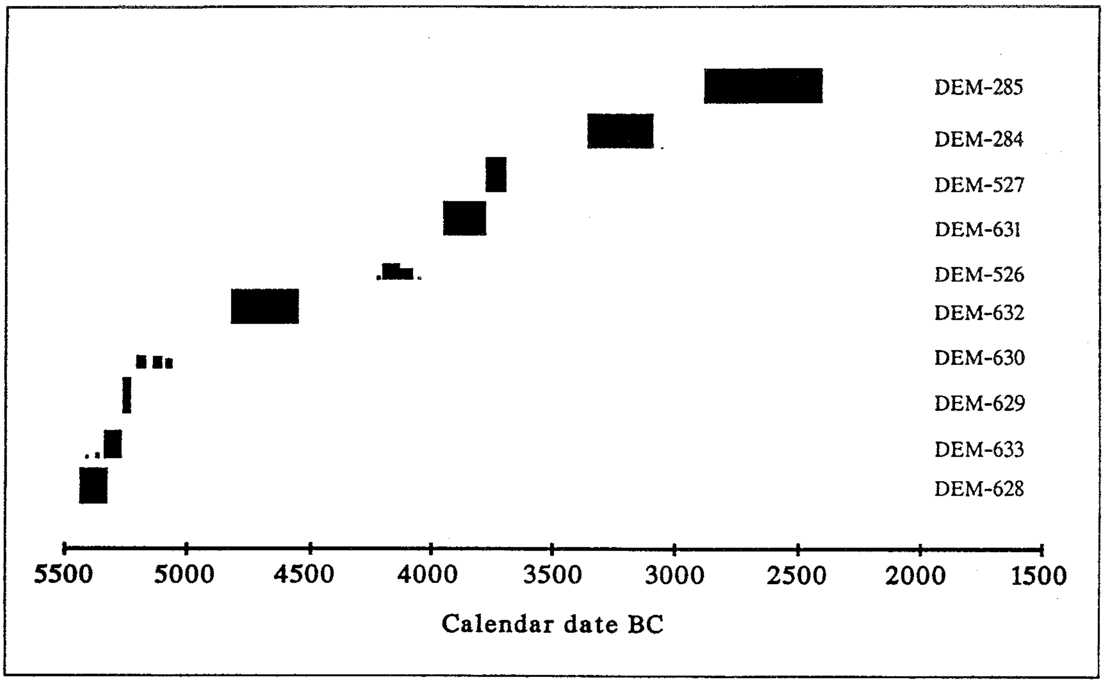

Fig. 6 : Calendar dates of charcoal samples from the "Cave of Drakaina" sorted by age. The length and the height of each bar represent the age range and the percent probability that the sample is in the specific range, respectively.

study of the data. Further, we thank the colleagues of the same institution the topographer engineer Mr. Th. Chatzitheodorou, the conservators Mr. P. Polidoropoulos and Mrs. P. Gioni and the draftsperson Mr. T. Vailas. Finally, we would like to thank the ex-authorities of the municipality of Poros and the prefect of Cephalonia-Ithaca Mr. G. Metaxas-Aggeletatos for their financial and moral support. Many thanks are also due to the director of the 6th Ephory of Classical and Prehistoric Antiquities of Patras, Mr. L. Kolonas for the support of the excavation by providing specialised technical staff.

APPENDIX : RADIOCARBON DATING METHOD

All the samples dated in this study consisted of small charcoal pieces. They were prepared for radiocarbon dating in the Laboratory of Archaeometry of the National Center for Scientific Research "Demokritos" in Athens using the procedure which has been described elsewhere (Facorellis *et al.*, 1997 ; Facorellis and Maniatis, 1999) and measured in gas proportional counters.

The results of all the samples are shown in table 1. The radiocarbon dates were calculated using $\delta^{13}C$ = -25 ‰ which is the usual value for the charcoal samples. They were calibrated using the computer program Calib Rev. 4.0 (Stuiver and Reimer, 1993 ; Stuiver *et al.*, 1998). The calendar dates are given with one and two standard deviations (probabilities of 68.3 % and 95.4 %, respectively). Figure 6 shows the calibrated age ranges of the samples sorted by age. The length and the height of each bar represent the age range and the percent probability that the sample is in the specific range, respectively.

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NEW EVIDENCE FOR THE CAVE DURING THE LATE NEOLITHIC PERIOD IN GREECE

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Abstract : Recent archaeological research showed that during the late part of the Late Neolithic I period (4800/700-4200 BC) and the early part of the Late Neolithic II period (4200-3800 BC) the use of the caves in Greece was very frequent. On the contrary, during the late part of the latter it reduces drastically, tending to an even more important attenuation during the Early Helladic I (transition from the Neolithic to the Chalcolithic period). Although the radiocarbon dates from the specific period are not numerous yet, they confirm the above observation and coincide at about the middle of the 4th millennium BC.

Résumé : Des recherches archéologiques récentes ont montré que pendant la dernière partie du Néolithique Récent I (4800/700-4200 BC) et la partie initiale du Néolithique Récent II (4200-3800 BC) l'usage des grottes par l'homme en Grèce était très fréquent. Au contraire, pendant la dernière partie du Néolithique Récent II la fréquence diminue considérablement, atténuant durant la période Helladique Initiale I (transition du Néolithique au Chalcolithique). Malgré que les dates par le radiocarbone appartenant spécifiquement à cette période ne soient pas encore nombreuses, elles confirment pourtant l'observation précédente et coïncident environ au milieu du 4ème millénaire avant J.-C.

Key-words : Cave occupation, Late Neolithic, Chalcolithic, transition, Greece, radiocarbon dates.

Mots-clés : Usage des grottes, Néolithique Récent, Chalcolithique, transition, Grèce, datations par le radiocarbone.

INTRODUCTION

It was believed, so far, that the caves in Greece were mainly inhabited during a period named the "Final Neolithic". This term, covering a time period as long as 1000 years, was introduced by Renfrew (1972) and followed by many archaeologists. However, there is much confusion about the age limits of that period, which cannot cover such a long time. During the last three decades, the archaeological research in neolithic sites has been multiplied and apart from good stratigraphical records we now possess series of radiocarbon ages which help us to re-evaluate the old theories.

For that purpose we will discuss ages of samples produced by the following Radiocarbon Laboratories :

1) Laboratory of Archaeometry of N.C.S.R. "Demokritos" at Athens, Greece, 2) Radiocarbon Laboratory of the University of Pennsylvania, USA, 3) Centre des Faibles Radioactivités at Gif-sur-Yvette, France, 4) Radiocarbon Laboratory of the Institute of Environmental Physics of the University of Heidelberg, Germany and 5) Dicar Corp and Dicarb Radioisotope Company, USA.

Some of the radiocarbon ages are presented for the first time and they are all converted to calendar dates uniformly using the latest high precision calibration curve INTCAL98 (Stuiver and Reimer, 1993 ; Stuiver *et al.*, 1998). The calibrated dates are reported in table 1 within 1σ and 2σ, probabilities of 68.3 % and 95.4 %, respectively, along with other related information (Laboratory code, name of the site, collection date, sampling location, type, name and institution of the submitter, $\delta^{13}C$ and conventional radiocarbon age of the sample). Figure 1 represents a map of Greece showing the archaeological sites mentioned in the text. Figure 2 represents the age span (within 1σ) of the sites based on the calibrated dates of the radiocarbon dated samples originating from the sites reported in table 1.

NEW EVIDENCE

Based on recent excavation works, as well as the study of the comparative and absolute chronology we have concluded that the Late Neolithic must be divided in two phases, the LN I and the LN II (fig. 2) (Sampson, 1990 ; Coleman, 1992). The first one includes the LN Ia which

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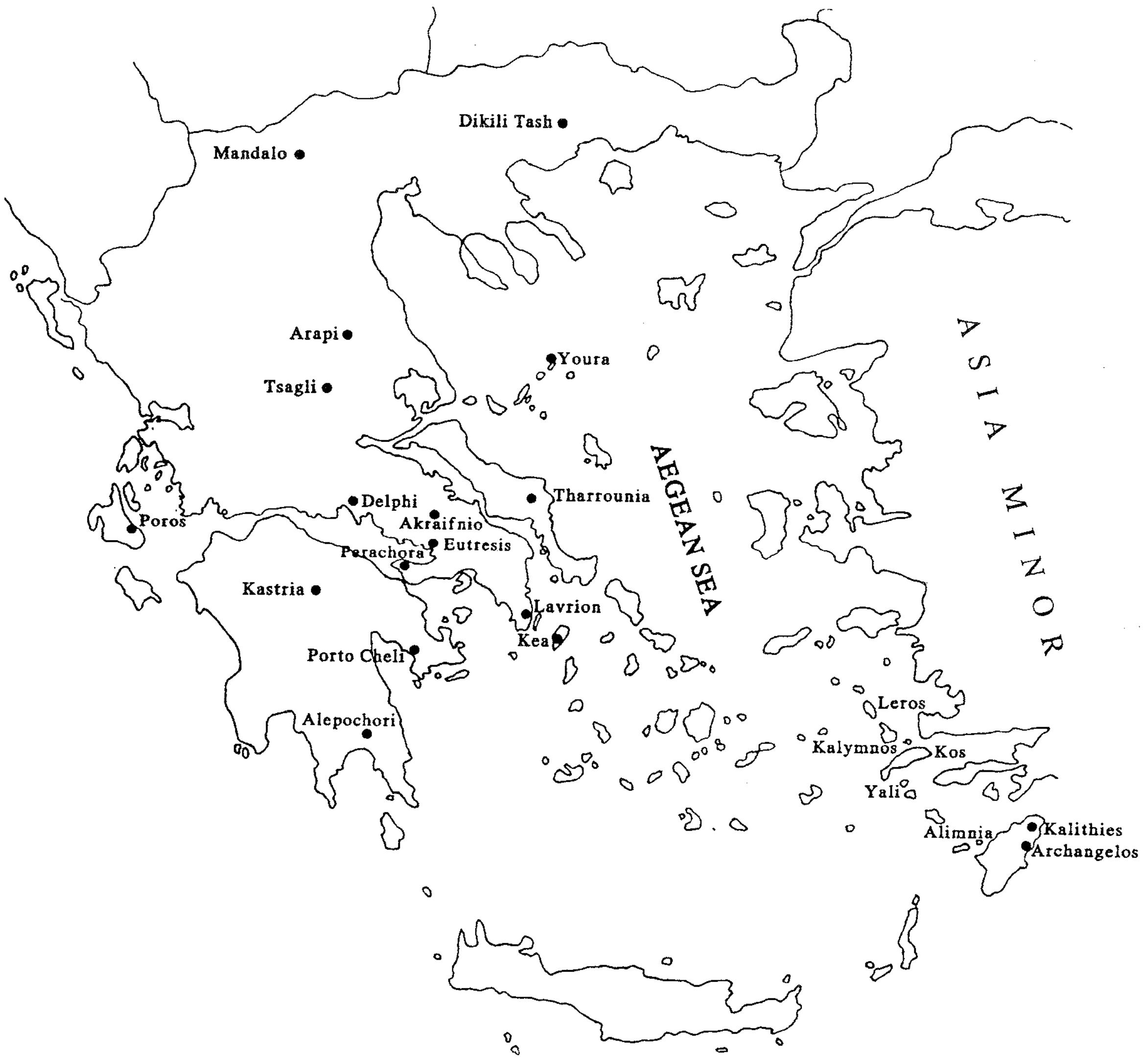

Fig. 1 : Map of Greece showing the archaeological sites mentioned in the text.

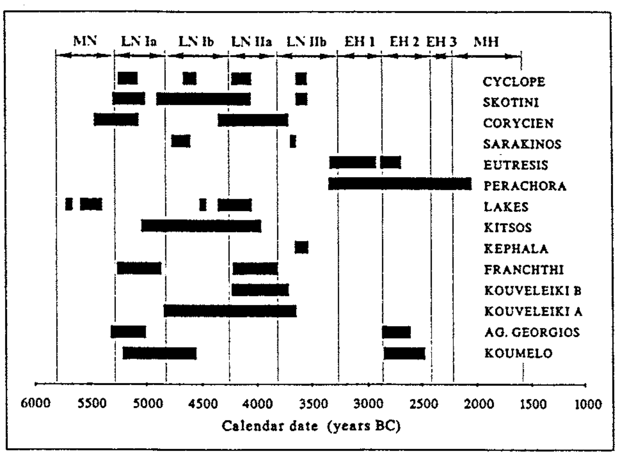

Fig. 2 : Age span (within 1σ) of the sites based on the calibrated dates of the radiocarbon dated samples.

corresponds to the phases Tsagli-Arapi in Thessaly (fig. 1) during which new ceramic forms (black and brown burnished and mattpainted ware) become abundant in the Helladic area. Its later part may be named LN Ib, which is a phase stratigraphically determined in the cave of Skotini at Tharrounia on Euboea (38° 31' N Lat., 23° 59' Long.) (Sampson, 1992, 1993). This phase has a relatively short duration and it is characterised by different ceramic forms, although the mattpainted wares still exist. Recently, LN Ib was also discovered in the cave of Lakes at Kastria, Peloponnese (38° 57' N Lat., 22° 08' Long.) (Sampson, 1997), the cave of Cyclope on Youra (39° 22′ N Lat., 24° 10′ Long.) (Sampson, 1996) and the cave of Sarakenos at Akraifnio in Boeotia (38° 28' N Lat., 23° 14' Long.) (figs. 1, 2) (Sampson, 1998), while by examining other excavated neolithic sites one may observe that the later part of LN I is present almost everywhere. The confusion is due to the fact that some researchers attribute this phase to the "Final Neolithic" and others to the Chalcolithic (Aslanis, 1993) trying to follow the standard chronology of Anatolia.

The LN II, which starts at the end of the 5th millennium BC, is characterised by the use of a new decorated ware, such as pattern burnished vessels. During this phase and also around its end new elements come from the area of the Aegean Sea, as well as from Asia Minor.

The inhabitation of caves seems much more common in the LN Ib and at the beginning of the LN II (LN IIa). We may say that this is the main period of inhabitation in caves. It is not coincidental that most of the radiocarbon dates from the cave of Skotini at Tharrounia, the two

Tab. 1 : ^{14}C results of the sites mentioned in the text.

LAB CODE	SITE	COLLECTION DATE	SAMPLING LOCATION	TYPE	SUBMITTED	$\delta^{13}C$ (‰)	AGE (years BP)	CALIBRATED AGE
P-1659	FRANCHTHI CAVE, PORTO CHELI, ARGOLIS (37° 26' N Lat., 23° 8' Long.)	1969	Area F/A, Unit 39, Depth 1.25-1.55 m	Charcoal with earth	T.W. Jacobson, Indiana Univ. M.H. Jameson Univ. of Pennsyl.	-	5163 ± 78	4040 – 3810 BC (68.3%) 4220 – 3780 BC (95.4%)
P-1660	FRANCHTHI CAVE, PORTO CHELI, ARGOLIS (37° 26' N Lat., 23° 8' Long.)	1969	F/A Balk, Unit 72 S, Depth 1.87-1.95 m	Charcoal with earth	T.W. Jacobson, Indiana Univ. M.H. Jameson Univ. of Pennsyl.	-	5261 ± 64	4220 – 3980 BC (68.3%) 4310 – 3960 BC (95.4%)
P-1630	FRANCHTHI CAVE, PORTO CHELI, ARGOLIS (37° 26' N Lat., 23° 8' Long.)	1969	F/A Balk, Unit 89 N, Depth 2.24-2.30 m	Charcoal with earth	T.W. Jacobson, Indiana Univ. M.H. Jameson Univ. of Pennsyl.	-	6110 ± 86	5210 – 4860 BC (68.3%) 5300 – 4780 BC (95.4%)
P-1661	FRANCHTHI CAVE, PORTO CHELI, ARGOLIS (37° 26' N Lat., 23° 8' Long.)	1969	F/A Balk, Unit 97 N, Depth 2.35-2.40 m	Charcoal with earth	T.W. Jacobson, Indiana Univ. M.H. Jameson Univ. of Pennsyl.	-	6156 ± 70	5260 – 4960 BC (68.3%) 5300 – 4850 BC (95.4%)
P-1920	FRANCHTHI CAVE, PORTO CHELI, ARGOLIS (37° 26' N Lat., 23° 8' Long.)	1971	F/A Balk, Unit 83S Dark reddish grey earth	Charcoal with earth	T.W. Jacobson, Indiana Univ.	-	6170 ± 60	5260 – 5000 BC (68.3%) 5300 – 4860 BC (95.4%)
P-1280	KEPHALA, KEOS (37° 42' N Lat., 24° 18' Long.)	1964		Carbonised beans	J.L. Caskey Univ. of Cincin.	-	4826 ± 56	3660 – 3530 BC (68.3%) 3710 – 3380 BC (95.4%)
P-317	EUTRESIS, SW THEBES, BOEOTIA (38° 17' N Lat., 23° 09' Long.)	1958	Habitation deposits, Trench A, West, Depth 1.17 m, Early Helladic II (Eutresis Group VIII)	Charcoal	J.L. Caskey Am. School of Classical Studies at Athens	-	4210 ± 64	2890 – 2690 BC (68.3%) 2910 – 2600 BC (95.4%)
P-307	EUTRESIS, SW THEBES, BOEOTIA (38° 17' N Lat., 23° 09' Long.)	1958	Habitation deposits, Depth 1.5 m, Early Helladic I (Eutresis Group III)	Charcoal	J.L. Caskey Am. School of Classical Studies at Athens	-	4440 ± 64	3330 – 2920 BC (68.3%) 3360 – 2910 BC (95.4%)
P-306	EUTRESIS, SW THEBES, BOEOTIA (38° 17' N Lat., 23° 09' Long.)	1958	Floor deposit in House L, Room III, Depth 2.5 m, Early Helladic I (Eutresis Group IV)	Charcoal	J.L. Caskey Am. School of Classical Studies at Athens	-	4450 ± 75	3340 – 2920 BC (68.3%) 3360 – 2900 BC (95.4%)
DIC-451	LAKE VOULIAGMENI, PERACHORA (38° 02' N Lat., 22° 53' Long.)	1972	Sample above thick destruction level	Charcoal	John Fossey McGill Univ. Montreal	-	4010 ± 105	2840 – 2350 BC (68.3%) 2870 – 2210 BC (95.4%)

LAB CODE	SITE	COLLECTION DATE	SAMPLING LOCATION	TYPE	SUBMITTED	$\delta^{13}C$ (‰)	AGE (years BP)	CALIBRATED AGE
P-2474	LAKE VOULIAGMENI, PERACHORA (38° 02' N Lat., 22° 53' Long.)	1972	Sample 2B, Trench AI, Level 5E Thick destruction level of final phase of Early Bronze II period bldg.	Charcoal	John Fossey McGill Univ. Montreal	-	4060 ± 60	2840 – 2490 BC (68.3%) 2870 – 2460 BC (95.4%)
DIC-449	LAKE VOULIAGMENI, PERACHORA (38° 02' N Lat., 22° 53' Long.)	1972	Sample above thick destruction level	Charcoal	John Fossey McGill Univ. Montreal	-	4270 ± 200	3310 – 2580 BC (68.3%) 3500 – 2310 BC (95.4%)
DIC-453	LAKE VOULIAGMENI, PERACHORA (38° 02' N Lat., 22° 53' Long.)	1972	Sample 2B, Trench AI, Level 5E Thick destruction level of final phase of Early Bronze II period bldg.	Charcoal	John Fossey McGill Univ. Montreal	-	4330 ± 210	3350 – 2630 BC (68.3%) 3630 – 2410 BC (95.4%)
Gif-2122	ANTRO CORYCIEN, PARNASSOS, DELPHI (38° 29' N Lat., 22° 30' Long.)	1971	70/02, Layer 2	Charcoal	N. Lambert, French School at Athens	-	5230 ± 290	4350 – 3710 BC (68.3%) 4690 – 3370 BC (95.4%)
Gif-2123	ANTRO CORYCIEN, PARNASSOS, DELPHI (38° 29' N Lat., 22° 30' Long.)	1971	70/01, Layer 3	Charcoal	N. Lambert, French School at Athens	-	6250 ± 90	5320 – 5060 BC (68.3%) 5470 – 4950 BC (95.4%)
Gif-2124	ANTRO CORYCIEN, PARNASSOS, DELPHI (38° 29' N Lat., 22° 30' Long.)	1971	71/03, Layer 3b	Charcoal	N. Lambert, French School at Athens	-	6380 ± 90	5470 – 5300 BC (68.3%) 5510 – 5080 BC (95.4%)
Gif-1610	GROTTE DE KITSOS, LAURION (37° 44' N Lat., 24° 2' Long.)	1968 - 1971	Kitsos 1610, Layer 3, Sounding 2 Hearth in homogeneous ashy layer corresponding to a dwelling level	Charcoal	N. Lambert, French School at Athens	-	5350 ± 200	4430 – 3960 BC (68.3%) 4580 – 3710 BC (95.4%)
Gif-1280	GROTTE DE KITSOS, LAURION (37° 44' N Lat., 24° 2' Long.)	1968 - 1971	Kitsos 335, Layer 3a, Sounding 1 Dwelling level	Charcoal	N. Lambert, French School at Athens	-	5470 ± 150	4460 – 4050 BC (68.3%) 4610 – 3970 BC (95.4%)
Gif-1670	GROTTE DE KITSOS, LAURION (37° 44' N Lat., 24° 2' Long.)	1968 - 1971	Kitsos 1830-31, Layer 4, Hearth Φ 3 Dwelling level	Charcoal	N. Lambert, French School at Athens	-	5550 ± 150	4550 – 4230 BC (68.3%) 4710 – 4040 BC (95.4%)
Gif-1832	GROTTE DE KITSOS, LAURION (37° 44' N Lat., 24° 2' Long.)	1968 - 1971	Kitsos 2/540, Layer 4 Fireplace	Charcoal	N. Lambert, French School at Athens	-	5650 ± 130	4670 – 4350 BC (68.3%) 4780 – 4250 BC (95.4%)
Gif-2541	GROTTE DE KITSOS, LAURION (37° 44' N Lat., 24° 2' Long.)	1972	Ref. B II, c 8, Level 7	Charcoal	N. Lambert, CNRS, Paris	-	5680 ± 150	4710 – 4350 BC (68.3%) 4900 – 4250 BC (95.4%)
Gif-1612	GROTTE DE KITSOS, LAURION (37° 44' N Lat., 24° 2' Long.)	1968 - 1971	Kitsos 1733, Layer 4, Sounding 2, Hearth Φ 2 Hearth in dwelling level	Charcoal	N. Lambert, French School at Athens	-	5700 ± 140	4710 – 4360 BC (68.3%) 4900 – 4250 BC (95.4%)
Gif-1729	GROTTE DE KITSOS, LAURION (37° 44' N Lat., 24° 2' Long.)	1968 - 1971	Kitsos 1826, Layer 4, Sounding 2	Charcoal	N. Lambert, French School at Athens	-	5750 ± 130	4770 – 4460 BC (68.3%) 4900 – 4340 BC (95.4%)

Kouveleiki caves at Alepochori in Laconia (36° 57' N Lat., 22° 46' Long.) (Kontaxi *et al.*, 1995 ; Deilaki, in press), the cave of Lakes at Kastria and the cave of Kitsos at Lavrion (37° 44' N Lat., 24° 2' Long.) (table 1, figs. 1, 2) characterise this period (Delibrias *et al.*, 1974, 1986). Furthermore, the inhabitation in some sites (Youra, Tharrounia, Kastria, Antro Corycien) (table 1, figs. 1, 2) in the LN Ib is longer in duration and intensity compared to the following LN IIa phase.

By examining the area of the Peloponnese, one can see that the number of the neolithic sites at the end of 5th and the beginning of the 4th millennium BC increases and the inhabitation becomes denser, particularly in caves (27 %) (Diamant, 1974). In the last years the interpretation of cave inhabitation or cave use has been the subject of many studies (Diamant, 1974 ; Sampson, 1992 ; Sampson, 1993). Whitehouse (1971) believes that during this time, when there was successful mixed economy, the inhabitation of caves was not necessary. However, this usually did not mean inhabitation, but instead the use of the caves for family or social relations. Diamant associates the increase of inhabitation in the LN I and LN II with the increase of cattle breeding and this may be in general acceptable. In the southern Peloponnese, where the use of the caves is more frequent, one cannot exclude the possibility that the rate of increase in the number of domesticated animals was greater due to pedological or climatological reasons. During the Late Neolithic caves may have had different uses. Their use as a habitat is a function of many factors, such as the environmental conditions, the size and the shape of their rooms, the opening and the orientation of the cave entrance. It seems that some caves were used either on a circumstantial or on a seasonal basis in those times (Sampson, 1985, 1992). Their use as a burial place is in general very frequent everywhere, while there are indications that they were also used as places for some kind of cult (cave of Skotini at Tharrounia). However, recent excavation works

LAB CODE	SITE	COLLECTION DATE	SAMPLING LOCATION	TYPE	SUBMITTED	$\delta^{13}C$ (‰)	AGE (years BP)	CALIBRATED AGE
Gif-2539	GROTTE DE KITSOS, LAURION (37° 44' N Lat., 24° 2' Long.)	1972	Ref. B I, b 7, Level 4	Charcoal	N. Lambert, CNRS, Paris	-	5840 ± 150	4900 – 4500 BC (68.3%) 5060 – 4360 BC (95.4%)
Gif-2538	GROTTE DE KITSOS, LAURION (37° 44' N Lat., 24° 2' Long.)	1972	Ref. B II, d 9, Level 3	Charcoal	N. Lambert, CNRS, Paris	-	5950 ± 150	5040 – 4620 BC (68.3%) 5250 – 4470 BC (95.4%)
HD-11342	CAVE OF KOUMELO, ARCHANGELOS, PHODES (36° 12' N Lat., 28° 8' Long.)	1979	Trench A, LAN 4	Charcoal with earth	A. Sampson Ephory of Cyclades	-25.91	4060 ± 95	2860 – 2470 BC (68.3%) 2880 – 2310 BC (95.4%)
HD-11329	CAVE OF KOUMELO, ARCHANGELOS, PHODES (36° 12' N Lat., 28° 8' Long.)	1979	Trench B, LAN 3	Charcoal with earth	A. Sampson Ephory of Cyclades	-25.24	5960 ± 220	5210 – 4550 BC (68.3%) 5370 – 4350 BC (95.4%)
HD-11343	CAVE OF AGHIOS GEORGIOS, KALITHIES, PHODES (36° 20' N Lat., 28° 10' Long.)	1980	Trench A, Layer 4, LAN 4	Charcoal with earth	A. Sampson Ephory of Cyclades	-24.42	4160 ± 50	2878 – 2605 BC (68.3%) 2885 – 2577 BC (95.4%)
HD-11345	CAVE OF AGHIOS GEORGIOS, KALITHIES, PHODES (36° 20' N Lat., 28° 10' Long.)	1980	Trench A, Layer 1	Charcoal with earth	A. Sampson Ephory of Cyclades	-23.41	6220 ± 125	5320 – 5000 BC (68.3%) 5470 – 4810 BC (95.4%)
DEM-521	CAVE OF CYCLOPE YOURA, N. SPORADES (39° 22' N Lat., 24° 10' Long.)	5/7/1995	Trench C/East, Layer 14, Square 9 Depth 2.03 – 2.13 m	Charcoal	A. Sampson Ephory of Cyclades	-25.00	4815 ± 25	3646 – 3537 BC (68.3%) 3651 – 3530 BC (95.4%)
DEM-267	CAVE OF CYCLOPE YOURA, N. SPORADES (39° 22' N Lat., 24° 10' Long.)	3/7/1992	Trench B, Layer 7, Squares (1-4) Depth 1.18 m	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5311 ± 35	4226 – 4044 BC (68.3%) 4241 – 4000 BC (95.4%)
DEM-345	CAVE OF CYCLOPE YOURA, N. SPORADES (39° 22' N Lat., 24° 10' Long.)	5/7/1993	Trench C/West, Layer 5, Squares (1-4) Depth 0.80 – 0.90 m	Sea shells	A. Sampson Ephory of Cyclades	1.00	6731 ± 38	5225 – 5067 BC (68.3%) 5273 – 5018 BC (95.4%)
DEM-525	CAVE OF CYCLOPE YOURA, N. SPORADES (39° 22' N Lat., 24° 10' Long.)	5/7/1995	Trench C/East, Layer 14, Square 9 Depth 2.03 – 2.13 m	Sea shells	A. Sampson Ephory of Cyclades	2.55	6755 ± 34	5248 – 5131 BC (68.3%) 5286 – 5048 BC (95.4%)
DEM-104	CAVE OF SKOTINI THARROUNIA, EUBOEA (38° 31' N Lat., 23° 59' Long.)	1986	Trench A, Layer 6, Square 4 Depth 0.80 m	Charcoal	A. Sampson Ephory of Cyclades	-25.00	4812 ± 42	3648 – 3533 BC (68.3%) 3692 – 3390 BC (95.4%)

LAB CODE	SITE	COLLECTION DATE	SAMPLING LOCATION	TYPE	SUBMITTED	$\delta^{13}C$ (‰)	AGE (years BP)	CALIBRATED AGE
DEM-106	CAVE OF SKOTINI THARROUNIA, EUBOEA (38° 31' N Lat., 23° 59' Long.)	1986	Trench A, Layer 13, Square 3 Depth 1.80-1.90 m Floor surface	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5564 ± 276	4710 – 4050 BC (68.3%) 5040 – 3790 BC (95.4%)
DEM-107	CAVE OF SKOTINI THARROUNIA, EUBOEA (38° 31' N Lat., 23° 59' Long.)	8/1988	Trench A, Layer 15 Depth 1.95-2.00 m Floor surface with hearth	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5658 ± 54	4550 – 4400 BC (68.3%) 4610 – 4360 BC (95.4%)
DEM-113	CAVE OF SKOTINI THARROUNIA, EUBOEA (38° 31' N Lat., 23° 59' Long.)	8/1988	Trench A, Layer 21 Depth 2.75 m, Floor surface underlying hearth deposits	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5706 ± 64	4670 – 4460 BC (68.3%) 4770 – 4360 BC (95.4%)
DEM-143	CAVE OF SKOTINI THARROUNIA, EUBOEA (38° 31' N Lat., 23° 59' Long.)	8/1990	Trench C, Layer 24, Squares (5-6) Depth 3.20 m Floor surface with hearth	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5738 ± 39	4671 – 4503 BC (68.3%) 4707 – 4461 BC (95.4%)
DEM-103	CAVE OF SKOTINI THARROUNIA, EUBOEA (38° 31' N Lat., 23° 59' Long.)	8/1988	Trench A, Layer 12 Depth 2.75 m, Floor surface underlying hearth deposits	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5769 ± 89	4710 – 4510 BC (68.3%) 4830 – 4400 BC (95.4%)
DEM-138	CAVE OF SKOTINI THARROUNIA, EUBOEA (38° 31' N Lat., 23° 59' Long.)	1986	Trench A, Layers 4-5, Square 8 Depth 0.50-0.65 m Disturbed burial	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5817 ± 37	4768 – 4617 BC (68.3%) 4775 – 4549 BC (95.4%)
DEM-144	CAVE OF SKOTINI THARROUNIA, EUBOEA (38° 31' N Lat., 23° 59' Long.)	8/1990	Trench C, Layer 14, Square 2 Depth 2.00 m Dark sediment with angular stones and hearths	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5935 ± 69	4900 – 4720 BC (68.3%) 4990 – 4620 BC (95.4%)
DEM-145	CAVE OF SKOTINI THARROUNIA, EUBOEA (38° 31' N Lat., 23° 59' Long.)	8/1988	Trench A, Layer 16, Squares (1-2) Depth 2.15 m, Hearth deposit in reddish occupation layer	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5961 ± 40	4903 – 4781 BC (68.3%) 4933 – 4726 BC (95.4%)
DEM-105	CAVE OF SKOTINI THARROUNIA, EUBOEA (38° 31' N Lat., 23° 59' Long.)	1986	Trench A, layer 5, Square 7 Depth 0.50-0.65 m	Charcoal	A. Sampson Ephory of Cyclades	-25.00	6151 ± 43	5208 – 5000 BC (68.3%) 5259 – 4863 BC (95.4%)
DEM-136	CAVE OF SKOTINI THARROUNIA, EUBOEA (38° 31' N Lat., 23° 59' Long.)	8/1990	Trench C, Layer 28, Squares (3-4) Depth 3.70 m Thick hearth deposit	Charcoal	A. Sampson Ephory of Cyclades	-25.00	6163 ± 36	5225 – 5043 BC (68.3%) 5259 – 4962 BC (95.4%)
DEM-137	CAVE OF SKOTINI THARROUNIA, EUBOEA (38° 31' N Lat., 23° 59' Long.)	8/1990	Trench C, Layer 30, Square 4 Depth 3.90-4.00 m Thick hearth deposit	Charcoal	A. Sampson Ephory of Cyclades	-25.00	6247 ± 49	5299 – 5081 BC (68.3%) 5318 – 5056 BC (95.4%)
DEM-550	CAVE OF LAKES KASTRIA, KALAVRYTA (38° 57' N Lat., 22° 08' Long.)		Trench C2, Layer 10 Depth 1.95-2.10 m	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5312 ± 29	4223 – 4045 BC (68.3%) 4245 – 4002 BC (95.4%)
DEM-549	CAVE OF LAKES KASTRIA, KALAVRYTA (38° 57' N Lat., 22° 08' Long.)		Trench C, Layer 9 Depth 1.85-1.95 m	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5396 ± 27	4325 – 4173 BC (68.3%) 4333 – 4054 BC (95.4%)

LAB CODE	SITE	COLLECTION DATE	SAMPLING LOCATION	TYPE	SUBMITTED	δ13C (‰)	AGE (years BP)	CALIBRATED AGE
DEM-344	CAVE OF LAKES KASTRIA, KALAVRYTA (38° 57' N Lat., 22° 08' Long.)		Trench B1, Layer 3 Depth 0.80-1.00 m	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5439 ± 45	4339 – 4248 BC (68.3%) 4356 – 4165 BC (95.4%)
DEM-394	CAVE OF LAKES KASTRIA, KALAVRYTA (38° 57' N Lat., 22° 08' Long.)		Trench C, Layer 22 Depth 3.80-3.85 m	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5444 ± 105	4440 – 4060 BC (68.3%) 4460 – 4000 BC (95.4%)
DEM-270	CAVE OF LAKES KASTRIA, KALAVRYTA (38° 57' N Lat., 22° 08' Long.)		Trench A2, Layer 13 Depth 1.85-1.95 m	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5447 ± 29	4338 – 4252 BC (68.3%) 4346 – 4246 BC (95.4%)
DEM-271	CAVE OF LAKES KASTRIA, KALAVRYTA (38° 57' N Lat., 22° 08' Long.)		Trench A2, Layer 16 Depth 2.30-2.35 m	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5484 ± 34	4356 – 4258 BC (68.3%) 4442 – 4248 BC (95.4%)
DEM-395	CAVE OF LAKES KASTRIA, KALAVRYTA (38° 57' N Lat., 22° 08' Long.)		Trench C, Layer 28 Depth 4.80-4.90 m	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5657 ± 32	4522 – 4456 BC (68.3%) 4548 – 4373 BC (95.4%)
DEM-272	CAVE OF LAKES KASTRIA, KALAVRYTA (38° 57' N Lat., 22° 08' Long.)		Trench A2, Layer 21 Depth 3.54-3.60 m	Charcoal	A. Sampson Ephory of Cyclades	-25.00	6528 ± 55	5600 – 5390 BC (68.3%) 5610 – 5370 BC (95.4%)
DEM-672	CAVE OF SARAKENOS AKRAIFNIO, BOEOTIA (38° 28' N Lat., 23° 14' Long.)	10/10/1994	Trench A, Layer 7, Square 6 Depth 1.40 m Dark brown sediment with grey spots	Charcoal	A. Sampson Ephory of Cyclades	-25.00	4873 ± 48	3700 – 3640 BC (68.3%) 3763 – 3535 BC (95.4%)
DEM-671	CAVE OF SARAKENOS AKRAIFNIO, BOEOTIA (38° 28' N Lat., 23° 14' Long.)	10/10/1994	Trench A, Layer 7, Square 3 Depth 1.40 m Dark brown sediment with Gary spots	Charcoal	A. Sampson Ephory of Cyclades	-25.00	5820 ± 52	4770 – 4600 BC (68.3%) 4800 – 4540 BC (95.4%)
DEM-263	KOUVELEIKI CAVE A ALEPOCHORI, LAKONIA (36° 57' N Lat., 22° 46' Long.)	24/6/1992	Trench Z, No 3, Layer 2, Pass 3, Depth 1.40 m Compact sediment overlying a hearth	Charcoal	E. Stravopodi Ephory of Paleoant. and Spel.	-25.00	5076 ± 230	4220 – 3640 BC (68.3%) 4360 – 3370 BC (95.4%)
DEM-262	KOUVELEIKI CAVE A ALEPOCHORI, LAKONIA (36° 57' N Lat., 22° 46' Long.)	24/6/1992	Trench Z, No 2, Layer 2, Pass 3, Depth 1.40 m Compact sediment overlying a hearth	Charcoal	E. Stravopodi Ephory of Paleoant. and Spel.	-25.00	5640 ± 286	4840 – 4110 BC (68.3%) 5010 – 3810 BC (95.4%)
DEM-259	KOUVELEIKI CAVE A ALEPOCHORI, LAKONIA (36° 57' N Lat., 22° 46' Long.)	23/6/1992	Trench A4, Layer 2, Pass 4, Depth 0.50 m Fine loose ashy sediment with a lot of stones	Charcoal	E. Stravopodi Ephory of Paleoant. and Spel.	-25.00	5797 ± 115	4780 – 4500 BC (68.3%) 4910 – 4360 BC (95.4%)
DEM-261	KOUVELEIKI CAVE A ALEPOCHORI, LAKONIA (36° 57' N Lat., 22° 46' Long.)	18/9/1992	Trench Z, No 1, Layer 2, Pass 3, Depth 1.40 m Compact sediment overlying a hearth	Charcoal	E. Stravopodi Ephory of Paleoant. and Spel.	-25.00	5807 ± 53	4770 – 4550 BC (68.3%) 4800 – 4500 BC (95.4%)
DEM-264	KOUVELEIKI CAVE A ALEPOCHORI, LAKONIA (36° 57' N Lat., 22° 46' Long.)	24/6/1992	Trench A, Layer 2, Pass 4 Depth 1.37 m Compact coarse sediment with ash	Charcoal	E. Stravopodi Ephory of Paleoant. and Spel.	-25.00	5849 ± 112	4840 – 4550 BC (68.3%) 4960 – 4460 BC (95.4%)

LAB CODE	SITE	COLLECTION DATE	SAMPLING LOCATION	TYPE	SUBMITTED	δ13C (‰)	AGE (years BP)	CALIBRATED AGE
DEM-518	KOUVELEIKI CAVE A ALEPOCHORI, LAKONIA (36° 57' N Lat., 22° 46' Long.)	24/9/1994	Trench A3, Layer 3, Pass 4, Depth 0.48 m Fine loose sediment without stones	Charcoal	E. Stravopodi Ephory of Paleoant. and Spel.	-25.00	5881 ± 43	4798 – 4712 BC (68.3%) 4847 – 4621 BC (95.4%)
DEM-260	KOUVELEIKI CAVE A ALEPOCHORI, LAKONIA (36° 57' N Lat., 22° 46' Long.)	24/6/1992	Trench B2, No 1, Layer 2, Pass 5, Depth 0.50-0.60 m Fine grey sediment with many big stones	Charcoal	E. Stravopodi Ephory of Paleoant. and Spel.	-25.00	5885 ± 57	4830 – 4693 BC (68.3%) 4906 – 4596 BC (95.4%)
DEM-519	KOUVELEIKI CAVE A ALEPOCHORI, LAKONIA (36° 57' N Lat., 22° 46' Long.)	29/9/1994	Trench A3, Layer 4, Pass 5, Depth 0.52 m Wet fine relatively compact layer with a lot of organics in the region of hearths	Charcoal	E. Stravopodi Ephory of Paleoant. and Spel.	-25.00	5932 ± 28	4844 – 4736 BC (68.3%) 4900 – 4721 BC (95.4%)
DEM-604	KOUVELEIKI CAVE B ALEPOCHORI, LAKONIA (36° 57' N Lat., 22° 46' Long.)	12/6/1996	Square 3,20-3,30, Layer 6-6a, Pass 7, Depth 1.55-1.62 m	Bones	C. Kontaxi Ephory of Paleoant. and Spel.	-21.00	5017 ± 62	3940 – 3710 BC (68.3%) 3960 – 3660 BC (95.4%)
DEM-397	KOUVELEIKI CAVE B ALEPOCHORI, LAKONIA (36° 57' N Lat., 22° 46' Long.)	27/9/1993	#1509, No 2, Square 4,40, Layer 3, Pass 5, Depth 1.65 m Dark brown sediment	Charcoal	C. Kontaxi Ephory of Paleoant. and Spel.	-25.00	5198 ± 82	4220 – 3820 BC (68.3%) 4230 – 3800 BC (95.4%)
DEM-396	KOUVELEIKI CAVE B ALEPOCHORI, LAKONIA (36° 57' N Lat., 22° 46' Long.)	18/12/1993	#1509, No 3, Square 4,40, Layer 3, Pass 5, Depth 1.65 m Dark brown sediment	Charcoal	C. Kontaxi Ephory of Paleoant. and Spel.	-25.00	5263 ± 45	4219 – 3989 BC (68.3%) 4224 – 3974 BC (95.4%)
DEM-398	KOUVELEIKI CAVE B ALEPOCHORI, LAKONIA (36° 57' N Lat., 22° 46' Long.)	24/9/1993	#1508, No 1, Square 4,40, Layer 3, Pass 4, Depth 1.45 m Dark brown compact sediment	Charcoal	C. Kontaxi Ephory of Paleoant. and Spel.	-25.00	5320 ± 48	4229 – 4043 BC (68.3%) 4324 – 3992 BC (95.4%)

confirm that the caves were used, intensively or not, for the storage of goods, as it is suggested by the numerous pithoid vessels found and the excellent conditions for food preservation that prevailed in some of them (Sampson, 1992, 1997).

Diamant has suggested four interpretations for the use of the caves by humans : 1) population growth, 2) political turmoil or invasions, 3) erosion or depletion of the cultivated earth, and 4) climatic change. The population growth in the LN II has been confirmed. However, it is not necessarily associated with the inhabitation or the use of the caves, as there were plenty of fields for cultivation in plains or plateaux, whereas the caves were usually situated in inaccessible mountainous regions. The second interpretation has not been confirmed so far by the archaeological research, and as for the last two reasons, which have direct dependence on each other, there is no evidence up to now. However, one cannot rule out the possibility that a continuous and non-systematic use of the earth for two millennia could have depleted the soil obliging the population to seek and find alternative nutritional resources.

On the other hand, although there is a lot of debate concerning the magnitude of climatic changes (Pirazzioli *et al.*, 1982 ; Stiros, 1994), many recent palaeoclimatological studies tend to prove that the effect of the climate also played an important role (Flint, 1971 ; Psychoyos, 1988 ; Schultz, 1989). Today, we know that the important climatic changes, which occurred in the beginning of the 5th millennium BC, drastically affected the economy. This was a warm and dry period, during which the mean temperature was two degrees higher than today's mean and which probably had an unfavorable influence on the cultivation in the plains and obliged people to find shelter in the mountains, where there must have been more water reserves. Maybe this was the reason for the increase in the number of the animals bred and the specialisation in cattle breeding.

It is believed that the rainfall decrease and the temperature increase continued till the middle of the 4th millennium BC, when an important mean sea level rise of 3 m compared to the present mean is observed. However, recent archaeological research shows that the use of caves in the late part of the LN II is very sparse and became sparser in the following Early Helladic 1 (EH 1) period.

It is not yet known what caused neolithic people to decrease their visits to the caves and to stop storing their products inside. In some caves there was not much activity after the neolithic period. The number of the finds is very small from the Early Helladic (EH), Middle Helladic (MH) and Mycenian period, as well as in the historic times, which testifies sporadic visits for burials and cult. If we admit that the storage in the caves concerned more the products of cattle-breeding (milk, cheese, salt meat) than those of harvesting, the sparse use of the caves in the LN IIb maybe due to the reduced activity in cattle-breeding and the shift of the people towards intensive cultivation.

At the cave of Skotini at Tharrounia in Euboea (fig. 1), there is intensive inhabitation till the LN IIa, while during the LN IIb the human presence is very sparse. The final phase of inhabitation of that cave is determined by the radiocarbon age (3648-3533 BC) of a charcoal sample (DEM-104) (table 1, fig. 2), while during the same time the inhabitation of the settlement outside the cave becomes more intensive. The ages of the rest of the samples (DEM-106, -107, -113, -143, -103, -138, -144, -145, -136, -137) belong to the beginning and the middle of the 5th millennium BC (Facorellis, 1996).

At the cave of Lakes at Kastria (fig. 1), the inhabitation is intensive from the LN Ib till the beginning of the LN IIa, while during the final phase of the LN IIb the cave was not inhabited (table 1, fig. 2). The dates of the intensive inhabitation phase fluctuate from 4400 to 4100 BC (DEM-271, -270, -394, -344, -549), while the sample DEM-550 gave the younger date 4223-4045 BC (Facorellis and Maniatis, 1997). At the Antro Corycien (38° 29' N Lat., 22° 30' Long.) at Parnassos and the cave of Franchthi at Porto Cheli in Argolis (37° 26' N Lat., 23° 8' Long.) (fig. 1) the final phases of the Neolithic period are almost absent (table 1, fig. 2) (Lawn, 1971, 1974). However, a sample (Gif-2122 : Delibrias *et al.*, 1974) from the former gave a date of 4350-3710 BC (table 1). The cave of Cyclope on Youra represents a different situation since it is scarcely used during the whole LN II period. The most recent radiocarbon dates in the neolithic period from that cave are 4226-4044 BC (DEM-267) and 3646-3537 BC (DEM-521) (Facorellis *et al.*, 1998). The two caves of Kouveleiki (A and B) have also given dates belonging to the 4th millennium BC, DEM-263 : 4220-3640 BC, DEM-604 : 3940-3710 BC and DEM-397 : 4220-3820 BC (table 1) (Facorellis, 1996). In addition the cave of Franchthi also gave a date which falls in the same age range 4040-3810 BC (P-1659 : Lawn, 1971) (table 1, fig. 2).

An exception to the previous evidence is the cave of Sarakenos at Akraifnio in Boeotia (fig. 1), where during the excavation works (1994-96) thick layers belonging to the final phase of the Neolithic period (LN IIb) were found. Obviously, the local climatic and environmental conditions of that region, which are probably associated with the water level of the neighbouring lake, were the causes of the intensive use of that cave. The only radiocarbon date so far of that phase is 3700-3640 BC (DEM-672) (table 1, fig. 2). In the same cave finds belonging to the EH 2 and the MH period are present, while the EH 1 period is absent.

A few radiocarbon dates, belonging to the middle of the 4th millennium BC, from the cave of Cyclope on Youra and the cave of Skotini at Tharrounia (table 1, fig. 2), characterise the latest phase of the neolithic period during which the use of the caves becomes sparse. A sample (P-1280) from that phase from the rockshelter of Kephala on Keos (37° 42' N Lat., 24° 18' Long.) (Coleman, 1977) gave an equivalent date of 3660-3530 BC (table 1, fig. 2) (Stuckenrath and Lawn, 1969).

Theoretically, the following EH 1 phase begins at 3300-3200 BC and lasts till 2900-2800 BC. The radiocarbon ages of charcoal samples from Eutresis in south-western Thebes (38° 17' N Lat., 23° 09' Long.) (fig. 1) (Caskey, 1960) for that phase are 3330-2920 BC (P-307) and 3340-2920 BC (P-306) (table 1, fig. 2) (Ralph and Stuckenrath, 1962). For the same period two samples (DIC-449 and -453) from Perachora in the Lake Vouliagmeni (38° 02' N Lat., 22° 53' Long.) (fig. 1) gave comparable dates 3310-2580 BC and 3350-2630 BC (table 1, fig. 2) (Fishman and Lawn, 1978), respectively, although with a considerable age span. However, the EH 1 is a quite undetermined and rare phase even for open-air sites. This transitional period of the Late Neolithic and the beginning of the Chalcolithic (fig. 2) represent another phase of abandonment of the caves.

At the cave of Koumelo at Archangelos in Rhodes (36° 20' N Lat., 28° 10' Long.) (fig. 1) during the LAN 4 (Late Aegean Neolithic) the small amount of ceramic sherds shows a gradual abandonment. A radiocarbon age from this transitional phase (HD-11342 : 2860-2470 BC) is considered quite recent (table 1, fig. 2), implying that in isolated parts of the Dodecanese the latest neolithic phase of inhabitation probably had a longer duration overlapping the Early Bronze Age (EBA). In addition, a sample (HD-11343) from the cave of Aghios Georgios at Kalithies in Rhodes (36° 20' N Lat., 28° 10' Long.), where this phase is hardly present, gave a similar radiocarbon date of 2878-2605 BC (table 1, fig. 2). At the same time the inhabitation in open-air sites such as Yali (Sampson, 1988), Partheni in Leros, Alimnia and Kos (Sampson, 1987) becomes more intensive. In the Dodecanese inhabitation is observed in the end of the EBA in the cave of Aspri Petra on Kos (Levi 1925/26) and the cave of Vathi on Kalymnos.

CONCLUSIONS

Summarising, the inhabitation or use of the caves becomes more intensive in the later part of the LN I, as well as the early part of the LN II period, while at the end of that period (LN IIb) it decreases significantly. Furthermore, there is a trend for an even more significant decrease during the transitional EH 1 phase (fig. 2). On the contrary, the open-air sites of the same period are inhabited intensively. This is observed on the mainland of Greece, as well as the Aegean islands. This phenomenon is probably due to environmental causes and the change in economy at the end of the Neolithic period.

The radiocarbon dates that we have from the late part of LN I and the early part of LN II are abundant, but only a few concern the last phase of the Neolithic and the beginning of the EBA. If the archaeological record and the ^{14}C evidence suggest a small amount of interest in the occupation of most of the caves during LN IIb and the beginning of EBA in Greece, it does not mean that the Greek mainland was sparsely populated or totally uninhabited for six or seven centuries (3800/3700-3200/3100 BC) as Coleman argues (1999). The dates from Tharrounia, Youra, Sarakenos, Kouveleiki A and B, Poros Cephalonia (Stratouli *et al.*, this volume) belong to the 4[th] millennium BC and cover well this "hiatus", while the date from Kephala, Keos (P-1280 : 3660–3530 BC) (table 1, fig. 2) perfectly fits in the same period (Stuckenrath and Lawn, 1969 ; Coleman, 1977). However, Coleman would rather characterise the latter and the one from Tharrounia (DEM-104 : 3648–3533 BC) erroneously late (Sampson, 1993). An increase or decrease of population used to be a common explanation for the existence or non-existence of sites in every period, but the possibilities of research in the Greek area still have a promising future, and, given the low number of prehistoric sites excavated so far, it is considered premature to extract generalised conclusions. The hiatus during this period in Mandalo (Maniatis and Kromer, 1990) and Dikili Tash (Andreou *et al.*, 1996) in northern Greece (fig. 1) or the abandonment of the cave occupation at Kastria, Peloponnese (Sampson, 1997) are not adequate evidence to generalise for the whole of Greece. It seems that during LN IIb and EH 1 new open-air sites are occupied, usually small in extent, as we can judge from Euboea and Boeotia.

A major problem is the earliest stages of the EBA population of mainland Greece. In spite of the increase of sites in recent years (Cosmopoulos, 1991) most of the ceramic material comes from surface research, and serious problems remain in distinguishing between EH 1 and EH 2 sherds and in deriving reliable statistics from those. Even the dating of the beginning of EH 1 is quite uncertain and, though many scholars agree for a date around 3300-3200 BC, others prefer a higher date around 3600-3500 BC (Coleman, 1992 ; Warren, 1996). Neither is based on a series of ^{14}C dates, because, except for Eutresis and Perachora, we do not have other radiocarbon dates. Moreover, the lack of EH 1 occupation in the majority of Greece (Sampson, 1990, 1993a) is characteristic, and it would be preferable to speak about a hiatus in the transition between LN IIb and EH 2 rather than at the end of the Neolithic. Also the lack of real settlements during EH 1 is equally opposed to the theory of a migration of Indo-European speakers or "Proto-Greeks" from the Pontic-Caspian region, north and east of the Black sea, to Greece around 3400-3200 BC (Gimbutas, 1997 ; Antony, 1995 ; Coleman, 1999).

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CHRONOLOGIE DES AGES DES MÉTAUX DANS LA BASSE VALLÉE DU SEGRE (Catalogne, Espagne) A PARTIR DES DATATIONS ^{14}C

Natàlia ALONSO, Emili JUNYENT*, Angel LAFUENTE* et Joan B. LOPEZ**

Résumé : Les recherches sur la Protohistoire récemment développées dans la zone occidentale de la Catalogne ont confirmé que cette région connaît une évolution particulière au regard du reste du pays. En conséquence, la thèse jusqu'à présent admise d'une périodisation valable pour l'ensemble du nord-est ibérique est remise en cause et l'on propose ici un nouveau schéma chronologique.
Ce modèle régional rejette les périodes chronologiques abusivement fondées sur les «fossiles directeurs» et met l'accent sur d'autres paramètres, tels que l'évolution des stratégies économiques, l'organisation sociale, les pratiques funéraires et, particulièrement, l'évolution de l'habitat et de l'urbanisme qui en devient, de fait, le témoin archéologique le plus significatif.
Au plan méthodologique cette périodisation est fondée sur les datations par le radiocarbone calibrées. Pour l'exploitation de ces données on propose une démarche fondée sur les valeurs centrales des intervalles de probabilité maximale (jusqu'à 90 % de probabilité) exprimées à partir de la médiane. A cet égard, une réflexion et un consensus de l'ensemble de la communauté scientifique internationale sont attendus à propos des méthodes d'exploitation des dates calibrées.

Abstract : Recent researches on the Protohistory carried out on western Catalonia confirm a particular evolution of this region compared to the rest of the area. Consequently, the traditional chronological scheme for the northeastern part of Iberian is questioned in this paper and a new one proposed.
This regional model refuses chronological slices founded on «guiding fossils» to emphasize other parameters as the economic strategies, social organization, funeral practices and specially the settlement and urbanistical evolution wich are the clearest archaeological evidence of its singularity.
From the methodological point of view, this new periodization is founded on the calibrated radiocarbonical dates. In order to explotate these data, using the central values of maximal probability intervals (until 90 % minimum security), represented by the median, is put forward. A reflection and an accord of the international scientific community on the calibrated dates explotation methodes are also claimed here.

Mots-clés : Péridodisation, calibration, Protohistoire, Segre, Catalogne.

Key-words : Periodization, calibration, Protohistory, Segre river, Catalonia.

INTRODUCTION

Depuis les années 1990, le *Grup d'Investigacio Préhistorica* de l'Université de Lleida a engagé un programme de recherche et de révision concernant la Protohistoire, *lato sensu,* d'une région située dans la partie occidentale de la Catalogne dont l'identité et la singularité de l'évolution historique ont été soulignées depuis longtemps, surtout pour ce qui concerne le Bronze final (urbanisme précoce, nécropoles tumulaires,...). Toutefois, les caractéristiques et les causes précises de ce phénomène demeuraient encore méconnues.

Dans le cadre de ce projet, de nouvelles fouilles ont été mises en oeuvre : Vilars, Minferri, Roques del Sarro... et une enquête sur l'ensemble des 238 sites connus a été réalisée, visant à replacer et à classer l'important volume d'informations existantes.

Parmi les axes de cette recherche l'élaboration d'une périodisation globale fondée sur des datations absolues est devenue l'un des objectifs principaux et le but de cette communication n'est autre que de présenter un premier bilan des résultats acquis.

On peut, actuellement, disposer d'une série de trente et une datations radiocarbone provenant de onze sites différents qui se répartissent entre la moitié du IIIe et la moitié du Ier millénaires (2700 - 600 cal. BC) et qui couvrent, malgré certaines nuances, toute la Protohistoire. Deux autres dates correspondent à l'époque néolithique.

Le lot est constitué de vingt datations déjà publiées (Maya, 1992 ; Royo, 1882 ; Equip Minferri, 1997) et de treize autres présentées ici pour la première fois. Sauf trois obtenues sur le site de Masada de Raton (Mequinensa, Saragosse) par J. Rey (1), le reste provient des recherches propres de l'équipe (fig. 1).

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N° Inv.	Site	Commune	Province	Lab.	BP	±	cal BC (2 sigma)	Med. 2 sig.	Med. IMP
1	*Roques del Sarró	Lleida	Lleida	Beta-92208	4830	40	3696 (3639) 3523	3609,5	3608
2	*Roques del Sarró	Lleida	Lleida	Beta-92207	4670	70	3634 (3496, 3461, 3377) 3155	3384,5	3473
3	Balma de cal Porta	Torà	Lleida	UBAR-288	4160	60	2891 (2862, 2812, 2741, 2726, 2697) 2503	2697	2730,5
4	*Roques del Sarró	Lleida	Lleida	Beta-92206	4040	60	2863 (2568, 2519, 2504) 2408	2635,5	2584
5	*Roques del Sarró	Lleida	Lleida	Beta-92205	3950	90	2854 (2461) 2145	2499,5	2402,5
6	Balma de cal Porta	Torà	Lleida	UBAR-297	3890	60	2554 (2397, 2379, 2348) 2145	2349,5	2341,5
7	*Masada de Ratón	Fraga	Huesca	Beta-75772	3430	240	2453 (1737, 1714, 1701) 1129	1791	1779,5
8	Minferri	Juneda	Lleida	Beta-92280	3410	90	1928 (1731, 1728, 1686) 1510	1719	1720,5
9	Minferri	Juneda	Lleida	Beta-92279	3380	70	1876 (1677) 1513	1694,5	1649,5
10	Cova de Punta Farisa	Fraga	Huesca	GrN-18058	3360	80	1876 (1671, 1664, 1636) 1442	1659	1614,5
11	*Roques del Sarró	Lleida	Lleida	Beta-92204	3330	60	1743 (1613) 1449	1596	1619
12	Riols I	Mequinensa	Saragosse	GrN-14081	3280	60	1684 (1522) 1418	1551	1552
13	*Masada de Ratón	Fraga	Huesca	Beta-75770	3060	110	1523 (1312) 993	1258	1257
14	*Roques del Sarró	Lleida	Lleida	Beta-92203	3050	70	1437 (1306) 1060	1248,5	1274
15	Carretelà	Aitona	Lleida	I-12449	3040	90	1506 (1294, 1284, 1268) 1004	1255	1231
16	Castellets II, los	Mequinensa	Saragosse	GrN-13977	3040	140	1606 (1294, 1284, 1268) 901	1253,5	1218,5
17	Carretelà	Aitona	Lleida	I-12448	3020	90	1444 (1262) 993	1218,5	1218,5
18	Genó	Aitona	Lleida	GrN-18061	2970	45	1372 (1196, 1181, 1165, 1141, 1139) 1019	1195,5	1167
19	Masada de Ratón	Fraga	Huesca	GrN-18638	2873	16	1113 (1013) 946	1029,5	1051,5
20	Genó	Aitona	Lleida	GrN-18062	2860	90	1297 (1004) 817	1057	1044
21	Masada de Ratón	Fraga	Huesca	GrN-18639	2852	15	1034 (1000) 929	981,5	981
22	Castellets II, los	Mequinensa	Saragosse	GrN-14083	2820	30	1028 (976, 965, 935) 900	964	965,5
23	Masada de Ratón	Fraga	Huesca	GrN-18640	2816	16	1001 (971, 969, 931) 909	955	955
24	Castellets II, los	Mequinensa	Saragosse	GrN-14085	2780	35	1000 (911) 830	915	915,5
25	Castellets II, los	Mequinensa	Saragossa	GrN-14084	2755	30	974 (900) 822	898	879
26	*Masada de Ratón	Fraga	Huesca	Beta-75771	2720	60	995 (837) 796	895,5	873
27	*Els Vilars	Arbeca	Lleida	Beta-72610	2670	70	929 (814) 767	848	877
28	*Els Vilars	Arbeca	Lleida	Beta- 72611	2640	60	903 (805) 609	756	731,5
29	*Els Vilars	Arbeca	Lleida	Beta-92278	2580	50	819 (793) 539	679	677
30	Castellets II, los	Mequinensa	Saragosse	GrN-17274	2560	70	828 (785) 412	620	650
31	Castellets II, los	Mequinensa	Saragosse	GrN-17276	2530	90	833 (768) 397	615	608
32	Tossal del Molinet	Poal	Lleida	I-8271	2475	85	807 (754, 690, 536) 386	596,5	596,5
33	*Els Vilars	Arbeca	Lleida	Beta-92277	2460	50	786 (750, 746, 526) 399	592,5	586

Fig. 1 : Tableau général datations C14 calibrées (*datations inédites).

La définition d'un modèle régional fonde la démarche employée face aux habitudes visant à placer l'ensemble de la Catalogne dans un unique schéma chronologique qui s'est déjà avéré défaillant. Parallèlement, la méthode classique des fossiles directeurs a été écartée et un autre découpage chronologique a été établi à partir de l'ensemble des traits culturels spécifiques à la région.

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1 - LE CADRE GÉOGRAPHIQUE DE L'ENQUÊTE

La zone étudiée se situe dans la partie méridionale de la province de Lleida (Catalogne, Espagne), comprenant toute la moyenne et la basse vallée du Segre et ses affluents orientaux (fig. 2). Du point de vue géomorphologique, elle s'insère dans la partie centrale de l'unité structurale dénommée Dépression de l'Ebre. La superficie de cette aire très vaste est estimée à environ 5000 km^2.

Il s'agit d'un région parfaitement délimitée par plusieurs chaînes montagneuses au nord (Pré-Pyrénées), au sud (Montagnes de Prades) et à l'est (Montagnes de la Portella et de Pinos) mais qui s'étend aussi vers l'ouest en territoire aragonais. Elle a été désignée sous le nom de Plaine occidentale catalane et constitue un cadre très cohérent pour réaliser une enquête régionale relative au peuplement protohistorique. Ses caractéristiques principales sont :

- Homogénéité du relief : vastes plaines inférieures à 400 m d'altitude couvrant la plus grande partie du territoire et larges collines doucement étagées sur les marges jusqu'à 700 ou 800 mètres. Présence d'un réseau hydrographique autour d'un émissaire principal orienté de nord en sud (le Segre) et de plusieurs affluents secondaires d'est en ouest, qui constituent les axes du peuplement humain.
- Situation privilégiée au carrefour de plusieurs voies naturelles de communication : le Segre qui assure le lien avec l'Europe continentale et l'Ebre qui permet l'accès tant vers la Méditerranée que vers l'Atlantique.

2 - L'EXPRESSION TEMPORELLE DE LA PÉRIODISATION : MÉTHODE D'EXPLOITATION DES MESURES CALIBRÉES

Jusqu'à une date très récente (Maya, 1992), la périodisation de la Protohistoire en Catalogne recourait aux données radiocarbone non calibrées. C'est essentiellement à partir des recherches développées par l'équipe de l'Université autonome de Barcelone (Castro, 1994 ; Castro, Lull et Mico, 1996) que l'usage de la calibration a été progressivement introduit et que de nouvelles propositions sont ensuite apparues (Maya et Mestres, 1996 ; Maya, 1997).

Néanmoins, il n'existe pas encore d'accord général quant à l'opportunité de cette pratique et, parmi ceux qui y recourent, il n'y a pas non plus de consensus sur la façon d'exploiter les données calibrées. Ces questions ont été abordées lors de la réunion tenue à Lleida en 1995

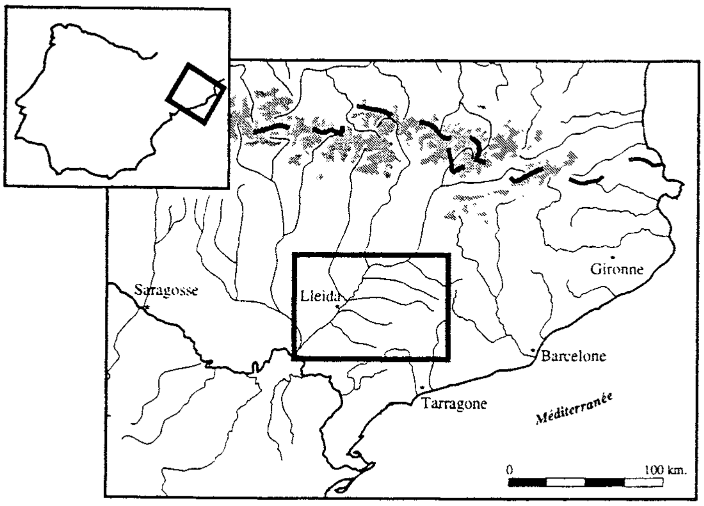
(Junyent, Lopez et Martin, 1995) mais les positions et les solutions proposées continuent à s'affronter à l'image des débats engagés. On peut ainsi brièvement résumer les principaux désaccords :

- l'utilisation de de la calibration à 1 sigma (68,3 % de probabilité) ou 2 sigma (95,4 % de probabilité) ;
- l'exploitation de ces données sur la base de la totalité des intervalles de calibration ou de la seule partie médiane de ceux-ci et, dans ce cas, l'adoption d'une valeur précise (points d'intersection dans la courbe de calibration, médiane, moyenne...).

En ce qui concerne la Catalogne et les régions voisines (fig. 3) la plupart des périodisations parues jusqu'à présent résultent de calibration à 2 sigma, sauf dans un cas (Castro, Lull et Misco, 1996). Une divergence majeure persiste cependant quant au second de ces problèmes. D'une part il a été proposé la méthode de la somme des probabilités comme la solution la plus objective pour établir la comparaison au sein d'une série de données (Mestres et Martin, 1996) ; d'autre part on a considéré soit l'ensemble de la valeur des intervalles pour définir les plages chronologiques (Burillo et Picazo, 1992 ; Castro, Lull et Mico, 1996, soit les intervalles les plus fréquents (Maya, 1997) ou, encore, les valeurs moyennes des points d'intersection (Gasco, 1995). Tant et si bien que ces diverses approches concluent parfois sur une discordance d'environ 350 ans quant au début d'une même période (le Bronze ancien par exemple).

Conscients de ce que la lecture des données calibrées n'est qu'une façon d'exploiter statistiquement l'information et que les âges obtenus ne sont qu'une expression numérique de cette lecture, dans l'impossibilité où l'on se trouve d'établir avec exactitude la date calendaire, notre équipe a fait le choix d'une méthode n'offrant pas plus d'avantages ou d'inconvénients que les autres dans l'attente d'un accord général sur la manière d'exprimer ces mesures.

Ainsi, pour la datation d'un évènement concret (une



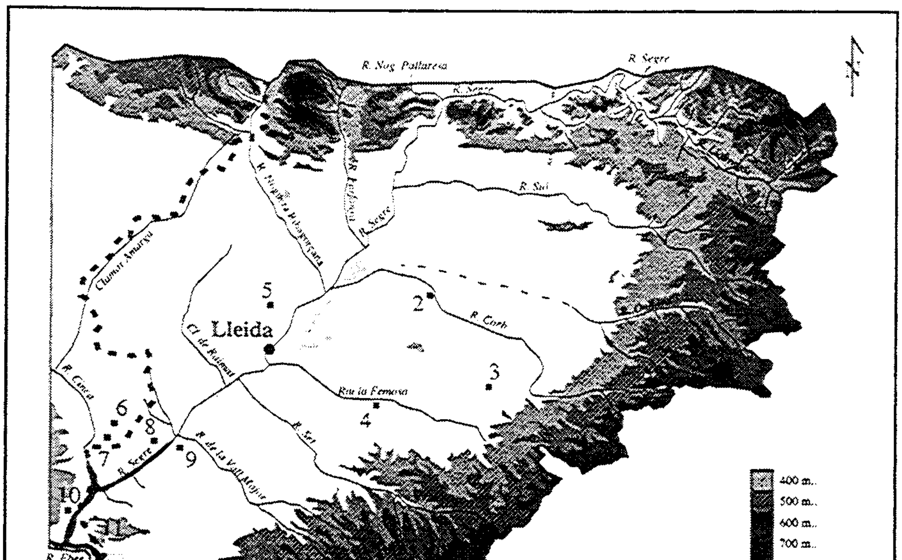


Fig. 2 : Carte de la basse vallée du Segre (Catalogne, Espagne) et des sites avec datations C14 : 1. Balma de cal Porta ; 2. Tossal del Molinet ; 3. Vilars ; 4. Minferri ; 5. Roques del Sarro ; 6. Cova de Punta Farisa ; 7. Masada de Raton ; 8. Carretelà ; 9. Geno ; 10. Riols I ; 11. Castellets II.

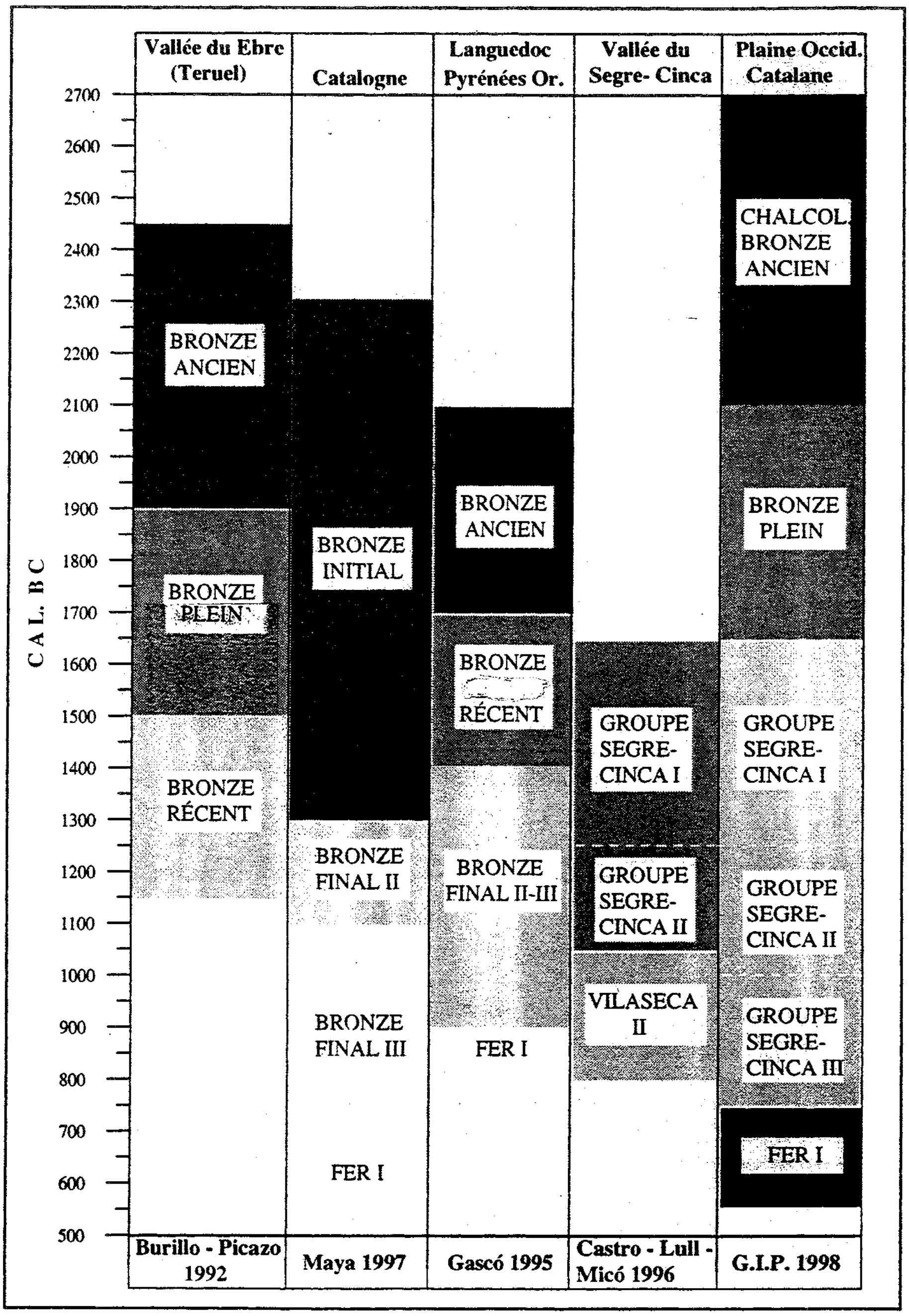


Fig. 3 : Tableau comparatif des périodisations de l'âge des Métaux dans le nord-est de la Péninsule Ibérique et le Languedoc.

structure, une phase sur un site,...), nous avons utilisé la méthode de la moyenne pondérée (MYP) avec le recours préalable au test de la «t» pour vérifier l'homogènéité des datations (Ward et Wilson, 1978 ; Long et Rippetau, 1974 ; Guillespie, 1986 ; Ottaway, 1986).

Pour l'analyse d'une série de données visant à délimiter une période dans le temps nous avons recouru à la médiane des intervalles de probabilité maximale pour les dates radiocarbone calibrées à 2 sigma avec un minimum de 90 % de certitude (IMP). Il s'agit d'une méthode qui attribue un traitement spécifique à chaque datation mais qui permet de supprimer l'impact des plateaux aux extrémités des courbes de calibration.

L'ensemble des données a été calibré avec le logiciel CALIB 3.0.3 (version Macintosh) fondé sur les courbes de Seattle et de Belfast (Stuiver et Pearson, 1993 ; Pearson et Stuiver, 1993).

3 - CHRONOLOGIE PROPOSÉE

- Chalcolithique - Bronze ancien (2700 - 2100 cal. B.C.)

Il s'agit d'une phase mal connue pour laquelle deux sites (Roques del Sarro et Balma de cal Porta) fournissent quatre datations (n° 3, 4, 5 et 6). Les premiers objets en cuivre (alênes) sont présents à la Balma de cal Porta et permettent de situer la période vers 2730 cal. B.C.et permettent de placer le début de la période vers 2730 cal. B.C. Puis on trouve à Roques del Sarro les premiers campaniformes de style pyrénéen vers 2559 cal. B.C. (MYP). La fin de cette phase, qui paraît connaître une solution de continuité avec le début du Bronze ancien est encore impossible à établir à ce jour.

On peut y rattacher trente sites, dont huit sont des grottes sépulcrales et vingt deux des habitats de plein-air ou en grotte. Leur répartition traduit une préférence pour les zones périphériques de la plaine au couvert forestier plus dense et peut-être en relation avec une économie fondée sur l'élevage. Cependant, d'autres sites co-existent au milieu des plaines.

Seul le site de Roques del Sarro a été fouillé : il s'agit d'un abri occupé de façon permanente et qui pourrait marquer le début d'une certaine organisation hiérachisée de l'habitat.

En ce qui concerne les pratiques funéraires, la plupart des sépultures correspondent à des inhumations collectives, aussi bien secondaires que primaires. On connaît toutefois une inhumation individuelle secondaire à Cova del Parco et une inhumation double à Rocallaura, témoignant d'un possible rituel spécifique à certains individus ou, encore, l'existence de groupes culturels distincts.

- Bronze plein (2100 - 1650 cal. B.C.)

La fouille du site de Minferri (Equip Minferri, 1997) a permis d'identifier un nouveau type d'habitat caractérisé par la présence, sur un même espace, de structures d'habitat (maison en bois et torchis), de production et de stockage (silos, foyers, fosses) et funéraires (inhumations individuelles, doubles et multiples dans des silos désaffectés). Conjointement on a pu constater le développement d'une métallurgie locale du bronze attestée par une fosse de réduction, des creusets, des moules de haches plates et de ciseaux ainsi que différents objets en bronze.

Il s'agit aussi d'une agglomération étendue sur une aire d'environ dix hectares. Les recherches interdisciplinaires ont également montré la sédentarité de cet habitat avec une économie céréalière, à cycle court ou moyen, et incluant l'élevage d'ovicaprins comme appoint.

Ce site connait deux dates (n° 8 et 9) d'environ 1651 cal. B.C. (MYP) et permettent de proposer la reconnaissance d'une phase du Bronze plein dont le début demeure toutefois inconnu, mais dont la fin pourrait correspondre avec l'âge des deux silos désaffectés qui ont permis les mesures, voire un peu plus tardivement.

A partir de ce modèle d'autres découvertes anciennes ont pu être reconsidérées de telle sorte qu'un ensemble de vingt trois sites peut être rapporté à cette phase, distribués dans la totalité de la plaine mais avec une concentration principale autour du fleuve Segre. Quelques grottes continuent à être également fréquentées.

- Le début du Groupe de Segre-Cinca (1650- 1250 cal. B.C.)

L'apparition de l'architecture en pierre, l'introduction de nouvelles cultures comme le millet, l'installation des premières nécropoles tumulaires à inhumations ainsi que la présence de certains éléments culturels issus d'outre-Pyrénées tels que la céramique avec anses à bouton, constituent les critères qui définissent une nouvelle phase marquant le début du Groupe du Segre - Cinca.

Une croissance démographique paraît s'installer avec, dès lors, l'existence de cinquante quatre sites dont une nécropole. Le mode d'habitat en plein-air est désormais généralisé et les grottes ne sont utilisées que comme installations secondaires.

On dispose d'un lot de dix datations (n° 7, 10 à 14, 19, 21, 23 et 26) pour préciser la durée de cette phase. Le début correspondrait aux sites de Cova de Punta Farisa et Roques del Sarro, vers 1616 cal. B.C. (IMP). La première nécropole connue dans ce secteur, Riols I, s'installe vers 1559 cal. B.C. La fin de la phase est plus problématique car le site de Masada de Raton fourni quelques dates peu homogènes et qu'il convient de considérer avec prudence. Néanmoins, hormis la perduration ponctuelle de quelques caractères primitifs, on peut considérer le début de la phase suivante comme bien établi (TAQ).

- La consolidation du Groupe (1250 - 1000 cal. B.C.)

C'est l'épisode d'expansion maximale avec quatre vingt un sites recensés, dont quatre nécropoles. On observe, pour la première fois avec certitude, l'existence des premiers villages enclos sur les petites collines caractéristiques de la région. De même on constate la pleine expansion de l'architecture de pierre et de terre (bauge, torchis) et les premiers contacts avec le complexe des Champs d'Urnes qui se traduisent par la lente diffusion de la pratique de l'incinération et l'implantation systématique des nécropoles à proximité des habitats.

Le début de la phase est bien calé par cinq dates (n° 15 à 18, 20). Sites de Carretelà : 1266 cal B.C., de Geno : 1138 cal. B.C. (MYP) et nécropole de Castellets II : 1218 cal. B.C.). Cette nécropole tumulaire maintient le rite de l'inhumation mais les offrandes incorporent déjà les décors cannelés typiques des nouvelles influences.

- La fin du Groupe (1000/800 - 750 cal. B.C.)

A une date encore imprécise on observe l'amorce d'un processus de concentration des habitats et d'une expansion relative vers des zones latérales moins peuplées. Cela se traduit par la présence de cinquante et un sites dont neuf nécropoles.

L'usage de l'incinération est désormais exclusif et les nécropoles tumulaires sont majoritaires. L'habitat adopte un plan régulateur tandis qu'apparaissent les premières architectures en adobe. De nouveaux faciès céramiques locaux se développent et l'artisanat ainsi que la diffusion du métal paraissent occuper une place majeure dans l'économie.

On ne dispose que de quatre datations issues de la nécropole de Castellets II (n° 24, 25, 30 et 31) pour situer son fonctionnement entre 915 et 608 cal. B.C. et qui ne peuvent, à elles seules, témoigner de la durée de cette phase.

- Le premier Age du fer (800/750 cal. B.C. - 550 a.C.)

Le processus de concentration des habitats amorcé durant la phase précédente se poursuit nettement parallèlement à la colonisation de nouveaux terroirs : trente quatre sites connus dont huit nécropoles.

Une hiérarchie entre les différentes formes d'habitat se met clairement en place, reflet d'une évolution sociale vers les chefferies. Tombes avec chevaux, forteresses..., attestent la puissance d'une aristocratie émergente. Un cas exceptionnel est celui du site de Vilars (Garcés *et al.*, 1997) : forteresse enceinte d'un rempart à parements multiples de cinq mètres d'épaisseur avec tours de flanc, chevaux-de-frise et fossé. A l'intérieur s'organise un urbanisme à plan radial très régulier autour d'une place centrale aménagée par une citerne de 9 x 6 mètres avec couloir d'accès. Les premiers témoins d'une métallurgie locale du fer sont également enregistrés sur ce site.

On dispose de quatre datations (n° 27 à 29, 33) pour situer la fondation du site et l'activité métallurgique et le Tossal del Molinet en fournit encore une autre (n° 32) pour la même phase. La date de 777 cal. a.C (IMP) est indicative du début si l'on ne retient pas les âges n° 32 et 33 qui correspondent à la «crise de Hallstatt» affectant alors la courbe de calibration. Cependant, si on ne considère que les intervalles de probabilité les plus étendus, ces valeurs seraient très proches (690 cal. B.C) de la date escomptée.

Le début de la période ibérique ancienne (550 a.C.) est fournie par les premières importations.

4 - CONCLUSION

A partir des données ^{14}C calibrées, nous avons proposé une nouvelle périodisation de la Protohistoire de la vallée du Segre (fig. 4) qui peut être résumée en trois grandes étapes :

- Période de fixation des premières communautés paysannes dans le terroir, sédentarisation et apparition des premières agglomérations (Chalcolithique - Bronze moyen : 2700 - 1650 cal. B.C.).
- Période d'apparition et développement d'un groupe culturel spécifique avec les premières manifestations urbaines de Catalogne (Groupe du Segre-Cinca : 12650 - 800/750 cal. B.C.).
- Période de grandes transformations socio-économiques et de fort développement urbain (Premier Age du Fer).

La datation et une meilleure définition des phases propres à chaque période nécessiteront encore un important effort de recherche, au delà de la première approche esquissée ici.

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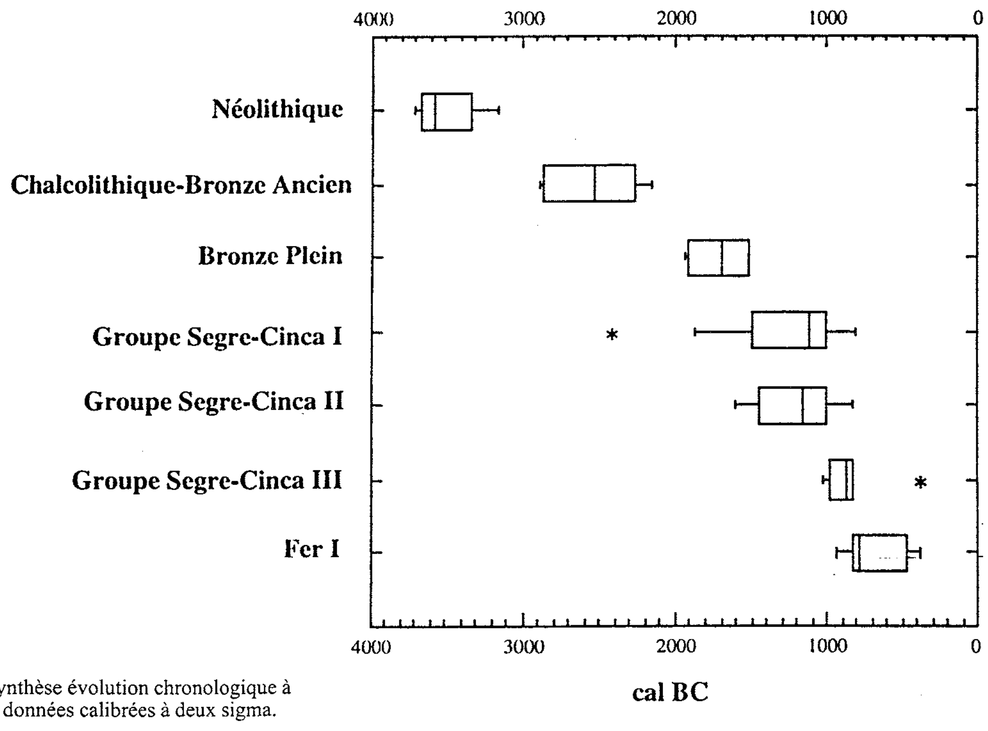

Fig. 4 : Synthèse évolution chronologique à partir des données calibrées à deux sigma.

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RADIOCARBON DATING OF MONUMENTS IN EUROPEAN SCYTHIA

Ganna I. ZAITSEVA, Goran POSSNERT**, Andrey Yu. ALEKSEEV***, Valentin A. DERGACHEV**** and Anatoloiy A. SEMENTSOV**

Abstract : The first radiocarbon dates for the famous monuments of European Scythia were produced for the Kelermes, Seven brothers, Solokha and Chertomlyk barrows by both AMS and traditional methods. The ^{14}C dates obtained confirmed the traditional archaeological chronology based on the analysis of written data, the typological comparisons of individual artefacts in Scythian culture with similar objects found in Ancient East and Greece. The radiocarbon chronology of European scythian monuments testified the chronological synchronisms between the base Asiatic and European Scythian monuments. Calibrated calendar age for the barrows investigated is agreement in common with the archaeological data.

Résumé : On a obtenu les premières dates du radiocarbone par la méthode traditionnelle comme celle d'AMS pour les monuments de Scythes Européens : les kourganes de Kelermes, Semibratni, Solokha et Tchertomlik. En général, ces dates confirment la chronologie archéologique traditionnelle basée sur la typologie, les données écrites et la comparaison des artefacts des Scythes Européens et des objets importés de Proche-Orient et de Grèce. La chronologie du radiocarbone des monuments des Scythes Européens peut être synchronisée avec celle de la période des Scythes du territoire de l'Asie russe. L'âge calibré du radiocarbone des kourganes étudiés correspond aux données archéologiques.

Key-words : European Scythia, radiocarbon, chronology, archaeological data, Asian Scythia, comparison.

Mot-clés : Scythes Européens, radiocarbone, chronologie, données archéologiques, cultures des Scythes d'Asie, comparaison.

INTRODUCTION

European Scythia formed an impressive and distinctive culture in the Early Iron Age. It appeared in the steppe and forest-steppe zones of European Russia, Ukraine, Northern Caucasus and the Black Sea area during the 1st millennium BC, and left an appreciable trace in the history of the world culture. One of the main problems of European Scythia resides in the origin of Scythian nomadic groups, the mechanism of their migrations and the reason why these groups have suddenly disappeared.

The answers to most all these questions lie in the historical time-scale. The traditional chronology of the European Scythian is based on the analysis of written data related to the history of North Black Sea region, the typological comparisons of individual artefacts in the Scythian culture with the similar objects found in Ancient East and Greece, as well as the styles of ceramics and rare prestige items (Alekseev, 1992, 1996 ; Brashinskii, 1965).

The main problem resides in the development of a chronology that would be independent from traditional archaeological sources, the radiocarbon dating being the optimal option. This method had been successfully applied on numerous occasions for the chronology of the sites in Asian Scythia (Marsadolov 1984, 1987, 1994, 1996 ; Zaitseva, 1996, 1997). This chronology had been initially developed based on the analogies with the European Scythia. The radiocarbon dates obtained for Asian Scythian sites have allowed out to devise an independent time scale. Thus, the chronological correlation between European and Asian Scythia took form of a "pendulum effect" : the lack of radiocarbon determinations for the European Scythian monuments swung the chronological correlation into the direction of Asian Scythia.

The important difference between Asian and European Scythian antiquities consists in the fact that the Asian Scythian sites contain the materials suitable both for the tree-ring and radiocarbon chronologies. Asian Scythian

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sites were rich in organic materials, well preserved due to the low temperature prevailing under the barrows. In contrast, in the European Scythian barrows, organic materials, particularly wood, were totally destroyed. Therefore, it was almost impossible to find samples of wood suitable for tree-ring chronology. Besides, the European Scythian sites have been excavated mostly in the 19th - early 20th centuries well in advance of the radiocarbon technology and the samples for dating were naturally not collected. Various materials resulting from the later excavations of European Scythian sites are held in museum collections, yet in the majority of cases these materials may be dated only with the use of AMS technique. The majority of ^{14}C dates recently available for European Scythian sites were obtained by this technique. Now when the first ^{14}C dates are obtained, one can hope that the balance between Asian and European Scythian chronology will be restored.

RESULTS

The first ^{14}C dates have been obtained for the materials from well-known European Scythian sites, held in the collections of the State Hermitage Museum and on several occasions exhibited in other museums around the world. The map of their locations is presented in fig. 1.

The samples from the following sites were dated : the Kelermes barrow No 31 ; the Seven Brothers, barrows Nos 4, 6 and 7, all these sites belonging to the 'older group' the younger group being represented by the main barrows of Solokha and Chertomlyk (Alekseev, 1992).

The ^{14}C dates were measured by the Svedberg Laboratory of Uppsala University (AMS technique) and by the Radiocarbon Lab of the Institute of the History of Material Culture in St.Petersburg (traditional method).

The dated samples consist of the remains of clothes : wood, leather, fur, wool and textile. In total, 16 radiocarbon dates we can be presented for discussion.

The first ^{14}C dates have been obtained for the most well known European Scythian monument materials from which is presented at the State Hermitage Museum collection and exhibited in other museums around the world.

The samples from following monuments were dated : the Kelermes barrow No 31 ; the Seven Brothers barrows Nos 4,6 and 7, all these monuments belonging to the "older group" the younger group being represented by the main barrows of Solokha and Chertomlyk (Alekseev, 1992 ; Sylant'eva, 1967 ; Butjagin, 1996).

These monuments under investigation were excavated : the Kelermes - in 1903-04 and from 1983-1990, the Seven Brothers barrows - in 1875-76, the most rich and famous tomb of the Solokha monument - in 1913, the Chertomlyk - in 1862-63 and again from 1981-86.

The first ^{14}C data for the European Scythian monuments were published in Russia (Zaitseva, Possnert *et al.*, 1997) and were presented in the 16th International Radiocarbon Conference (Zaitseva, Possnert *et al.*, 1998).

The results of ^{14}C dating for the samples from these monuments are represented in table 1.

The ^{14}C dates were produced by the Svedberg Laboratory of Uppsala University and by the Radiocarbon Lab of the Institute of the History of Material Culture (St.Petersburg). Only isolated samples from Kelermes barrow No 31 could be dated by traditional method. They consist of the remains of wooden barrow construction presented by badly preservation (Le-5185) and from the

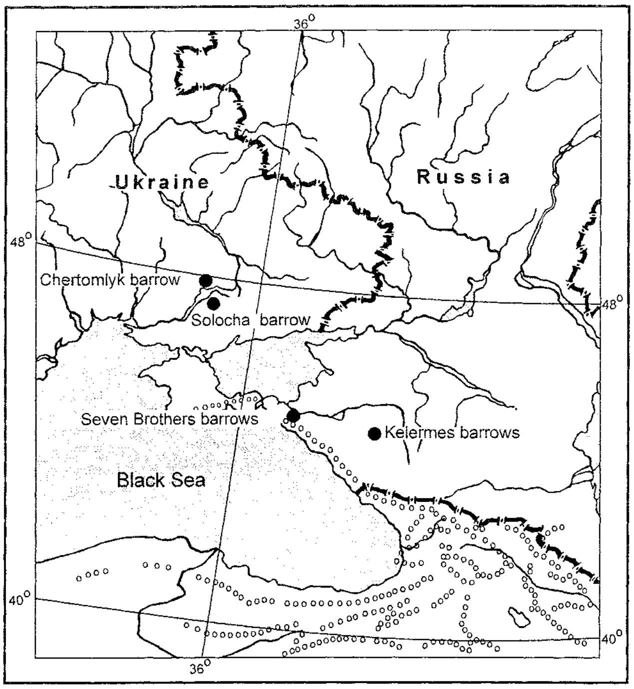

Fig. 1 : The map of the location of the European Scythian monuments.

bone from dogs (Le-5229, Le-5231). These samples were dated by AMS (Possnert, 1990) also and the results are similar into the errors (Ua-11671 and Ua-11672).

The materials from the other barrows could be dated only by AMS. The representative samples consist of the remains of clothes : leather, fur, wool and textile ; and the bone fragments from the casket from the Seven Brothers barrows. The sample from Solokha barrow consist of sheep bone from the cauldron.

It is very interesting that the samples from Chertomlyk barrows consist of wood remains from spears used for arrows and made from the different types of wood : lime-tree and birch. In total, 14 radiocarbon dates we can be presented for discussion.

DISCUSSION

The radiocarbon data set produced confirms the traditional archaeological chronology of sequence of the barrow's construction : the Kelermes barrow No 31, the Seven Brothers barrows No 4, No 6 and the Solokha - Chertomlyk barrows.

As it was noted above, the materials from the monuments of European Scythia were used as the basis for the comparison of the chronology of the Asian Scythian monuments. The synchronism between the key monuments of European and Asian Scythia have been established. Thus, the materials from the Arzhan barrow in Tuva have been compared with materials from the Kelermes barrows, but the chronology of the Arzhan barrow is considered to be some older than the Kelermes barrow. The materials from the group of Pazyryk barrows in Gornyi Altai region show the resemblance with materials from the Seven Brothers barrows (Marsadolov, 1987).

The development of the calendar time scale chronology forms a fundamental problem for the European Scythia. The radiocarbon chronology implies the difficulties connected with the character of the calibration curve for ^{14}C dates during the Scythian period within the limits of the 2400-year cycle of the fluctuations of ^{14}C concentration in the atmosphere of the Earth. According

N	Lab No	^{14}C age, BP	$\delta^{13}C$ ‰	No barrow	Material	Calibrated age, BC	
						1σ	2σ
Kelermes barrows , Russia (the northern Caucasus)							
1.	Ua-11671	2555±50	-17.72	b. 31	bone (dogs jaw)	800-760 678-656 636-550	812-516
2.	Ua-11672	2520±60	-27.29	b.31	wood	792-752 698-530	800-480 452-414
3.	Le-5185	2610±60	-27.29	b.31	wood	836-762 672-666 630-594 578-556	902-752 728-714 704-530
4.	Le-5229	2540±40	-17.72	b.31	bone (dog)	794-760 678-658 634-552	802-750 734-526
5.	Le-5231	2690±150	-17.72	b.31	bone (dog)	1040-760 680-540	1200-410
The group of Seven brothers barrows, Russia (the Kuban river basin)							
6.	Ua-11664	2440±40	-20.91	b.4	leather from clothes	752-698, 532-410	762-628, 598-572, 562-402
7.	Ua-11668	2530±40	-25.37	b.4	textile from clothes	790-760, 680-654 640-548	800-744 742-522
8.	Ua-11669	2255±35	-19.06	b.4	wool from clothes	382-356 294-242 234-208	390-342 326-200
9.	Ua-11665	2305±60	-22.55	b.6	bone from casket	404-351 296-240 236-208	516-434 424-192
10.	Ua-11667	2235±40	-20.69	b.6	fur from clothes	368-350 312-272 268-206	382-196
11.	Ua-11670	2060±40	-21.88	b.7	wool from clothes	106-2 AD	174-21 AD 42AD-56AD
Solokha barrow (Ukraine)							
12.	Ua-11673	2265±50	-20.12		sheep bone	388-354 296-240 238-208	396-334 332-200
Chertomlyk barrow (Ukraine)							
13.	Ua-11674	2130±50	-24.05		spear for arrows from lime-tree	194-62	358-288 252-224 212-30 22-4
14.	Ua-11675	2150±50	-24.32		spear for arrows from birch	348-326 204-94 82-66	362-282 258-44

Tab. 1 : The list of ^{14}C dates for the famous barrows of classical European Scythian culture.

to the Stuiver calibration curve, there are several calendar time intervals for almost all the ^{14}C dates obtained. The lack of tree-ring materials in the European Scythian monuments prevents one from obtaining a closer calendar time interval, yet there occurs a possibility to choose a reliable calendar time interval using the archaeological evidences.

The calendar time intervals determined by the Stuiver calibration curve (Stuiver, 1993) and by the calibration program (van der Plicht, 1993) and the intervals according to archaeological point of view for the monuments under investigation are represented in fig. 2 and 3.

The reliable calendar time interval for the Kelermes barrow, based on the typology of prestige items manufactured by the Middle-Eastern craftsmen is estimated as 650-580 BC and this interval is confirmed by radiocarbon dates (Alekseev 1992, 1996 ; Brashinskii, 1965).

A different pattern emerges for the Seven Brothers barrows. The barrow No 4 of this group, according to archaeological data based on the analyses of imported materials (particularly, horse bridles) is dated to 460-425 BC (Sylant'eva, 1967 ; Butyagin, 1996). The same interval is suggested by a single ^{14}C date. According to

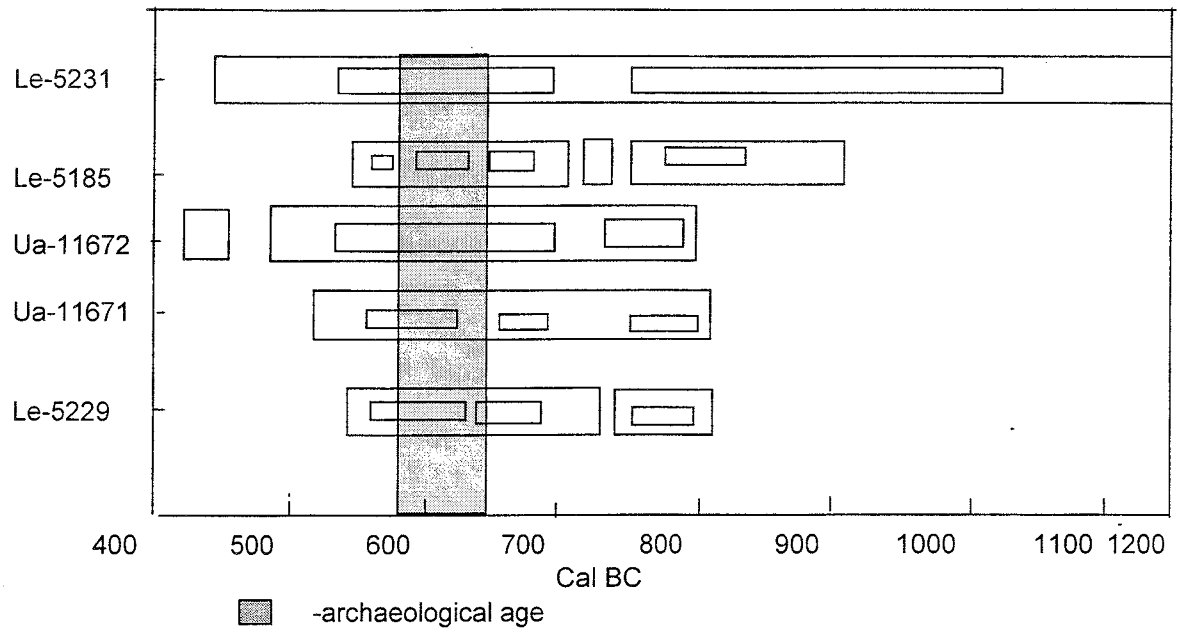

Fig. 2 : The calendar time intervals of ^{14}C dates according to Stuiver calibration curve and reliable archaeological age for the Kelermes barrow.

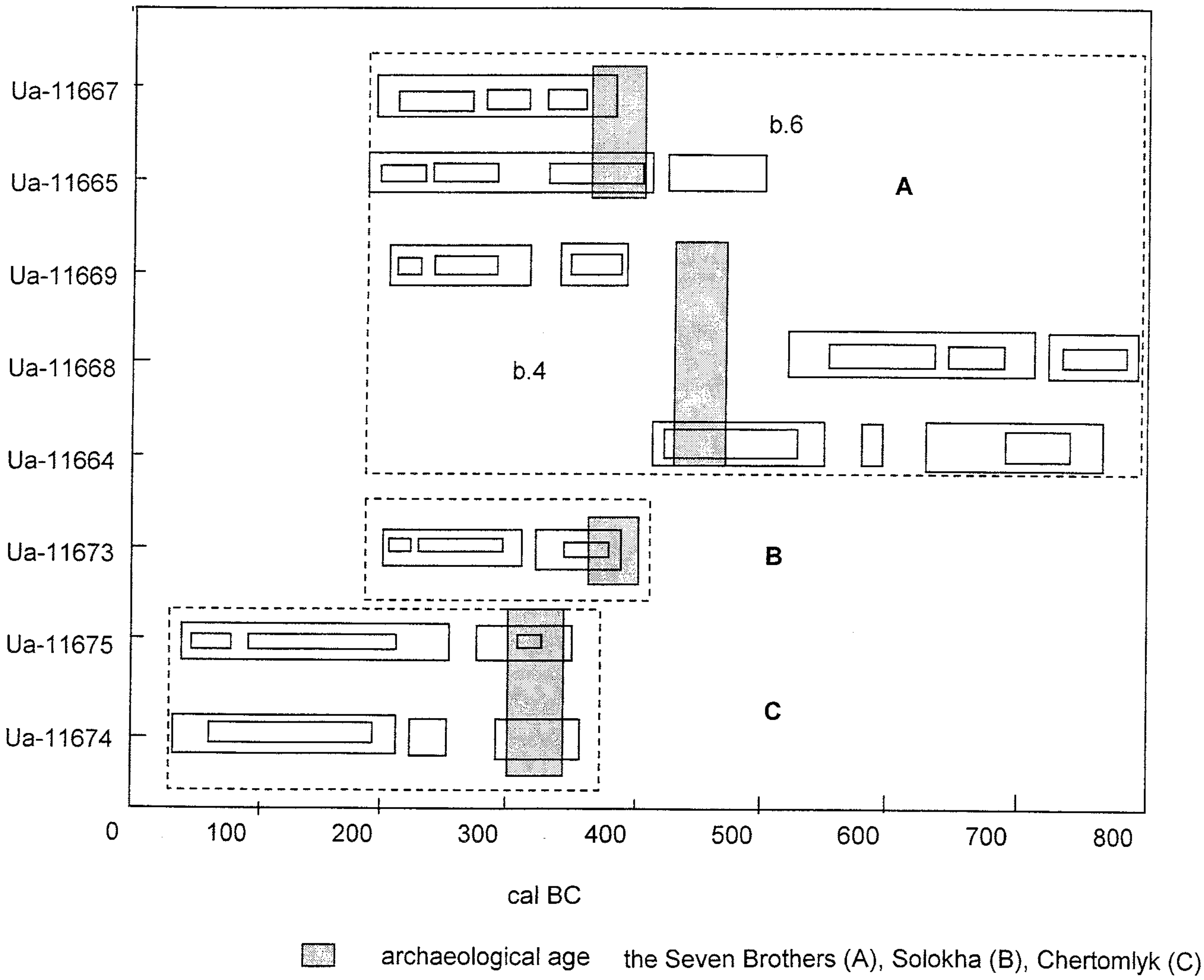

Fig. 3 : The calendar time intervals of ^{14}C dates according to Stuiver calibration curve and reliable archaeological age for the Seven Brothers (A), Solokha (B) and Chertomlyk (C) barrows.

the archaeological data, the barrow No 6 was erected between 400-380 BC BC (Sylant'eva, 1967 ; Butyagin, 1996) and the calibrated ^{14}C dates for this barrow indicate the same interval. The calibration interval for the ^{14}C date of the Solokha barrow falls into the interval of 400-375 BC, again in accordance with the age suggested by several archaeologists (Alekseev, 1992, 1996). For the Chertomlyk barrow the interval of 348-325 BC (1σ) is a reliable estimate for the calibration calendar and close to the archaeological date (350-325 BC). Our investigations allowed us to define the *terminus post quem* for the Solokha and the Chertomlyk barrows as 396-362 BC (2σ).

CONCLUSIONS

The first radiocarbon dates produced for the monuments of European Scythia confirmed the traditional archaeological chronology both its sequence and calendar time intervals of their erections. The radiocarbon dates of the monuments of European Scythia offer a possibility to synchronise the chronology of Asian and European Scythia on the common radiocarbon time scale. In general, the calibration calendar intervals of ^{14}C dates fall into the calendar time intervals accepted by archaeologists.

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ORIGIN AND DIFFUSION OF METALLURGY IN SPAIN : A REVIEW AT THE LIGHT OF RADIOCARBON DATES

*Salvador ROVIRA**

Abstract : The knowledge about metallurgy in Spain and in all the Iberic peninsula is now changing because of the research projects in archaeometallurgy and due to new discoveries in the last years. According to the previous generally accepted idea, the Iberic Peninsula used to be a peripheric region, far from the centres where metallurgy was created, in which copper metallurgy occured thanks to active prospectors coming from the eastern Mediterranean regions. Taking into account the primitive features of the early chalcolithic industry, the new hypothesis make the Peninsula an autonomeous area. It was also suggested that the origin has to be found in the increasing complexity of the Spanish neolithic societies. Recent discoveries in Almeria demonstrate how reliable is this hypothesis.
The date list of radiocarbon dates from the Late Prehistory in Spain is very long. Part of those dates are associated with sites or graves including evidences of metallurgy. We selected the oldest dates connected with metallic artefacts and/or mine or metallurgy of copper, bronze, tin and silver. There is no date for the oldest golden objects.

Résumé : La question de l'origine de la métallurgie en Espagne et, par extension, dans la Péninsule Ibérique, est en train de changer après les projets de l'archéométallurgie et les nouvelles découvertes faites ces dernières années. L'idée, généralement acceptée, était que la Péninsule était une région périphérique, éloignée des centres d'invention métallurgique, à laquelle n'aboutissait la métallurgie du cuivre que grâce à d'actifs prospecteurs du métal arrivés des régions de la mer Méditerranée orientale. La nouvelle hypothèse en fait une origine autonome en se basant sur le caractère primitif des traits de la première métallurgie chalcolithique (Montero, 1994, 282). On a suggéré aussi que l'origine devait être recherchée dans la complexité croissante des sociétés néolithiques espagnoles (Rovira, *in* Hurtado, 1995, 34). Les récentes découvertes en Almérie montrent que cette proposition est valable (Montero & Ruíz Taboada, 1996).
Il existe une grande liste de dates radiocarboniques pour la Préhistoire récente espagnole (Castro, Lull & Micó, 1996). Une partie de ces dates se réfère à des sites ou sépultures avec des témoignages de métallurgie. On n'a sélectionné que les plus anciennes, en rapport direct avec des objets de métal et/ou de la mine et de métallurgie du cuivre, du bronze à l'étain et de l'argent [(1)]. Il n'y a aucune date radiométrique pour les plus anciens objets en or.

Key-words : Radiocarbon dates, Iberic Peninsula, metallurgy.

Mots-clés : Dates radiocarbone, Péninsule ibérique, métallurgie.

COPPER METALLURGY

Earliest evidences have been unearthed in the Southeast, at Cerro Virtud (Cuevas del Almanzora, Almería), on the top of a hill worked for copper, lead, silver and iron up to recent times. Oldest occupation is a Neolithic settlement with huts and burials. The find is a slagged sherd, a fragment of basin-furnace used for smelting copper ores nearby the site. It was found in a strata dated between 6160±180 bp (Beta-101424) and 5660±80 bp (Beta-90884) (Montero & Ruíz Taboada, 1996, 65 ; Delibes & Montero, 1977).

A long hiatus occurred between this isolated Neolithic find and the Chalcolithic metallurgy in the region. In fact, only since Middle Chalcolithic we have well-dated metallurgical contexts (Millarian Culture) at Los Millares (Santa Fe de Mondújar, Almería) : 4380±120 bp (KN-72) (Schuaberdissen & Freundlich, 1966, 21), 4295±85 bp (H204-247) (Almagro Basch & Arribas, 1963), Almizaraque (Cuevas del Almanzora, Almería) : 4300±90 bp (UGRA-170)[(2)] (González, Sánchez & Villafranca, 1987, 1202 ; Castaño *et al.*, 1991, 50) and many other sites. A large set of copper and arsenical copper objects, smelting-melting metal drops, basin-furnace

(1) Material identification and archaeometallurgical analysis have been performed by the research project *Arqueometalurgia de la Península Ibérica. Tecnología y cambio cultural durante la Edad del Bronce*, DGICYT (I+D) PB92-0315.
(2) The sample UGRA-170 dates the end of the Almizaraque foundation phase, but copper metallurgy is already documented in the beginning of such phase. Then, metallurgical activity started before that date.

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fragments and minerals has been collected. Copper metallurgy continued with few changes along El Argar Culture.

More or less at the same times the Millarian Culture flourished in the eastern Andalucía, Chalcolithic sites in the North Meseta also show metallurgical activeness. At Las Pozas (Casaseca de las Chanas, Zamora), awls and crucible fragments have been recovered, dating of 4425±35 bp (GrN-12125) (Delibes & Santonja, 1986, 205). Another settlement with awls and smelting debris is La Teta (Gilbuena, Avila) : 4340±40 bp (GrN-17347) (Fabián, 1995, 219).

There are no radiocarbon dates for the few chalcolithic sites excavated in the region of Madrid. At El Ventorro, the occupation strata dated in or before 3880±90 bp (I-12100) (Priego & Quero, 1992, 368) did not offer any metallurgical remains. It is immediately after this date that copper metallurgy commenced in the site, being coincident with Bell Beaker Horizon.

In the South Meseta, earliest dates for the cultural phase named Bronce de La Mancha belong to settlements such as Motilla de Azuer (Daimiel, Ciudad Real) : 4030±130 bp (UGRA-132) (González, Sánchez & Domingo, 1985, 613) and Morra del Quintanar (Munera, Albacete) : 3920±80 bp (UGRA-310) (González, 1992, 136). Copper objects and smelting-melting remains have been recovered.

Early Chalcolithic sites in the Cantabrian seacoast are not well known. In regard to radiocarbon dates for metallurgy, the sequence starts with Pico Ramos (Musquiz, Vizcaya) : 4210±110 bp (I-16501) (Zapata, 1995, 59 ; Salgado & Zapata, 1995, 121). Other available dates are referred to latter archaeological assemblages, but it is interesting to emphasise that in Cueva de Gobaederra (Subijana-Morillas, Alava), dated in 3660±100 bp (I-3984), only copper objects have been found (Apellániz, 1968, 144).

Two Late Chalcolithic-Early Bronze Age mines of the northern region have been dated. One of them is El Aramo (Riosa, Asturias) : 4090±70 bp (OxA-1833) (Hedges *et al.*, 1990, 107) and the other is El Milagro (Cangas de Onís, Asturias) : 3990±90 bp (OxA-3005) (Delibes & Santonja, 1986, 199).

Another region with good radiocarbon series is the Norteast. At Cova del Frare (Matadepera, Barcelona) there existed copper objects and basin-furnaces in 3990±100 bp (Y35-C3), Bell Beaker Horizon (Maya, 1992, 526), but an earlier chalcolithic tomb in the cave is dated in 4450±100 bp (MC-2297) (Martín, 1987). Unfortunately the burial, with verazian type pottery, has no metal. Copper metallurgy is also documented in Bauma del Serrat del Pont (Tortellà, Gerona) : 4020±100 bp (Beta-64939)(3) (Alcalde *et al.*, 1997, 80).

In the Levante region, two dates underline early copper : Cova Puntassa (Coratxá, Castellón), 4510±110 bp (UGRA-336) (González, 1992, 135) and Ereta del Pedregal (Navarrés, Valencia), 3950±250(4) bp (M-753) (Crane & Griffin, 1961, 121).

By general rule, the dates point out terminus ante quem for copper metallurgy, as they do not date the earliest strata of each site (except in burial contexts). The lack of radiocarbon dates for many other regions of Spain makes difficult to draw a more accurate scenario for chalcolithic metallurgy. It seems evident that the beginning of metallurgy in Galicia or in a great part of the lower Guadalquivir valley must be analysed at the light of what occurs in Portugal. For example, if the dates of La Pijotilla (Badajoz) : 3960±70 bp (unknown laboratory) (Hurtado, 1987, 43) and Valencina de la Concepción (Sevilla) : 4050±105 bp (I-10187) (Fernández Gómez & Oliva, 1986, 43) are representative of Chalcolithic with early metallurgy in Extremadura and Sevilla, it signifies that copper technology takes several centuries to arrive there from the south of Portugal(5), where metallurgy commenced earlier. In fact, some settlements in the Southwest such as Papa Uvas (Aljaraque, Huelva) indicate that a non-metallurgical Chalcolithic phase existed in the area(6).

In spite of the lacks for some regions, it seems quite clear that earliest dates are located in the Southeast (fig. 1). More investigation is needed to confirm and make a better definition of the Neolithic metallurgy discovered at Cerro Virtud(7). Meanwhile, copper metallurgy was a common feature in the region during Middle Chalcolithic (Los Millares Culture), circa 4500 bp.

The fact the upper Guadalquivir Valley and the South Meseta have no sites dated before 4000 bc suggests that copper metallurgy of the North Meseta (Las Pozas, La Teta) arrived from Portugal, where Vila Nova de Sao Pedro and Zambujal could act as drive centres.

Early metallurgy in Cataluña circa 4000 bp is not so easy to explain. Many Chalcolithic up to Middle Bronze Age material characteristics connect better with contemporary cultures of the other side of the Pyrenees border than with neighbouring Spanish regions (Maya, 1992, 525). Then, the key to the problem must perhaps be searched in the Southeast of France.

TIN-BRONZE METALLURGY

An early but isolated date for tin-bronze in the Northwest is 4020±40 bp (GrN-16108), obtained in the Chalcolithic site of Guidoiro Areoso (Villagarcía de Arousa, Pontevedra (Alonso & Bello, 1997, 506).

In the Northeast, recent discoveries at Bauma del Serrat del Pont (Tortellá, Gerona) points out the presence of a bronze object (an arrowhead), dated in 4020±100 bp (Beta-64939) (Alcalde *et al.*, 1997, 80), early Bell Beaker Horizon. Copper and bronze metallurgy coexisted in the site until, at least, 3840±90 bp (Beta-69597) (Alcalde *et al.*, 1997, 19). In the same region, at Cova del Toll (Moiá, Barcelona), a riveted dagger can be associated to the date 3490±80 bp (MC-1469) (Maya, 1992, 527).

In the middle Ebro Valley, at Monte Aguilar (Bárdenas Reales, Navarra), we found evidences of bronze produc-

(3) The sample also dates tin-bronze objects in Bauma del Serrat.
(4) The large deviation in the date makes it unusable.
(5) The archaeological assemblage of La Pijotilla shows similar features than neighbouring Portuguese sites. Valencina de la Concepción is also comparable to Vila Nova de Sao Pedro and Los Millares.
(6) Papa Uvas : 4940±120 bp (CSIC-485) (Martín de la Cruz, 1986, 313). The end of Papa Uvas occupation is estimated around 2500 bc.
(7) Montero & Ruíz Taboada (1996, 73) have "tracked down" some indirect evidences on that subject in literature. In effect, in Cueva de la Cocina (Dos Aguas, Valencia) was found a copper awl in a Neolithic stratum, which presence could not be well understood up to now. Likewise, in Cueva del Tocino (Priego, Córdoba), a Middle and Late Neolithic cave, a slagged fragment of basin-furnace was recovered, unfortunately out of context ; but the archaeological assemblage does not contain any material more modern than Neolithic.

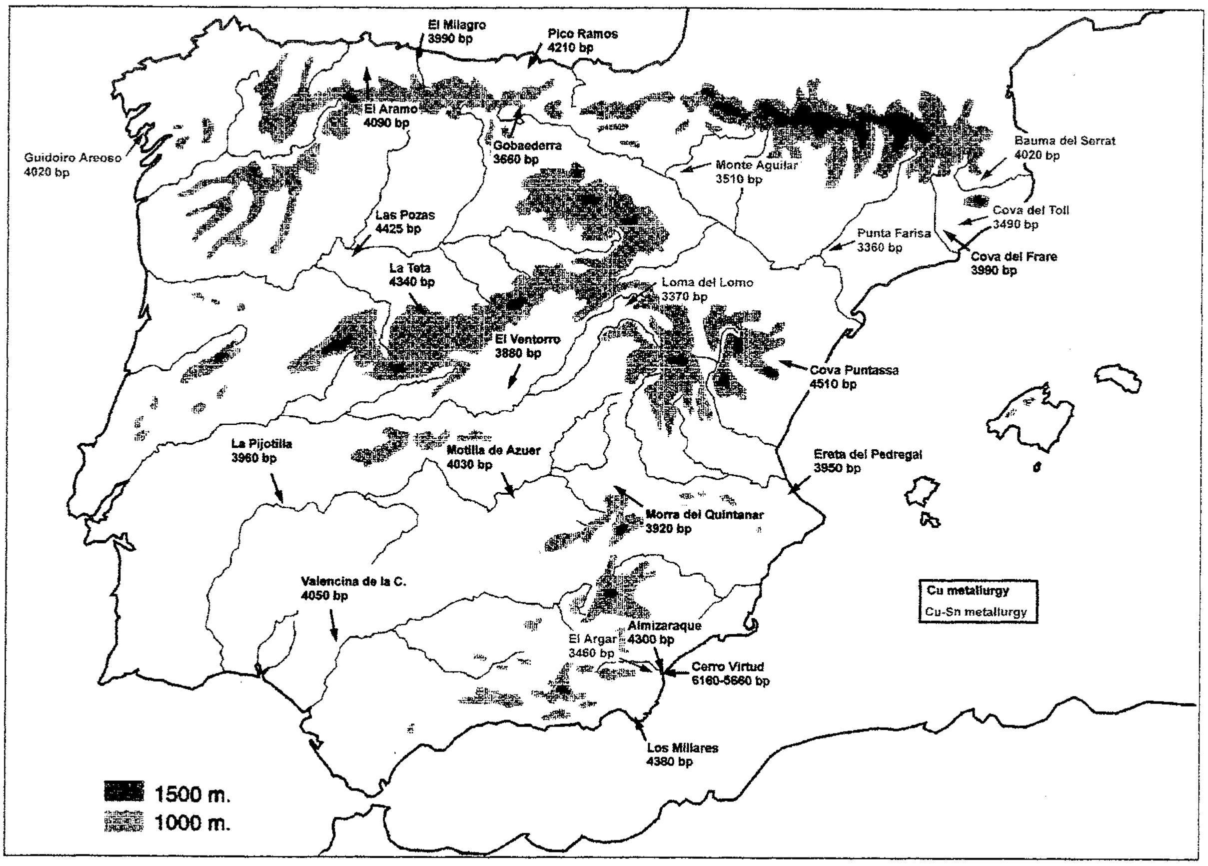

Fig. 1 : Copper and bronze metallurgy. Early dates of Spain.

tion dated in 3510±20 bp (GrN-19671) (Fernández-Miranda, Montero & Rovira, 1995, 63), in a late Early Bronze-early Middle Bronze Age settlement. Another site of the area is Punta Farisa (Fraga, Huesca), where bronze awls dated in 3360±80 bp (GrN-18058) (Maya, Francés & Prada, 1992, 223) have been analysed.

Going downward in the map (fig. 1), proofs of bronze metallurgy can bee seen at La Loma del Lomo (Cogolludo, Guadalajara) : 3370±100 bp (unknown laboratory) (Valiente, 1992, 190)[8].

During El Argar Culture[9], first dated bronze in the Southeast appears in the Tomb 554 of El Argar (Antas, Almería) : 3460±60 bp (OxA-4966) (Hedges *et al.*, 1995, 425). It is a sword with silver rivets.

The set of radiocarbon dates for early bronze metallurgy is really short, and many regions remain, by the moment, completely obscure. As it has been argued, the new technology started in some sites of the northern provinces during late Chalcolithic-Early Bronze Age and progressed southward very slowly (Fernández-Miranda, Montero & Rovira, 1995).

A different question is to establish how the knowledge to produce tin bronze reached Spain, almost at the same time (circa 4000 bp), in two places as distant as Guidoiro Areoso (Galicia) and Bauma del Serrat del Pont (Catalonia). It could arrive from Western Europe. Maritime relations between Spanish Northwest and British Islands, Ireland and Bretagne could be taken into account, but earliest bronzes in those regions (radiocarbon dated) are scarce and well below 4000 bp. The Northeast is well connected with the Mediterranean France, but something similar happens with radiometric dates. Notwithstanding, it has been proposed that tin-bronze metallurgy entered to Spain by a northern way as a "complete package", in spite of the lack of well-dated material in the immediate boundaries (Fernández-Miranda, Montero & Rovira, 1995).

Bronze implements are scarce during the Middle Bronze Age, coexisting with a copper metallurgy that still conserves many chalcolithic features in all the sites we have analysed. Only in the advanced Late Bronze Age the technological substitution was completed.

SILVER METALLURGY

The use of silver decorative objects has been related to the Argaric Culture. Earliest dates are, by the moment, 3670±70 bp (CSIC- 248) (Alonso *et al.*, 1978, 168 ; Montero, Rovira & Gómez Ramos, 1995, 98) of the Tumba de Herrerías, and 3635±60 bp (OxA-4970) (Hedges *et al.*, 1995, 425), obtained in the Tomb 62 of El Oficio (Antas, Almería). The ornaments are two silver earrings and a bracelet, and they demonstrate that the argaric people used silver since the first times.

(8) A date *post quem* for the beginning of copper metallurgy in La Loma del Lomo is 3780±110 bp (I-15329) (Valiente, 1992, 196). The Chalcolithic phase of the site, with no radiocarbon date, has no copper remains.
(9) First steps of the Argaric Culture have been dated in 3970±90 (B-3943) at Fuente Alamo (Cuevas del Almanzora, Almería) (Schubart & Arteaga, 1986, 292).

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APPENDIX

Datelist on metallurgy cited in the text

SITE	DATE bp	DATE bc	RANGE cal BC (1σ)*	LABORATORY	NOTES
Cerro Virtud (Cuevas del Almanzora, Almería)	6160±180	4210±180		Beta-101424	Neolithic. Date *post quem* for copper metallurgy
Cerro Virtud (Cuevas del Almanzora, Almería)	5660±80	3710±80		Beta-90884	Neolithic. Date *ante quem* for copper metallurgy
Cova Puntassa (Coratxá, Castellón)	4510±110	2560±110	3390-3020	UGRA-336	Bones. Chalcolithic. Date *post quem* for copper metallurgy
Las Pozas (Casaseca de las Chanas, Zamora)	4425±35	2475±35	3113-2967	GrN-12125	Charcoal. Middle Chalcolithic. Copper metallurgy
Los Millares (Santa Fe de Mondújar, Almería)	4380±120	2430±120	3170-2920	KN-72	Charcoal. Middle Chalcolithic. Copper metallurgy
La Teta (Gilbuena, Avila)	4340±40	2390±40		GrN-17347	Middle Chalcolithic. Copper metallurgy
Almizaraque (Cuevas del Almanzora, Almería)	4300±90	2350±90	3000-2882	UGRA-170	Charcoal. Middle Chalcolithic. Copper metallurgy
Los Millares (Santa Fe de Mondújar, Almería)	4295±85	2345±85	2986-2882	H-204-247	Charcoal. Middle Chalcolithic. Copper metallurgy
Pico Ramos (Muskiz, Vizcaya)	4210±110	2260±110	3081-2470 (2σ)	I-16501	Chalcolithic. Copper metallurgy
Mina El Aramo (Riosa, Asturias)	4090±70	2140±70	2394-2161	OxA-1833	Reed antlers. Late Chalcolithic-Early Bronze. Copper mining
Valencina de la Concepción (Sevilla)	4050±105	2100±105	2750-2480	I-10187	Chalcolithic. Copper metallurgy
Motilla de Azuer (Daimiel, Ciudad Real)	4030±130	2080±130	2760-2410	UGRA-132	Charcoal. La Mancha Bronze. Copper metallurgy
Guidoiro Areoso (Vilanova de A., Pontevedra)	4020±40	2070±40		GrN-16108	Shells. Chalcolithic. Copper and bronze metallurgy
Bauma del Serrat del Pont (Tortellá, Gerona)	4020±100	2070±100	2876-2279 (2σ)	Beta-64939	Charcoal. Bell Beaker Horizon. Coper and bronze metallurgy
Mina El Milagro (Cangas de Onís, Asturias)	3990±90	2040±90	2628-2414	OxA-3005	Reed antlers. Late Chalcolithic-Early Bronze. Copper mining
Cova del Frare (Matadepedra, Barcelona)	3990±100	2040±100	2650-2390	Y35-C3	Charcoal. Bell Beaker Horizon. Copper metallurgy
La Pijotilla (Badajoz)	3960±70	2010±70	2562-2402		Chalcolithic. Copper metallurgy
Ereta del Pedregal (Navarrés, Valencia)	3950±250	1980±250		M-753	Turf. Early Bronze Age. Copper metallurgy
Morra del Quintanar (Munera, Albacete)	3920±80	1970±80	2530-2321	UGRA-310	Charcoal. La Mancha Bronce. Copper metallurgy
El Ventorro (Villaverde, Madrid)	3880±80	1930±80	2502-2228	I-12100	Charcoal. Bell Beaker Horizon. Date *post quem* for copper metallurgy
Tumba de Herrerías (Cuevas del A., Almería)	3670±70	1720±70	2172-1950	CSIC-248	Wood. El Argar Culture. Silver metallurgy
Cueva de Gobaederra (Subijana-Morillas, Alava)	3660±100	1710±100	2210-1920	I-3984	Human bones. Copper metallurgy
Tumba 62, El Oficio (Antas, Almería)	3635±60	1685±60		OxA-4970	Human bones. El Argar Culture. Silver metallurgy
Monte Aguilar (Bárdenas Reales, Navarra)	3510±20	1560±20	1890-1750 (2σ)	GrN-19671	Late Early Bronze-Middle Bronze Age. Copper and bronze metallurgy
Cova del Toll (Moiá, Barcelona)	3490±80	1540±80	1925-1720	MC-1469	Late Early Bronze-Middle Bronze Age. Copper and bronze metallurgy
Tomb 554, El Argar (Antas, Almería)	3460±60	1510±60		OxA-4966	Human bones. El Argar Culture. Copper and bronze metallurgy
Loma del Lomo (Cogolludo, Guadalajara)	3370±100	1420±100	1890-1420 (2σ)		Middle Bronze Age. Copper and bronze metallurgy
Punta Farisa (Fraga, Huesca)	3360±80	1410±80	1880-1440 (2σ)	GrN-18058	Middle Bronze Age. Copper and bronze metallurgy

* Calibrated range 1σ after Castro, Lull & Micó (1996)

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NEW RADIOCARBON DATES FROM THE SIBERIAN STEPPE ZONE AND ITS CONSEQUENCES FOR THE REGIONAL BRONZE AGE CHRONOLOGY

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Abstract : New radiocarbon dates from the Bronze Age in the Siberian Steppe Zone are presented. For some cultures, they are the first published dates. They allow comparisons with neighbouring regions.
As all of them are calibrated dates, they involve a complete reviewing of the chronology which was up to now admitted for the Bronze age. It seems that the absolute chronology of the South Siberian cultures is still far from being established.

Résumé : On présente de nouvelles datations radiocarbone pour l'Age du Bronze de la steppe de Sibérie. Ce sont parfois les premières pour certaines cultures. Des comparaisons sont faites avec les régions avoisinantes.
Comme ces datations sont toutes calibrées, elles conduisent à réviser la chronologie de l'Age du Bronze jusqu'à présent admise. Il apparaît que celle du sud de la Sibérie est encore loin d'être sûre.

Key-words : Radiocarbon dates, Bronze age, Siberian steppe.

Mots-clés : Datations radiocarbone, Age du Bronze, Steppe de Sibérie.

INTRODUCTION

The chronological problems of the Siberian Steppe Zone are under intensive investigation during the last years. No generally accepted chronological system existed for this region up to now. We present new ^{14}C-datings of samples from several excavation sites. In the graveyard of Suchanicha the authors themselves are working. We add other dates from the Okunevo sites of Cebaki and Ujbat V ; the samples have been given by A. Gotlib, Abakan, and I. Lazaretov, St. Petersburg. The samples from scythian kurgan burials from Doge Baary II were received from K. Cugunov, St. Petersburg. To all these excavators we give our thanks for their collaboration.

These samples give us new absolute dates for different Bronze Age cultures including Afanas'evo, Okunevo and Karasuk (Kamennyj Log phase) as well as for Scythian culture and the late Tes' phase of Tagar culture, related with the Huns. The dates allow a comparison of the Bronze Age development in Siberian Steppe Zone with other neighbouring regions. The presented datings are part of a cooperation project with the ^{14}C-laboratory and specialists of the Institute of the History of Material Culture of Russian Academy of Sciences (St. Petersburg) to investigate chronological problems of the South Russian and Siberian Steppe Zone.

METHODS

Chemical pretreatment of wood and charcoal samples was done by A-A-A treatment (Mook and Streuerman 1981). The dating was performed with gas proportional counters of the Houtermans-Oeschger type, using methane at 133.3 kPa pressure as filling gas (Kohl and Quitta, 1978). Measurement control and data processing were done with the help of computers (Görsdorf, 1990 ; Görsdorf and Bojadziev, 1996). The δ^{13}C-measurements were done by H. Erlenkeuser and colleagues (Leibniz-Labor, University of Kiel) and are reported with respect to PDB-standard.

RESULTS

The tree-ring count of charcoal and wood samples could not be determined. In the calibration programs (Ramsey, 1995 ; Weninger, 1986, 1992) we used the bidecadal calibration curve (Stuiver and Pearson, 1993 ; Pearson and Stuiver, 1993) as a first approximation (tab.).

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Suchanicha (53° 52′ 26″N, 91° 27′ 42″E)			
Bln-4764 wood	object 6, stone circle Afanas'evo culture		4409 ± 70 BP 3290 - 2910 cal BC
Bln-4765 wood	object 6, stone circle Afanas'evo culture	-24.86‰	4259 ± 36 BP 2920 - 2780 cal BC
Bln-4767 wood	object 6, grave 1 Afanas'evo culture	-25.27‰	4253 ± 36 BP 2910 - 2710 cal BC
Bln-4766 wood	object 2, grave 2 Afanas'evo culture	-24.82‰	4205 ± 44 BP 2890 - 2690 cal BC
Bln-4769 wood	object 6, grave 1 Afana'sevo culture	-24.08‰	4022 ± 40 BP 2580 - 2470 cal BC
Bln-4919 wood	object 6, grave 15 Afana'sevo culture	-24.90‰	3936 ± 35 BP 2470 - 2340 cal BC
Bln-4768 wood	object 4, grave 15 Karasuk culture, Kamennyj Log	-25.71‰	3031 ± 38 BP 1380 - 1210 cal BC
Bln-4962 wood	object 4, grave 20 Karasuk culture, Kamennyj Log	-26.54‰	2962 ± 36 BP 1260 - 1110 cal BC
Bln-4921 wood	object 4, grave 20 Karasuk culture, Kamennyj Log	-26.77‰	2943 ± 29 BP 1210 - 1060 cal BC
Bln-4836 birch bark	object 4, grave 15 Karasuk culture, Kamennyj Log	-26.33‰	2923 ± 37 BP 1190 - 1020 cal BC
Bln-4835 wood	object 4, grave 15 Karasuk culture, Kamennyj Log	-26.23‰	2906 ± 38 BP 1130 - 1010 cal BC
Bln-4763 charcoal	object 6, row of stones Karasuk culture, Kamennyj Log	-24.09‰	2762 ± 49 BP 930 - 830 cal BC
Bln-4922 wood	object 4, grave 22 Late Tagar, phase Tes' (Huns)	-26.90‰	2026 ± 33 BP 50 cal BC- 50 cal AD
Bln-4920 wood	object 4, grave 18 Late Tagar, phase Tes' (Huns)	-26.78‰	2008 ± 35 BP 35 cal BC - 60 cal AD
Bln-4961 wood	object 4, grave 18 Late Tagar, phase Tes' (Huns)	-26.86‰	1984 ± 35 BP 0 - 75 cal AD
Èebaki (54° 34′N, 89° 20′E)			
Bln-4948 charcoal	C-6 Okunev culture	-24.30‰	3664 ± 37 BP 2130 - 1970 cal BC
Bln-4947 charcoal	C-13 Okunev culture	-24.14‰	3488 ± 40 BP 1880 - 1740 cal BC
Ujbat V (53° 43′ 31″N, 90° 22′ 16″E)			
Bln-4762 wood	burial mound 4, grave 5 Okunev culture		3782 ± 62 BP 2300 - 2040 cal BC
Bln-4949 bone	burial mound 4, grave 20 Okunev culture	-20.55‰	3657 ± 43 BP 2120 - 1950 cal BC
Bln-4951 bone	burial mound 4, grave 4 Okunev culture	-19.79‰	3631 ± 41 BP 2040 - 1910 cal BC
Bln-4950 bone	burial mound 4, grave 15 Okunev culture	-19.51‰	3620 ± 35 BP 2030 - 1910 cal BC
Doge Baary II (51° 47′N, 94° 27′E)			
Bln-4838 wood	burial mound 3, grave 3 Scythian	-27.50‰	2425 ± 34 BP 750 - 400 cal BC
Bln-4924 wood	burial mound 15 Scythian	-27.14‰	2397 ± 32 BP 510 - 390 cal BC
Bln-4923 wood	burial mound 7 Scythian	-25.96‰	2364 ± 31 BP 480 - 385 cal BC
Bln-4925 charcoal	burial mound 16, grave 2 Scythian	-25.59‰	2319 ± 32 BP 401 - 371 cal BC

Tab.

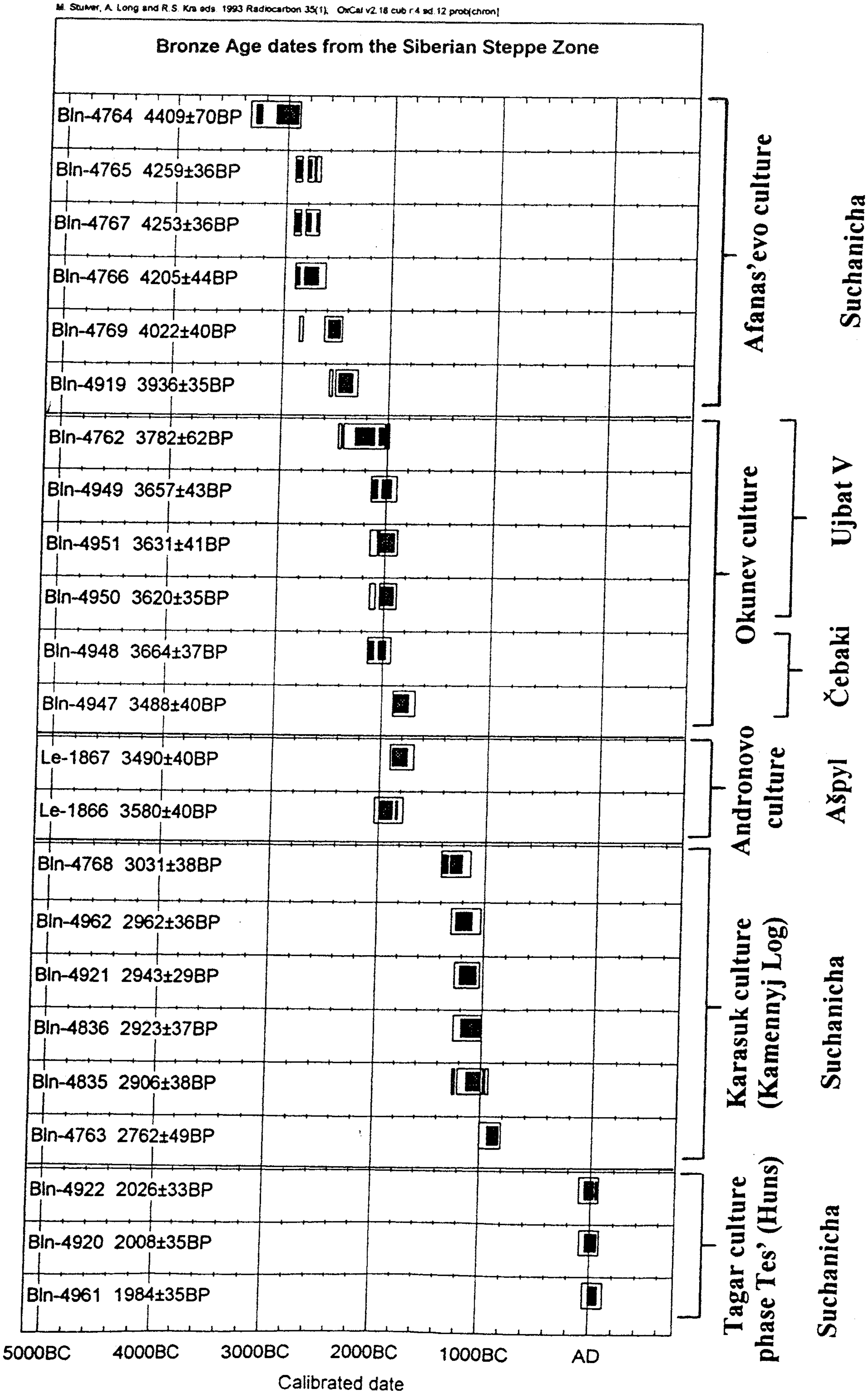
M. Stuiver, A. Long and R.S. Kra eds. 1993 Radiocarbon 35(1); OxCal v2.18 cub r:4 sd:12 prob[chron]
Bronze Age dates from the Siberian Steppe Zone
Bln-4764 4409±70BP
Bln-4765 4259±36BP
Bln-4767 4253±36BP
Bln-4766 4205±44BP
Bln-4769 4022±40BP
Bln-4919 3936±35BP
Bln-4762 3782±62BP
Bln-4949 3657±43BP
Bln-4951 3631±41BP
Bln-4950 3620±35BP
Bln-4948 3664±37BP
Bln-4947 3488±40BP
Le-1867 3490±40BP
Le-1866 3580±40BP
Bln-4768 3031±38BP
Bln-4962 2962±36BP
Bln-4921 2943±29BP
Bln-4836 2923±37BP
Bln-4835 2906±38BP
Bln-4763 2762±49BP
Bln-4922 2026±33BP
Bln-4920 2008±35BP
Bln-4961 1984±35BP
5000BC
4000BC
3000BC
2000BC
1000BC
AD
Calibrated date
Afanas'evo culture
Suchanicha
Okunev culture
Ujbat V
Čebaki
Andronovo culture
Ašpyl
Karasuk culture (Kamennyj Log)
Suchanicha
Tagar culture phase Tes' (Huns)
Suchanicha

Fig. 1.

COMMENTS AND CONCLUSIONS

The above presented dates from Suchanicha, Cebaki, Ujbat V and Doge Baary II can be considered as an important progress in absolute dating of South Siberian cultures. From Suchanicha e.g. we have now 15 dates from one and the same site, which seems extremely interesting. Nevertheless the results of these dates and their interpretation causes some trouble, if we compare them with the ideas on absolute chronology of South Siberian cultures dominating until now (Vadeckaja, 1986). That fact should not surprise, because all older dates published by specialists before have mostly been uncalibrated (Semencov *et al.*, 1969). But this means also, that the here presented dates can only be considered as a first step, which must be followed by much more dates from South Siberia and neighbouring regions to solve the still existing chronological problems.

The earliest graves from the widely extended graveyard of **Suchanicha** on the eastern shore of the river Jenisej North of Minusinsk belong to the *Afanas'evo culture*, considered to date between the middle of 3rd and the beginning of the 2nd millennium BC (Vadeckaja, 1986, 11-26). The calibrated dates from Suchanicha, however, speak for a quite earlier chronological position of this culture (fig. 1) : they mostly belong to the first half of the 3rd millennium BC, one of them even going back to the end of 4th millennium BC (Bln-4764).

In general terms, Afanas'evo is followed by the *Okunevo culture*. The above presented Okunevo-dates from **Cebaki** and **Ujbat V**, the first published datings of this culture, fit quite well in this new tendency of higher dating of South Siberian cultures. Okunevo was considered to start around 1800 BC and to end around the middle of the 2nd millennium BC (Vadeckaja, 1986, 27-40). But six new dates, from graves (Ujbat V) as well as from a hillfort-like

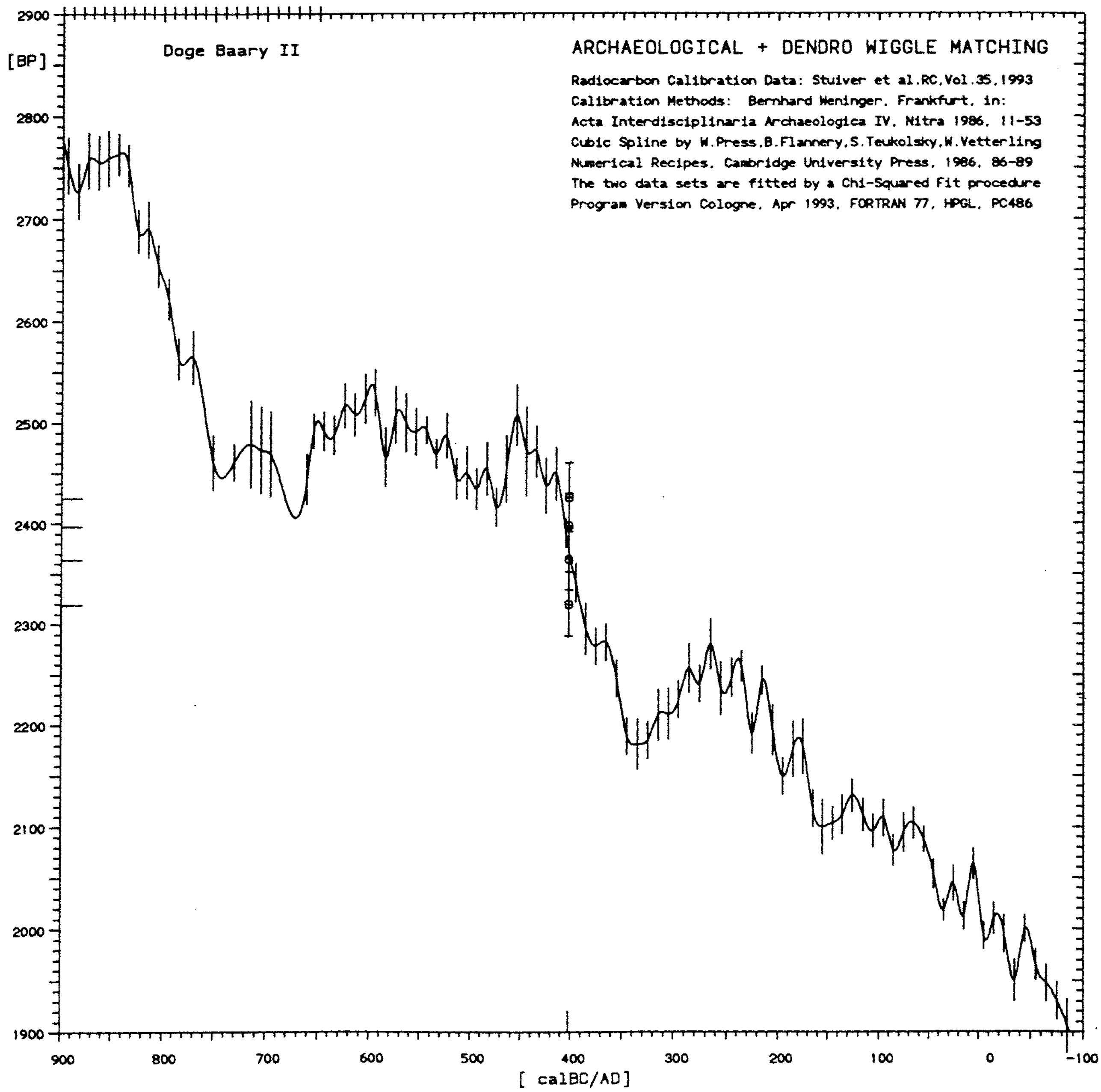

Fig. 2.

settlement or sanctuary (Cebaki), show the same result : they all belong to the last third of the 3rd millennium BC, reaching the very beginning of 2nd millennium BC (fig. 1). Also from the point of view of calibrated datings, Afanas'evo is immediately followed by Okunevo.

Unfortunately until now we cannot present new dates for the Andronovo culture, which should follow Okunevo, and 'classical' Karasuk. We find in modern literature two dates for the Andronovo culture from Ašpyl, South Siberia (Ermolova *et al.*, 1983) (fig. 1). The chronological relation between Andronovo and Karasuk - following each other or perhaps partly contemporaneous - is still an open question. Interpolating with the above presented dates, both cultures should belong to the first and second third of the 2nd millennium BC. The six Karasuk-datings from **Suchanicha** (fig. 1) represent the so called *'Kamennyj Log phase'* of that culture. There is a long discussion on the chronological position of Kammenyj Log ; some scholars consider it as early Karasuk, but others - and most of them - as a late Karasuk or even as a kind of transition to early Tagar (Leont'ev, Parzinger, Nagler, 1996, 175-204). If Kamennyj Log really represents late Karasuk and the transition to early Tagar, then the above presented datings, which - with the exception of Bln 4763 - date mostly to the last two centuries of the 2nd millennium BC, are a big surprise. The last third of the 2nd millennium BC is the time of late Shang dynasty (Anyang), as historical datings as well as new Chinese ^{14}C-dates prove (Lin Yün, 1986, 242). The relation between Anyang and Karasuk, however, is out of question. In any case, the problem is still not definitely solved. It depends also on the interpretation of Kamennyj Log, especially in relation to Karasuk, which is rather more an archaeological problem.

The datings of the *Scythian* burial mounds in central Tuva were done together with the ^{14}C-laboratory in St. Petersburg. The datings gave a basis for the construction of a dendrochronological sequences in the range between the 8th and the beginning of the 4th centuary BC (Zajceva *et al.*, 1996 ; Semencov *et al.*, 1997). The dating results of the Scythian burial mounds at **Doge Baary II** in central Tuva can be calibrated very precisely in the region of 400 cal BC (fig. 2). The datings give points to fix a floating dendrochronological sequences in the range between the 8th and the beginning of the 4th century BC, which is under construction (Marsadolov *et al.*, 1996 ; Marsadolov, 1997).

The youngest datings from **Suchanicha** belong to the latest phase of the Tagar culture, the so called *Tes' phase*, which Russian scholars always considered to represent the Huns, which are mentioned in Chinese annals for the last centuries BC in the North of their empire. The relative and also absolute chronology of that period is connected with many open questions. The Tes' phase of the Tagar culture was always dated into the last two centuries BC (Vadeckaja, 1986, 129-156). But the three new datings from graves from the Suchanicha graveyard are slightely younger (fig. 1).

It was our aim to show with the above mentioned datings, that the absolute chronology of most of the South Siberian cultures still is not at all sure. Thanks to calibrated ^{14}C-dates we definitely have to get used to the idea of a higher chronology for most of these cultures. The high age of the Afanas'evo culture in the Siberian Steppe e.g. contradicts the often expressed opinion that the pit-grave culture spread from west to east. A discussion on uncalibrated dates is completely useless and anachronistic. That also means a break with most of the traditional chronological points of view. The discussion definitely is in movement and the only solution is to go straight forward on that way, collecting as many samples for ^{14}C and also dendrochronology as possible in order to get a much more complete new net of datings.

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SOME QUESTIONS ON THE RADIOCARBON CHRONOLOGY OF THE SCYTHIAN TIME MONUMENTS IN THE CENTRAL ASIAN STEPPE ZONE OF RUSSIA (Southern Siberia and Tuva Republic)

Ganna I. ZAITSEVA, N.A. BOKOVENKO*, Anatoloiy. A. SEMENTSOV*, Goran POSSNERT** and K. CHUGUNOV****

Abstract : For the Central Asian territory the different monuments belonging to the scythian cultures of different time were known. The degree of their investigations are different. In common, the chronology and periodization of nomadic cultures in Central Asia are need of correction because the materials from new monuments excavated lately sometimes come into contradiction with the traditional archaeological point of view on the development of nomadic cultures in this region. The main question is the chronology of the scythian period cultures, which can be solved by radiocarbon dating. The radiocarbon dates produced recently by the ^{14}C Labs of St.- Petersburg, Berlin and Uppsala allowed to correct the archaeological images about the time of the barrow construction. The dates for the monuments of the Uyuk-Sagly culture (Teyplaya, Dogee-Baary-2, Chinge) testify a longer time of their existence and some earlier time of their forming. The age of the Aldy-Bel complex of the Kopto barrow is close to the age of the earlier Dogee-Baary-2 and Teyplaya barrows. All dates confirmed the archaeological assumption that in the Tuva region two burials traditions existed at the end of the IV-Vth century B.-C.

Résumé : A l'heure actuelle, on connaît pour la région de l'Asie centrale de Russie une quantité considérable de monuments qui appartient aux cultures de la période des Scythes. Le niveau de leur étude est différent. En général, la chronologie et la périodisation des cultures d'anciens nomades ont besoin d'être corrigés, parce que les matériaux des fouilles des dernières années sont parfois en contradiction avec les données archéologiques adoptées auparavant. Une question fondamentale liée à la chronologie des cultures des Scythes de cette région peut être résolue à l'aide de la méthode de datation du radiocarbone. On présente dans cet article les dates obtenues dernièrement dans les laboratoires de St. Petersbourg, Berlin et Uppsala qui permettent d'introduire des correctifs sur les données archéologiques concernant l'époque de la construction des kourganes. Les dates pour les monuments de la culture d'Uyuk-Sagly (Teyplaya, Dogee Baary-2, Chinge) témoignent d'une durée plus longue de leur existence et d'une époque plus ancienne de leur formation. L'âge des complexes d'Aldy-Bel des kourganes de Kopto est proche de celui des kourganes anciens de Dogee-Baary-2 et Teyplaya. En général, toutes les dates confirment les données archéologiques sur l'existence de deux traditions de rituels funéraires dans la région de Tuva aux IVème-Vème s. av. J.-C.

Key-words : Radiocarbon, chronology, Central Asian region of Russia, scythian time, nomadic cultures, calibration curve.

Mots-clés : Radiocarbone, chronologie, Asie centrale, Scythes, cultures des nomades, courbes calibrées.

INTRODUCTION

The vast steppe zone of Southern Siberia has an insular character ; its specific environmental conditions were reflected in the character of archaeological cultures. The Central Asian steppe region is located in the Upper Yenisei basin and its specific environmental conditions caused the nearness of mountains. The steppe zone is located in the hollows and the forest and meadows are located in the mountain region. The territory of Central Asia (South of Krasnoyarsk region and Tuva Republic) was the place of the existence and migration of different nomadic cultures. The main archaeological cultures investigated in this zone belong to the Iron Age ; they reveal both typological and chronological similarities in a wide area of European and Siberian steppe. The reconstruction of their interaction and possible directions of migrations requires the detailed chronology based both

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on archaeological materials and radiocarbon dates. In spite of lengthy investigations of scythian cultures in Siberia the detail time-scale for the successive change of cultures is still lacking. Numerous chronological questions are still under discussion, particularly concerning the initial stages in the existence of these cultures. New radiocarbon dates produced for the scythian cultures monuments and the discussion of their chronology are represented in this research.

RESULTS AND DISCUSSION

For the Central Asian territory the different monuments belonging to the scythian cultures of different time were known. The degree of their investigations are different.

The most famous monuments of the Central Asian region is the Arzhan barrow located in the Uyuk hollow (Tuva Republic). The materials from the Arzhan barrow are connected with the earlier stage of the scythian time cultures. Before now the Arzhan barrow has been more detail investigated comparing with other monuments located at this territory. For this barrow the radiocarbon data set has been produced and the tree-ring chronology has been carried out. The Arzhan barrow belongs to the groups of so-called elite barrows of the Sayan-Altai and takes one of the key positions in the research of the scythian time cultures for all Eurasian territory.

In common, the chronology and periodization of nomadic cultures at Central Asia are need of the correction because of the materials from new monuments excavated for the last time come sometimes into the contradiction with the traditional archaeological point of view on the development of nomadic cultures in this region.

The main question is the chronology of the scythian time cultures, which can be solved by radiocarbon dating.

The location of the barrows under investigation is shown in fig. 1.

It should be noted that in spite of certain discords, most of archaeologists subdivide the scythian cultures at the Tuva region on three types or stages of their existence (Grach, 1980 ; Gryaznov, 1983).

Most earlier stage is presented by the materials from the "tsar" barrow Arzhan.

If the radiocarbon dating of the samples from the Arzhan barrow was conducted beginning from the 1970th years, directly after its discovery, and it is continued right up to now (Zaitseva *& al.*, 1997, 1998 ; Hall, 1997). The Arzhan barrow is dated to the end of 9th century BC (Zaitseva, Vasiliev, Marsadolov *et al.*, 1997, 1998).

The next stage of scythian cultures at the Central Asia is so-called the aldy-bel culture. It belongs to the end of the early scythian period according to the funeral custom and archaeological evidences. The munuments of this culture is in generally characterised by individual graves the deep of which is not more than 2 m. These monuments are dated to the 7th -5th centuries BC (Bokovenko, 1994 ; Chugunov, 1994). The aldy-bel culture is succeeded by the uyuk-sagly culture dated to 5th- 2nd centuries BC (Semenov and Chugunov, 1995). This culture represents the classic stage of scythian epoch. The funeral custom is characterised by collective graves. There are the some archaeological signs of coexistence the aldy-bel and uyk-sagly cultures for a short time. The question is to which extent these archaeological signs are confirmed by radiocarbon dating. The radiocarbon dating for these monuments was began to use only during the last years (Sementsov *et al.*, 1997, 1998).

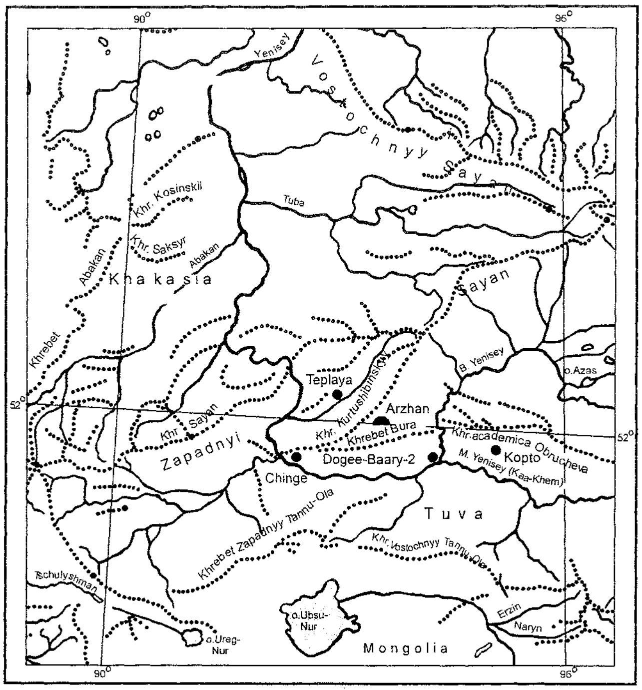

Fig. 1 : The location of the monuments of scythian time at the Central-Asian region of Russia.

The ^{14}C dates were produced by several radiocarbon laboratories : the Lab of the Institute of the History of Material Culture (St.Petersburg), the Berlin Lab and the Swedberg Radiocarbon Laboratory (Uppsala University, Sweden), last of them uses the AMS technique. The list of ^{14}C dates produced is presented in table 1, the calendar time intervals according to the computer calibration program (van der Plicht, 1993) are shown in fig. 2.

For the ^{14}C dating were used wooden samples from the Dogee-Baary-2, Chinge and Tyeplaya barrows (the uyuk-sagly culture) and from well stratified Kopto barrows (the aldy-bel culture). Some samples from Dogee-Baary-2 barrows were presented by the remains of leather and textile from cloth and they were dated by AMS, the remains of wood from barrow construction were dated by traditional technique. It is necessary to note that usually there are some problems with the dating of textile and wood samples from museum collections connecting with using unknown chemical reagents for the material protection during their preservation before dating. These chemical reagents unknown nature can be the case of ^{14}C dates deviations from the reliable age (Zaitseva, Possnert, Alekseev *et al.*, 1998). In our case these materials presented for AMS dating were collected during excavation and did not treated. The ^{14}C dates produced by both AMS and traditional technique originated from the same graves and barrows have the closely values in the limit of errors. The sample from the Chinge barrow was the textile from cloth and was dated only by AMS technique.

The Tyeplaya monument is located in the Krasnoyarsk district, near to the Arzhan barrow and it belongs to the Asian circle of the scythian cultures. Both the different artefacts and the type of barrow construction (the round stone fence, deep grave with wood framework) confirm the uyuk-sagly type of the scythian culture. The sample for ^{14}C dating from this barrow was presented by charcoal from fireplace under floor.

The radiocarbon dates produced allowed to correct the archaeological imagines about the time of the barrow

N	Lab No	^{14}C age, BP	$\delta^{13}C$ ‰	No barrow/ grave	Material	Calibrated age, BC*	
						1σ	2σ
Chinge barrow							
1.	Ua-12973	2360 ±45	-22.50	22/2	textile	510-380	750-256
2.	Ua-12970	2490 ±45	-21.56	1	textile	764-528	782-414
3.	Bln-4838	2425 ±34		3/2	wood	748-496	760-398
4.	Ua-12969	2435 ±45	-21.62	3	textile	754-408	762-400
5	Le-5214	2490 ±20		7	wood	762-535	766-525
6.	Bln-4923	2379 ±32		7	wood, 20 outside tree-rings	490-392	748-386
7.	Ua-12971	2420 ±45	-20.02	6	textile	752-402	762-394
8.	Le-5189	2385 ±25		10	wood, 20 central tree-rings from 130	482-396	516-392
9.	Le-5136b	2380 ±30		10	wood, 20 outside tree-rings from 90	486-392	748-388
10.	Le-5136a	2375 ±30		10	wood, 20 middle tree-rings from 90	482-392	522-386
11	Ua-12968	2425 ±45	-21.03	10	leather	752-404	762-396
12	Le-5212	2435 ±25		15	wood, single log	746-410	756-404
13	Bln-4924	2431 ±32		15	wood	748-496	760-398
14	Le-5211b	2365 ±35		15	wood, 30 central rings from 90	482-386	748-376
15.	Le-5211a	2300 ±35		15	wood, 20 outside rings from 90	398-260	402-208
16	Ua-12972	2450 ±45	-21.57	15	textile	758-410	764-404
17	Le-5213	2480 ±30		15	wood, from outside log	762-524	768-416
18	Le-5215	2360 ±39		16	wood	486-380	752-266
19	Bln-4925	2329 ±32		16	charcoal	402-380	405-388
20	Le-5188	2350 ±20		19/1	wood, 40 outside rings from 120	401-393	405-388
21	Le-5196	2510 ±25		20	wood, log about 100 rings	768-548	784-528
22	Le-5206	2410 ±25		20	wood, 18 outside rings from 100	510-404	752-398
Teyplaya barrow							
23	Le-5132	2490±60		2/1	charcoal	766-524	784-412
Kopto barrow							
24	Le-5220	2500 ±60		2/1	wood	770-528	792-412
25	Le-5224	2500 ±60		2/5	wood	770-528	792-412
26	Le-5216	2480 ±60		2/1	wood	764-424	772-410
27	Le-5217	2380 ±25		3/1	charcoal	476-394	514-390
28	Le-5221	2430 ±40		3/3	charcoal	752-406	762-398
29	Le-5218	2420 ±25		vertical camera	charcoal	514-406	752-402
30	Le-5219	2460 ±25		4/1	charcoal	758-416	762-410
31	Le-5222	2440 ±30		2/4	charcoal	752-410	760-402
32	Le-5225	2525 ±20		3/4	wood	777-555	787-546

* - all calibrated interval.

Tab. 1 : The list of ^{14}C dates of the Scythian time barrows for the Central Asia region of Russia.

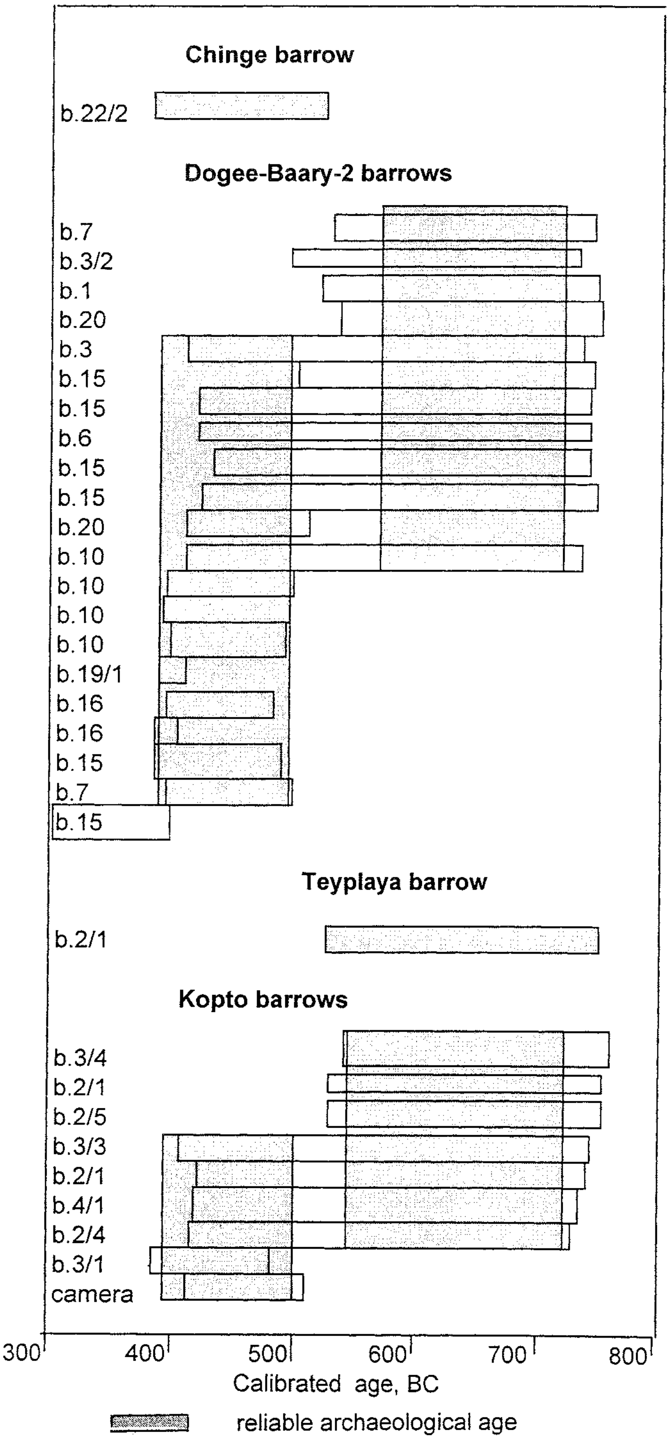

Fig. 2 : Intervals of calibration time of ^{14}C dates for the monuments investigated.

construction. The dates for the monuments of the uyuk-sagly culture (Teyplaya, Dogee-Baary-2 and Chinge) testify about more long time of their existence and about the some earlier time of their forming. The age of the aldy-bel complex of the Kopto barrow is closely to the age of the earlier Dogee-Barry-2 and Teyplaya barrows. All dates confirmed the archaeological assumption that at the Tuva region two burials traditions co-existed in the end of the 4th century BC. All nine dates for the Kopto barrows well correspond with the traditional archaeological chronology of the aldy-bel culture. These dates confirm the short period of the Kopto complex development.

It is necessary to note that the time of the origin and development of the scythian type cultures in Eurasia fall into the period of climatic changes. The calibration curve has a complicated character caused by the fluctuation of the ^{14}C concentration in the atmosphere. This time is the transition from Subboreal period to Subatlantic period (2800- 2500 BP) and it is characterised of the high rate of climatic changes (Nesje Atle, 1992).

CONCLUSION

^{14}C dating gives a possibility to work out the detailed chronology for some scythian cultures in Central Asia. New radiocarbon dates show the existence of chronological gap between the dates of the Arzhan barrow and the barrows of the earlier stage of the aldy-bel culture. Probably, this gap should be filled with some early aldy-bel cultures complexes. Unfortunately, at the moment there are no samples for radiocarbon dating from these complexes at our disposal.

ACKNOWLEDGEMENTS

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NEW INVESTIGATIONS ON THE CHRONOLOGY OF THE KEY SITES OF THE SCYTHIAN EPOCH IN THE SAYAN-ALTAI

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Abstract : The great barrows of the Sayan-Altai remain a major centre of interest, as they make it possible to resolve the outstanding problems of the origin, development and spreading of Scythian-Sarmatian cultures in Eurasia. Among these the Arzhan barrow is the key because it reflects the earlier stage of Scythian cultures for whole Eurasia. This article presents radiocarbon dates produced by several ^{14}C laboratories. To determine the calendar time interval for the construction of the barrow, we applied a statistical method. The most acceptable calendar interval is 800-820 BC, in agreement with archaeological data and previous results.

Résumé : Les grands tumulus de Sayan-Altai sont toujours d'un grand intérêt scientifique car ils permettent de résoudre les problèmes de l'origine, du développement et de l'extension des cultures "Scitho-Sarmates" en Eurasie. Parmi ceux-ci, le tumulus d'Arzhan est un site clé car il reflète les premiers stades des cultures "Scythes" dans toute l'Eurasie. Cet article présente les dates ^{14}C produites par plusieurs laboratoires ^{14}C à différentes périodes.
Pour déterminer l'intervalle de temps calendaire nécessaire à la construction du tumulus, nous avons appliqué une méthode statistique.
L'intervalle de temps calendaire le plus acceptable est 800-820 B-C en accord avec les données archéologiques et les résultats précédents.

Key-words : Elite barrows, Sayan-Altai, Scythian cultures, Arzhan barrow, chronology, calendar age, calibration curve, statistical analysis.

Mots-clés : Tumulus, Sayan-Altai, cultures "Scythes", tumulus Arzhan, chronologie, âge calendaire, courbe de calibration, statistiques.

INTRODUCTION

The major barrows of the Sayan-Altai remain in the centre of scientific interest as they make it possible to resolve the outstanding problems of the origin, development and the spreading of Scythian-Sarmatian cultures in Eurasia. The chronological problems are already under discussion for more than 50 years already (Archaeology of the USSR, 1992).

The first ^{14}C dates for the Arzhan and Pazyryk barrows were obtained in the 1960s (Butomo, 1965). A floating tree-ring scale encompassing some 600 years was developed in the 1960s - 80s for the major barrows including Arzhan, Tuekta, Shibe and Pazyryk 1-5 (Marsadolov 1988, 1996). To determine the zero year in the floating tree-ring scale and thus to establish the calendar time scale, a combination of radiocarbon and tree-ring dates have been used. Since the introduction of calibration, the older calendar dates for the construction time of the key sites in the Sayan-Altai have been revised. This was obtained by the correlation of the tree-ring and radiocarbon chronologies. The use of calibration curves made it possible to define the zero year of the floating tree-ring scale more accurately as 400±40 calBC (Marsadolov *et al.*, 1994 ; Zaitseva *et al.*, 1996).

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Later, a statistical method was used to estimate the confidence level in the correlation of the tree-ring- and radiocarbon dates. The initial age estimate was based on dates obtained about 15 years ago (Zaitseva *et al.*, 1997). New radiocarbon dates were obtained in 1996 for the samples from the floating tree-ring scale. The dates produced by the Radiocarbon Laboratory of the Institute for the History of Material Culture (St.Petersburg) and the Centre for Isotope Research (Groningen University) served as a basis for a new chronological determination (Zaitseva *et al.*, 1997a). We used a χ^2-test for calculating the chronological probability intervals for the Arzhan, Tuekta-1 and Pazyryk-5 barrow sequences (Zaitseva *et al.*, 1997, 1997a, 1998).

The chronological position of the Arzhan barrow remains one of the main topics of investigation, because it is the key for the earliest stage of Scythian cultures in whole Eurasia. The latest investigation on the chronology of the Arzhan barrow's construction was conducted by Chlenova (1996) and was based on both archaeological evidence and ^{14}C dates produced by the Radiocarbon Laboratory of the Geological Institute (Moscow). According to these data, the age of the Arzhan barrow is considered to be 7^{th}-6^{th} centuries BC (Chlenova, 1996), contradicting results obtained earlier (Marsadolov *et al.*, 1994 ; Zaitseva *et al.*, 1997, 1997a), opening again old discussions. We report here on a continuation of research on the chronology of the Arzhan barrow construction, based on the both "old" and "new" ^{14}C data.

RESULTS AND DISCUSSION

Previously, we have analysed the results of the ^{14}C measurements for the Sayan-Altai barrows Arzhan, Tuekta and Pazyryk (Zaitseva *et al.*, 1997, 1997a, 1998) using a χ^2 (chi-square) criterion for calculating the calibrated age. Three mathematical models were considered for the connecting the ^{14}C dates with the floating tree-ring scale, and to establish the zero position for the tree-ring scale. Alternatively, we considered a model where the ^{14}C determinations did non connect with tree-ring scale. For this model we obtained the best result. The age of the barrows using this model is shown in table 1.

We used the cross-section of logs from the barrow construction. Therefore, the time passed from the moment of the wood usage could be calculated from the outer treerings. We assume that the wood for the barrow construction was used during a time interval smaller than the error of the ^{14}C measurement. This is true, if the number of measured samples is not large and if all structures of the barrow constructions were erected at the same time.

We note that we used only eight ^{14}C dates for the Arzhan barrow. In the investigations of Chlenova the ^{14}C dates were used (Chlenova, 1996), and the same amount of ^{14}C dates were used by Hall for the chronological research of the Arzhan barrow (Hall, 1997). In the archives of the Radiocarbon Laboratory of the Institute of the History of Material Culture (St.Petersburg), there are 20 ^{14}C dates for the Arzhan barrow produced by this laboratory and others, including the ^{14}C dates produced during 1996-97. A full list of ^{14}C dates for the Arzhan barrow is shown in table 2.

All these dates used for our new investigation are discussed in this paper. Since in this case the number of ^{14}C dates is about 2 times more than used before, we expect to obtain qualitative new results. It is important to know whether the number of samples is moreless constant in time, or whether there are fluctuations. This was studied as follows. First, a histogram was constructed showing in which range of calendar time a certain number of samples is concentrated. For the histogram we took into consideration that a ^{14}C date can correspond with multiple calibrated dates, caused by "wiggles" in the calibration curve. We assume that we deal with several samples with a different calendar age, assigning a weight factor $w_i = 1/n$ to each sample ; 'n' is the number of intercepts with the calibration curve.

We define an index I_k as :

$$I_k = \sum_{i=1}^{k} w_i$$

The histogram describing the connection of the age of samples D_k with its index I_k is shown in figure 1 (curve 1). For further analysis it was necessary to smooth this relationship. We assume that the variables D and I are monotonous. Smoothing was carried out as the result of a minimization operation according to :

$$\Phi(f) = \sum_{k=1}^{N} \frac{(f(x_k) - y_k)^2}{\sigma_k^2} + \lambda \int^{N} \left(\frac{d^2 f(x)}{dx^2} \right)^2 dx$$

where *f(x)* is the smoothed curve, y_k -the mean of smoothed data, σ_k the error of y_k, and λ a parameter determining the smoothing efficiency. For *"f"*, we used a cubic spline function. Using this approach, we obtained the dependence *D=F(I)*, which is shown in figure 1 (curve 2).

Next, we inverted the dependence *D=F(I)* into *I=F(D)*, as shown in figure 2 (curve 1) (monotonous curve). The derivative *dI/dD* is the density of the number of samples on the single time interval. This dependence is shown in figure 2 (curve 2). It is interesting and unexpected that the *dI/dD* shows three maxima at 800, 820 and 900 BC. It is important, that according to these results including the majority of available ^{14}C dates, the age of the Arzhan barrow can not be younger than the beginning of the 8^{th} -

Barrow	Low chronological limit, BC	Probable chronological limit, BC	Upper chronological limit, BC
Arzhan	885	810	790
Tuekta-1	665	655	590
Pazyryk-5	410	380	335

Tab. 1 : Chronological intervals for barrows construction (95 % confidence).

N	Lab Index	^{14}C age, BP	Material. (No dendro-sample), total amount tree-rings	The tree-rings dated counting from the centre of log
1.	Le-5194^	2570±50	wood, single peg	
2.	Le-5144^	2590±90	wood,	30 middle rings
3.	GIN-8619	2600±40	wood, single peg	
4.	Le-4769	2610±40	wood	
5.	GIN-8425	2610±30	wood, single peg	
6.	GIN-8618	2620±40	wood, single peg	
7.	Le-5143^	2660±50	wood	
8.	Le-4772	2680±50	wood	
9.	Le-2312	2750±50	wood	18 rings
10.	Le-2311	2770±50	wood	
11.	Le-5141^	2790±40	bone, hoof	
12.	Le-2310	2800±50	wood	
13	Le-2449*	2740±40	D-38, 80 tree rings	36-60
14	Le-2444*	2790±40	D-38, 80 tree rings	15-35
15.	Le-2452*	2790±40	D-36, 126 tree rings	48-60
16.	Le-1698*	2770±40	D-36, 126 tree rings	1-25
17.	Le-5184*^	2670±25	D-36, 126 tree rings	97-126
18.	Le-5195a*^	2700±20	50 tree rings	39-50
19.	Le-5195b*^	2750±30	50 tree rings	21-38
20.	Le-5195c*^	2680±40	50 tree rings	1-20

^ - ^{14}C dates produced in 1996-97.

*- ^{14}C dates used for the pervious researches.

Tab. 2 : The list of ^{14}C dates for the Arzhan barrow.

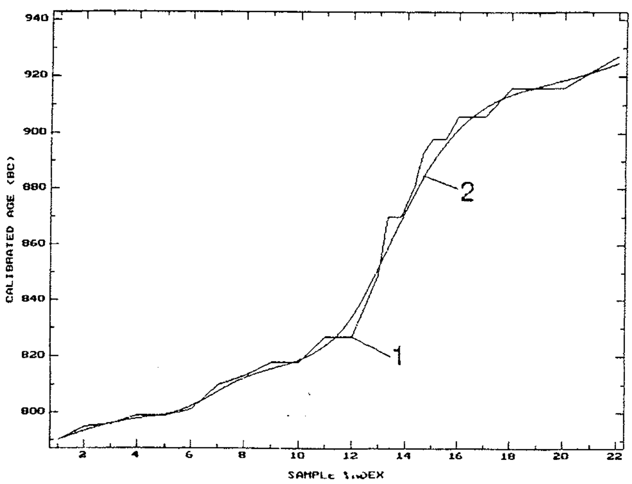

Fig. 1 : Histogram of the connection of the calendar age of ^{14}C date (D) with the Index I_k - curve 1- before smoothing, curve 2- the smoothed curve.

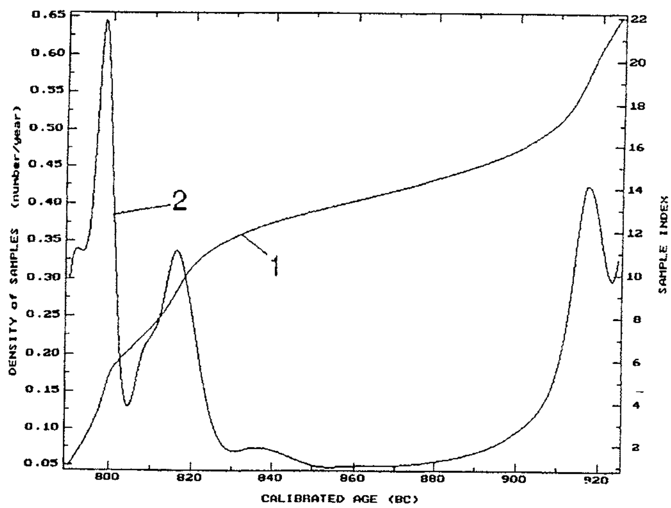

Fig. 2 : Histogram of connection of Index I_k with calendar age (D) (curve 1) and the results of differentiation of this function (curve 2).

the end of the 9th centuries BC, as was suggested by some researchers. The age of the Arzhan barrow in the intervals 800 - 820 BC based on both new ^{14}C dates and our new analysis is in agreement with our results obtained earlier, and also with the archaeological assessment of the age.

CONCLUSION

The analyses of ^{14}C dates produced for the Arzhan barrow at different times and by different radiocarbon laboratories, using a particular mathematical approach for the calculation of the calendar age shows that the age of this monument must be in the interval 800 - 820 BC, confirming earlier results.

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INTERPRÉTATION DE QUELQUES DATATIONS ^{14}C EN PROVENANCE DE MAHASTHAN, BANGLADESH

^{14}C Analysis for archaeological activities in Bangladesh

Jean-François SALLES, Shafiqul ALAM**, Marie-Françoise BOUSSAC*, Jean-Yves BREUIL***, Christine OBERLIN**** et Habibur RAHMAN***

Résumé : La contribution porte sur les fouilles franco-bangladaises de Mahasthangarh, au Nord-Bengale (Bangladesh). Après une brève présentation du site, on fait état des datations radiochronométriques recueillies à Mahasthan depuis 1993, les premières jamais effectuées sur un site archéologique du Bangladesh. Trois dates sont plus précisément étudiées dans leur contexte stratigraphique et historique : elles contribuent à mieux comprendre certaines phases-clefs de l'évolution de la ville de Mahasthan, et conduisent à quelques révisions des repères chronologiques traditionnels. Les collègues bangladais présentent un rapide panorama de l'archéologie de leur pays et expriment leurs besoins en datations au radiocabone.

Abstract : The paper deals with the new programme of French-Bangladeshi excavations at Mahasthangarh, North-Bengal, Bangladesh. After an overview of the archaeology and history of the site, reference is made to the radiocarbon datations collected from Mahasthan since 1993, the first ever realised and published in Bangladesh. Three dates are cautiously analysed in their stratigraphical and archaeological context : they contribute in shedding new light on some of the critical phases in the history of the ancient city, and lead to some revisions of the generally accepted chronological hallmarks. The Bangladesh archaeologists present an overview of the state of archaeology in their country, and express their needs in radiocarbon datations.

Mots-clefs : Archéologie de l'Inde, Bangladesh, période historique ancienne, Mahasthangarh, Chronologie Maurya et post-Maurya.

Key-words : Indian archaeology, Bangladesh, Early historic period, Mahasthangarh, Maurya and post-Maurya chronology.

L'objectif de cette contribution est seulement de présenter quelques repères radiocarboniques en provenance du site archéologique de Mahasthan, au Nord Bengale (fig. 1), ce qui constituera une première publication de datations effectuées au Bangladesh (*voir la contribution des collègues bangladais, ci-dessous*). La fouille inachevée et son interprétation en cours n'autorisent pas encore que soit établie une séquence ^{14}C continue pour l'ensemble du secteur exploré (fouille du «Rempart Est») — *voir le tableau de dates en annexe* —, encore moins pour le site entier, vaste d'1,5 km^2 (fig. 2) ; on manque de données ^{14}C pour les niveaux supérieurs où rien d'organique n'avait été préservé. Les conditions de survie des matériaux organiques sont en effet particulièrement néfastes dans un milieu lessivé chaque année par d'abondantes pluies de mousson qui stagnent dans une sorte de « baignoire », le site étant fermé par un haut rempart (jusqu'à 20 m par endroits) de près de 5 km de périmètre. Les écarts de température peuvent également avoir joué un rôle. Plusieurs échantillons recueillis dans des couches profondes se sont révélés en laboratoire n'être que de la terre noircie, sans carbone.

Mais une étude des résultats disponibles conduit à quelques révisions de l'histoire traditionnelle du site, qui devront être vérifiées au cours des recherches à venir.

L'histoire de Mahasthan est fondée sur un petit nombre de références textuelles dans les sources sanskrites, ainsi que sur des fouilles régulières effectuées en 1929-1933 par l'*Archaeological Survey of India*, en 1960-61 et 1968-69 par le *Department of Archaeology and*

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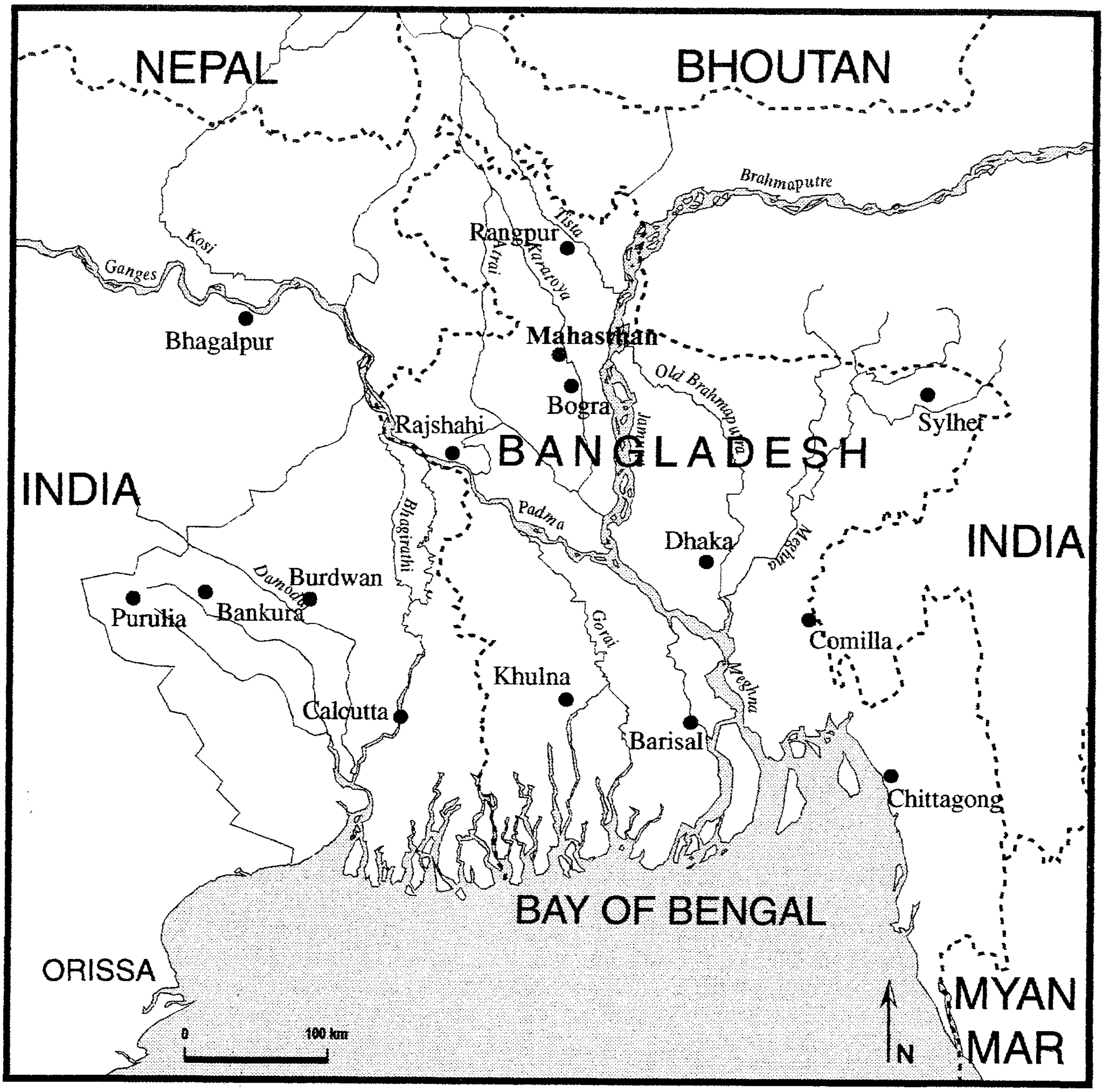

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Fig. 1 : Carte du Bangladesh (© Séverine Sanz).

Museums du Pakistan, et, plus sporadiquement depuis 1971, par le Directorat de l'Archéologie du Bangladesh : aucune de ces fouilles n'est publiée. Quelques rapports préliminaires peuvent être trouvés dans les *Annual Reports* de l'*ASI* et dans *Pakistan Archaeology*. Toutes les données sont rassemblées et résumées dans ce qui reste l'« ouvrage » de référence (en fait, un plaquette de 64 p. et XIX pl.), Ahmed, 1975, et dans une compilation ultérieure : Chakrabarti, 1992. Pour les premiers résultats de la fouille franco-bangladaise, voir Salles, 1995.

On résumera ci-dessous les données généralement admises.

• La ville (*Pundranagara*) aurait existé dès la fin du IV^{e}/début du III^{e} s. av. J.-C. comme « point fort/capitale régionale » de l'empire Maurya sur sa frontière orientale, en arrière du Brahmapoutre dont le cours était sans doute situé nettement plus à l'est : la ville était bordée par une importante rivière aujourd'hui sèche, la Karatoya. C'est de cette époque que daterait le premier rempart.

Sources : une inscription en écriture brahmi sur un fragment de pierre, document recueilli en surface dans les années trente (dates proposées : début du III^{e} s. ou milieu du II^{e} s. av. J.-C.) ; de la céramique à vernis noir caractéristique de l'époque Maurya (*Northern Black Polished Ware* — dates proposées : 600 - 50 av. J.-C.), et des monnaies à poinçons multiples (*punch-marked coins*) d'époque Maurya, dont certaines séries ont été émises jusqu'à la période Shunga et ont circulé jusqu'au début du II^{e} s. ap. J.-C. Aucun niveau archéologique construit daté de cette époque n'a été retrouvé nulle part dans le site.

• La phase post-Maurya (à partir du début du II^{e} s. av. J.-C., périodes dites shunga et kouchane en Inde gangétique, jusqu'au II^{e} s. ap. J.-C.) n'a pas livré de vestiges architecturaux bien reconnaissables (une seule référence dans le rapport de la fouille 1960-61). Mais du

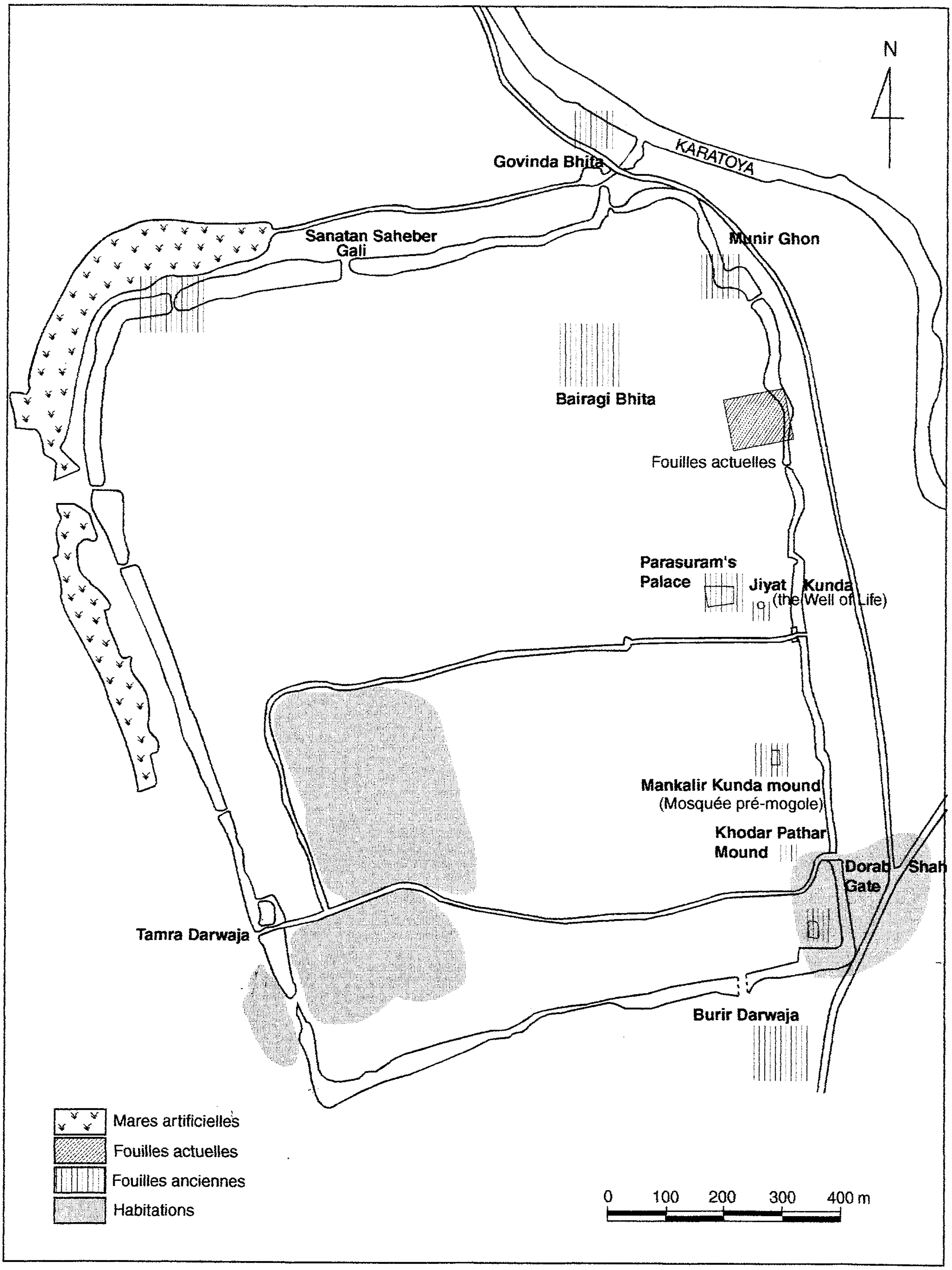

Fig. 2 : Croquis schématique du site et localisation de la fouille du «Rempart Est» (© Séverine Sanz et Sabine Sorin).

matériel caractéristique de ces époques a été recueilli en grandes quantités dans toutes les anciennes fouilles : terres cuites de style shunga ou kouchane, monnaies moulées en cuivre, perles en pierre dure, etc. Le rempart est massif dès cette époque. Aucune donnée historique n'existe sur le Bengale de cette période (dynasties ? monnayages ?).

• A partir du IV^{e} s. ap. J.-C., l'empire Gupta (IV^{e}-VI^{e} s.) étend sa domination sur cette partie du Bengale, et la ville est réputée florissante (*cf.* la visite à Pundranagara du moine-pélerin chinois Huien Tsiang au VII^{e} s.), bien que les données archéologiques ne soient pas à la hauteur de cette réputation : niveaux inférieurs des temples de Govinda Bhita et de Bairaghi Bhita (?), rempart... Peu de matériel bien daté de cette période a été retrouvé, mais on voit apparaître la statuaire en pierre (musées de Mahasthan et de Rajshahi).

• On n'évoquera pas ici les phases ultérieures de l'histoire du site, brillante sous les dynasties Pala (VIII^{e} - X^{e} s.) et post-Pala (X^{e} - XII^{e} s.) avant la conquête islamique au début du XIII^{e} s., puis une phase «Islamique Ancienne» mal définie (XIII^{e} - XIV^{e} s.).

Depuis la reprise d'une fouille franco-bangladaise à Mahasthan en 1993, douze datations ont été effectuées au Laboratoire de Radiocarbone de Lyon (toutes les dates et leur contexte sont présentées dans le rapport préliminaire 1993-1998, sous presse à Dhaka). Une seule date archéologique (charbon de bois) paraît peu cohérente avec son environnement stratigraphique, sans doute mal compris. Toutes les autres fournissent des informations positives sur les niveaux dans lesquels ont été recueillis les échantillons. On a volontairement choisi ici de n'étudier de manière détaillée que trois dates, parce qu'elles permettent de mieux évaluer quelques charnières historiques de l'archéologie régionale.

Ly 8304 (1997). Résultat : 1590 ± 55 BP ; intervalle calibré : + 361 - + 594. ; maximum probabilités : 444, 490, 594 ap. J.-C.

Charbon de bois. Carré D5, fosse 613, unit. strati 97-52 [19,71 - 19,65 m], fouille Jean-Yves Breuil. On peut associer au contexte des niveaux intermédiaires **Ly 6717** (1993). Résultat : 1760 ± 75 BP ; intervalle calibré : + 109 + 461. ; maximum probabilités : 257, 295, 319, 370 ap. J.-C. Charbon de bois, carré D6, unit. strati 15 [21,67 - 21,29 m], fouille Marie-Françoise Boussac.

L'échantillon **Ly 8304** provient d'une fosse d'extraction identifiée en 1997. Utilisée ensuite comme dépotoir, elle était remplie de matériel stratifié où a été recueilli le charbon de bois. Le temps qui s'est écoulé entre le creusement de la fosse et son comblement est sans doute réduit : les murs coupés par la fosse et ceux qui la recouvrent sont décalés en altitude de moins de 0,50 m à leur base, et appartiennent à deux niveaux successifs (niv. 12 et 13). La date ^{14}C est donc sans doute peu (?) antérieure au scellement de la fosse 613, et/ou peu postérieure à son creusement.

Les niveaux recouvrant la fosse témoignent d'une construction soignée bien que modeste, qui se retrouve dans tous les vestiges au-dessus ; ce sont les *niveaux supérieurs* du site, relativement bien préservés. Par contre, ceux qui ont été coupés par la fosse constituent la séquence stratigraphique et architecturale la plus perturbée du secteur exploré, *niveaux intermédiaires* qui n'ont livré que des lambeaux de sols et de murs. Si l'on interprête bien la date **Ly 8304**, la transition entre les niveaux intermédiaires et les niveaux supérieurs se situerait donc vers la fin, ou peu de temps après la fin du VI^{e} s. ap. J.-C. On verra plus loin les implications historiques de cette donnée.

Ly 6718 (1993). Résultat : 1845 ± 50 BP ; intervalle calibré : + 84 - 316 ap. J.-C. ; maximum probabilités : + 153, + 212. « La date est très limitée autour de la deuxième moitié du II^{e} s. ap. J.-C. » (*commentaire du laboratoire*).

Charbon de bois. Carré D6, unit. strati 20 [21,07 - 20,94 m], fouille Marie-Françoise Boussac.

L'échantillon provient d'un sol bien agencé en fragments de briques formant un dallage. Ce sol n° 14A a été trouvé à la base des niveaux intermédiaires perturbés signalés ci-dessus. En cet endroit précis du site (carré D6), les vestiges architecturaux des niveaux 11 (= sol 14A) et 10 sous-jacent sont peu représentatifs ; dans les carrés mitoyens, les niveaux 10 et 11 marquent la phase finale d'une succession de beaux sols dallés en briques, empilés sur environ 1,30 m d'épaisseur. Riche de cinq niveaux d'occupation (niv. 7 à 11 : nombreux dallages et restes de murs), la séquence des *niveaux inférieurs construits en brique* offre une réelle homogénéité des techniques architecturales et une grande cohérence dans les trouvailles matérielles : fragments de figurines en plaque (terre cuite) de syle shunga ou kouchane, poteries de type *Northern Black Polished* que Sandrine Elaigne ne date pas plus tard que la fin du I^{er}/ début du II^{e} s. ap. J.-C. (Elaigne, 1996).

Note : la désignation générique des niveaux (en italique) tente de simplifier une stratigraphie complexe de 17 phases d'occupation. Sous les niveaux inférieurs construits en brique, on trouve 4 phases où les vestiges d'occupation sont en *terre crue* (niv. 3 à 6), puis deux phases de *fosses d'extraction*, sans construction reconnue (niv. 1-2).

Les niveaux intermédiaires du secteur «Rempart Est» de Mahasthan semblent donc bien calés par les dates **Ly 6718** (date inférieure) et **Ly 8304** (date supérieure), entre la deuxième moitié/ fin (?) du II^{e} et le VI^{e} s. ap. J.-C. On a souligné plus haut le caractère très évanescent de ces niveaux intermédiaires. Historiquement, donc, si elle a vraiment existé dans ce secteur précis de la ville, la « grande » phase Gupta de l'histoire de Mahasthan n'y a laissé aucune sérieuse trace archéologique. Un commentaire semblable pourrait être formulé à propos du grand site voisin (moins de 100 km) de Bangarh, au Bengale occidental (Chattopadhyaya, 1993-1994) : les traces stratigraphiques de l'époque Gupta en Nord-Bengale demeurent incertaines.

Ly 7256 (1994). Résultat : 2240 ± 40 BP ; intervalle calibré : - 371 - 173 av. J.-C. ; maximum probabilités : - 351, - 305, - 229, - 206 av. J.-C.

Charbon de bois. Carré D6, unit. strati 72 [20,47 - 20,18 m], fouille Marie-Françoise Boussac. On peut associer au même contexte **Ly 7258** (1994). Résultat : 2195 ± 50 BP ; intervalle calibré : - 367 - 85 av. J.-C. ; maximum probabilités : - 329, - 229, - 199, -129 av. J.-C. Charbon de bois, carré D6, unit. strati 78 [20,18 - 19,82 m, sous unit. strati 72], fouille Marie-Françoise Boussac. Un changement net de contexte se rencontre à l'altitude *ca* 19,50 m, niveau 6.

En cet endroit de la fouille (carré D6, fig. 3), le niveau 7 d'où proviennent les dates n'a pas fourni de vestiges architecturaux extensifs et cohérents ; d'autres traces de la même phase sont mieux conservées dans les carrés voisins, ce qui permet de définir l'ensemble stratigraphique en question. On se trouve incontestablement à la base des *niveaux inférieurs construits en bri-*

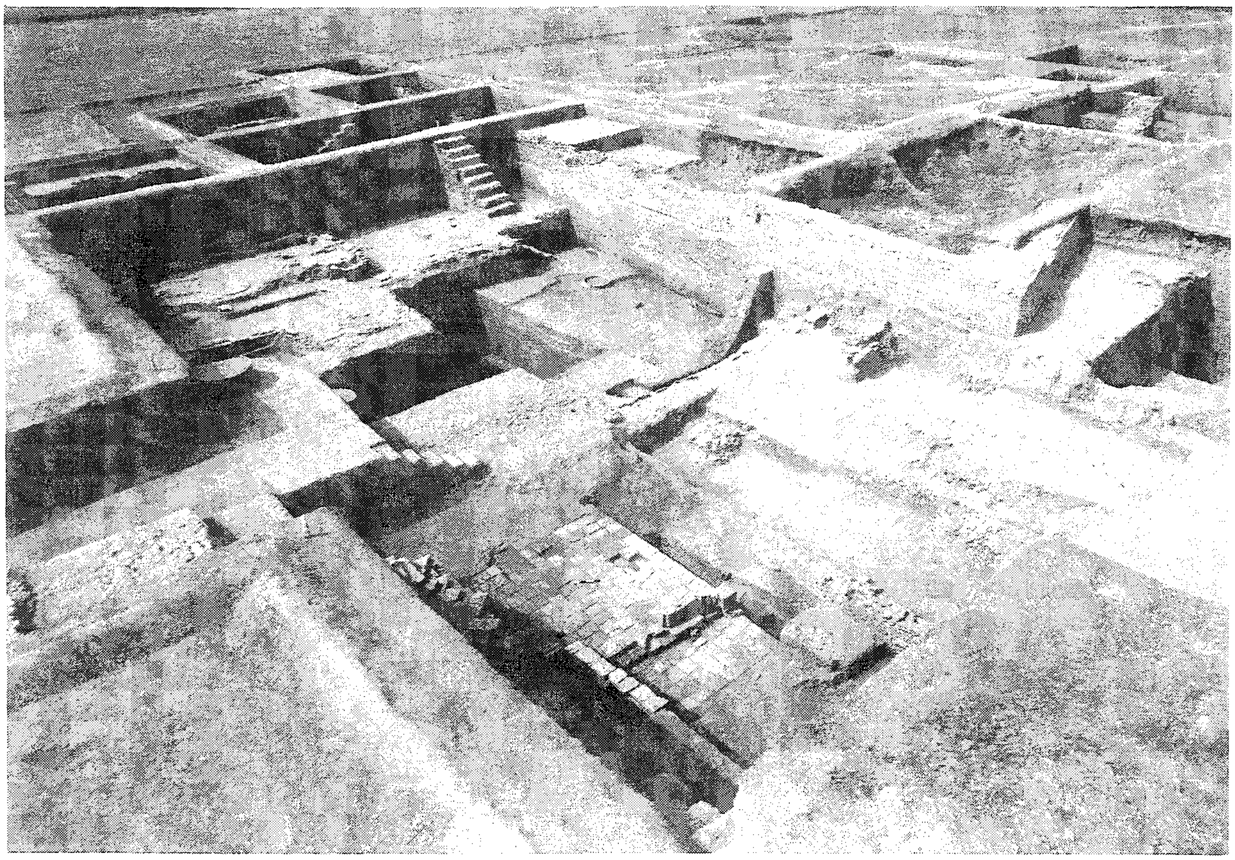

Fig. 3 : Vue générale du sondage profond (© Mission archéologique française à Mahasthan).

que, au-dessus d'épais sols d'argile verte (vers l'altitude 19,50/ 19,70 m) qui marquent le sommet des *niveaux profonds à occupation en brique crue* (niveaux 6 à 3). L'abondant matériel issu des niveaux construits en brique est aisément identifiable dans le contexte archéologique indien, par exemple (parmi des dizaines d'autres) :

— **MAH.94/521**, monnaie moulée en cuivre, carrée (1,2 x 1,4 x 02 m), en bon état. Au droit : à dr., éléphant vers la g., échelle sous l'éléphant, swastika et symbole taurin au-dessus de l'éléphant ; à g., étendard à couronnement triangulaire. Au revers : à dr., arbre dans une grille avec un symbole taurin au-dessus ; à g. colline à triple arche avec un croissant au-dessus, croix creuse en-dessous. L'émission de ce type est assigné à la période Maurya tardive, mais sa circulation se prolonge jusqu'au début de l'époque kouchane, II^{e} s. ap. J.-C. (catalogue des monnaies de Mahasthan [M.-F. Boussac], *rapport sous presse à Dhaka*. Réf. : Allan, *BMC, India*, pl. XI, n° 8-10 ; Bopearachchi-Pieper, 1998, p. 75, n° 7-8 ; au Bengale (Asutosh Museum), Sarmadhikari, 1984, p. 45 (Class IB) à Kausambi, Sharma, 1969, p. 87 n° 8. Voir aussi Mitchiner, 1978, p. 548, cat. 4290-4295 et 4301-4302).

— **MAH.94/660**, figurine en plaque, terre cuite, de style Maurya tardif ou post-Maurya (shunga) : personnage féminin déhanché, III^{e} s. av. J.-C. - I^{er} s. ap. J.-C. (fig. 4) ; voir Narain, 1978 pour des trouvailles semblables à Rajghat (Type XVI, sub-type VI, pl. XXVIII, p. 101, n° 181-183. Maurya-Sungha = Period IC (3rd-2nd B.C.) and I (2nd B.C.-1st A.D) ; et Singh, 1994, à Nahran (pl. XXII, 3), p. 143-144.

La cohérence entre les datations radiochronométriques et les dates traditionnellement attribuées aux divers types de matériel trouvé dans ces niveaux permet ainsi de caler une riche et épaisse période d'occupation entre la fin du III^{e}/début du II^{e} s. av. J.-C. et le milieu/fin (?) du II^{e} s. ap. J.-C. Une phase semblable et tout aussi prodique

Fig. 4 : Figurine en terre cuite, époque Maura tardive ou post-Maurya (MAH.94/660), III^{e} s. av. J.-C. - I^{er} s. ap. J.-C. (© Mission archéologique française à Mahasthan).

en matériel de qualité est connue dans quelques sites du Bengale occidental, Chandraketugarh et Tamluk, au sud de Calcutta : nous l'appellerons résolument post-Maurya, pour évacuer toute ambiguïté historique — dans la mesure ou aucune donnée « politiquement » shunga ou kouchane n'existe pour le Bengale.

On le voit, les données traditionnelles sur le développement historique de Mahasthan doivent être revues à la lueur des trouvailles archéologiques récentes, confortées par les datations ^{14}C. La comparaison n'est pas toujours facile à établir avec d'autres sites de la vallée du Gange, dans lesquels l'interprétation des résultats radiochronométriques est souvent difficile (dates non calibrées). Il n'en est que plus satisfaisant de trouver des horizons archéologiques contemporains offrant des dates calibrées comparables à celles de Mahasthan. Tel est le cas à Anuradhapura, au Sri Lanka (Coningham, Allchin, Batt, Lucy, 1996). Dans cette capitale intérieure de l'île, les *Periods* G et H sont datées par le radiocarbone de 200 av. J.-C à 130 ap. J.-C. : l'architecture (niveau H) y est caractérisée par l'utilisation de dallages en briques et l'usage de tuiles, et le matériel archéologique (en provenance d'une série de sondages-tests) inclut de la *Rouletted Ware*, de la céramique à vernis noir (*NBPW*), des vases de type *Arikamedu 10*, etc., dans une ville qui s'étend sur quelque 70 ha (*ibid.* ; 83). Il serait sans doute vain de vouloir poursuivre la comparaison entre Mahasthan et Anuradhapura — même si leurs positions respectives à la lisière de l'empire Maurya et leurs relations incertaines avec le «centre» y inciteraient —, mais il faut bien reconnaître la contemporanéité radiochronométrique d'horizons archéologiques assez semblables aux deux extrémités de la Baie du Bengale.

^{14}C ANALYSIS FOR ARCHAEOLOGICAL ACTIVITIES IN BANGLADESH

Though it is a small country in the world map, the cultural history of Bangladesh is one of the greatest and glorious heritage for which we the Bangladeshi are legitimately proud of. Its archaeological treasures are immense. Our activities in the field of archaeology goes back to more than a century. But most of these activities are concentrated only to historical period : the prehistory and early history of Bangladesh are still very obscure. As a result of traditional archaeological works, enormous archaeological wealth of historic period have come to light. These are in the shape of cities, palaces, monasteries, temples, stupas, mosques, mausolea, roads, bridges etc., scattered all over the country. Now it is almost known that this territory was inhabited not only in early historic period but in prehistoric period too. But due to absence of any radiometric date we do not know much of this absolute chronology both for prehistoric and historic periods.

Though sporadic prehistoric evidence had been reported earlier (prehistoric artifacts collected from Sitakund, Chittagong, Chagalnayya in Feni district, and Wari Bateswar in Narshingdi district), no systematic study was made before 1989. Dilip Chakrabarti and his team discovered a number of artifacts of fossilwood from Lalmai hill range of Comilla district. He defined these artifacts as "mixed industry comprising both Acheulean and Upper Palaeolithic elements" (Chakrabarti, 1992). In 1991, Shafiqul Alam carried out an intensive exploration in some areas of the Lalmai-Mainamati Hills and conducted a small scale excavation, collecting 240 artifacts. He defined this industry as "Neolithic" (Alam, 1992). A recent ^{14}C analysis of fossilwood made by the Chittagong University has given a date 16,333 years BP. It indicates that fossilwood industry must have developed after 12,000 yrs. BP and most probably in the Holocene period, *i.e.* within 10,000 yrs. BP : this supports Alam's view. But it can be said more firmly only if we get some more ^{14}C dates from Lalmai-Mainamati area and other prehistoric sites of the country.

It has already been mentioned that enormous ruins of early historic and medieval periods were discovered throughout the country. Among these the famous city sites are Mahasthan, Mainamati, Savar, Gour, Sonargaon, Bagerhat and Barobazar, etc. Among individual specialized sites, Paharpur deserves a special mention. The city sites of Muslim period like Gour, Sonargaon, Bagerhat and Barobazar do not pose much problems regarding their dates as we know more or less of the rise and fall of these cities through inscriptions and other cultural material. But fixation of absolute chronology in the case of city sites like Mahasthan and Mainamati, even the single site like Paharpur where several dynasties have ruled for a long period, or cultural debris of several building phases of the same dynasty have been exposed is really a problem.

For instance, we know by the chance discovery of an inscription that the date of Mahasthan, the ancient most and largest fort city of Bangladesh, goes back to the 3rd century B.C. But it is not sure that this was the earliest date of this city. We are not sure whether this city was founded by the Mauryans as their provincial capital as a completely new site, or whether it was built over the remains of an earlier period. If the later happens the earliest date may go further back. The city underwent several building and rebuilding phases. Only the relative dates of these phases have been given on the basis of cultural material. Similar problems we face when we try to fix the chronology of the huge suburbs which were developed 8 km around the fort city. Some important building remains like Vasu Bihar, Bihar, Gokul Madh, Mangalkot, Godai Bari Savar, have been exposed during the last sixty years. These sites also have been inhabited by several dynasties. In these case also only an attempt has been made to assign relative dates of each level very tentatively. No precise date for these sites could be given due to absence of radiometric analysis.

We know that the largest single monastery of Paharpur in Bangladesh was built by the great Pala emperor Dharmapala in the mid-8th century A.D. Like other establishments this gigantic monastery also underwent several building phases. Its chronology has been fixed from the 8th century onwards. But we do not know accurately when its major occupation levels were rebuilt. Our deep diggings in some areas of the monastery and in the central shrine in 1982 and 1983 clearly showed that the actual monastery was built over the remains of an earlier structure (Alam, 1982). Here we may recall the discovery of a 5th century A.D. copperplate grant which records the donation of lands by a Brahmin couple for a Jaina monastery located at Botgohali. It is not possible to know the nature and plan of the establishment associated with the remains exposed below the present monastery unless a considerable portion of the upper one is dismantled ; no datable material could be recovered from the limited excavations mentioned above. But these earlier materials could accurately be dated by ^{14}C analysis.

In Mainamati, the capital of ancient Samatata kingdom in the eastern part of Bangladesh, ruins of a series of religious establishments like Salban Vihara, Ananda Vihara, Kutila Mura, Charpatra Mura, Rupban Mura, Itakhola Mura, Bhoj Raja, Ranir Banglow, etc. have been exposed by regular excavation since the middle of this century. These excavations have revealed a long cultural sequence of several dynasties ranging from the 6th to the 13th centruy A.D. Again all these establishments showed several building phases. A substantial amount of architectural remains have been exposed in the upper levels, but those of the lower levels could not be exposed due to upper structures ; cultural material of these levels are scant. So we are not sure of the lower levels and their inhabitants (*e.g.* excavation conducted in the lower levels of Salban Vihara and Anada Vihara). Had there been any ^{14}C analysis of the earlier levels, we would have been sure of the chronology of the sites.

Recently, the Directorate of Archaeology welcomed the idea of a Bangladesh-France joint venture in Mahasthangarh. An agreement was signed by the two governements, and a joint excavation started at Mahasthan, Bogra on 2nd February, 1993. The project jointly carried out by the two teams is located close to the eastern rampart wall of Mahasthan, inside the fortified ancient city. It continues for about one to four months every year. The result of the expedition is very encouraging, and the excavation programme has now become a regular feature.

Among the scientific analysis of the antiquities of this joint venture, ^{14}C analyses are presented in the above paper.

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Unité stratigraphique	Nature échantillon	Code laboratoire	Date en années B.P.	Intervalle après correction
F 613	charbons	Ly-8304	1590 ± 55	(361, 594) ap.J.-C.
F 610	charbons	Ly-8305	1970 ± 50	(-60, 172) av./ap. J.-C.
UF 206	charbons	Ly-7392	2210 ± 40	(-366, -162) av. J.-C.
UF 190	charbons	Ly-7391	2195 ± 55	(-370, -72) av. J.-C.
UF 163	charbons	Ly-7390	1265 ± 75	(662, 949) ap.J.-C.
UF 78	charbons	Ly-7257	2195 ± 50	(-367, -85) av. J.-C.
UF 72	charbons	Ly-7256	2220 ± 40	(-371, -173) av. J.-C.
UF 19	charbons	Ly-6720	1885 ± 95	(-84, 370) av./ap. J.-C.
UF 18	charbons	Ly-6719	1895 ± 50	(20, 239) ap.J.-C.
UF 19/20	charbons	Ly-6718	1845 ± 50	(84, 316) ap.J.-C.
UF 15	charbons	Ly-6717	1760 ± 75	(109, 461) ap.J.-C.

Tableau des dates ^{14}C de Mahasthan, Bangladesh.

Actes du colloque « C14 Archéologie », 1998, p. 327-332.

CHRONOSTRATIGRAPHIE DES GISEMENTS ARCHÉOLOGIQUES ET PALÉONTOLOGIQUES DE SAO RAIMUNDO NONATO (PIAUI, BRÉSIL) : CONTRIBUTION A LA CONNAISSANCE DU PEUPLEMENT PLÉISTOCÈNE DE L'AMÉRIQUE

Fabio PARENTI, Michel FONTUGNE**, Nièdè GUIDON***, Claude GUERIN****, Martine FAURE***** et Evelyne DEBARD*******

Résumé : Le radiocarbone a largement contribué à la mise au point d'une première synthèse stratigraphique de l'Aire archéologique de São Raimundo Nonato (Sud-Est du Piaui), où environ 400 sites archéologiques ont été inventoriés, dont les deux tiers, d'âge holocène, sont connus pour leur art rupestre.

La Toca do Boqueirão da Pedra Furada présente une séquence chronologique qui commence à plus de 50000 + 5 000 ans BP (datations non calibrées) ; ce gisement, qui a livré une riche industrie lithique et de nombreux foyers, est un site-clé pour la connaissance du premier peuplement de l'Amérique. D'un point de vue culturel, on y observe une succession entre la Phase Pedra Furada, pléistocène, et la phase Serra Talhada, d'âge Holocène inférieur. La première est comprise entre plus de 50 000 et 11000 ans BP. La deuxième (11 000 - 5 000 ans BP) est caractérisée par une forte augmentation du nombre des sites, par l'affirmation de la pratique picturale et par une utilisation plus intensive du territoire, ainsi que par un travail de la pierre de plus en plus élaboré.

Les données sédimentologiques et culturelles ainsi obtenues ont été corrélées avec d'autres gisements de la région (Toca do Garrincho et Toca da Janela da Barra do Antonião), implantés dans un environnement karstique et renfermant une faune de mammifères que sa nature, sa biodiversité et son abondance nous conduisent à dater du Pléistocène supérieur. L'industrie lithique provenant de ces sites karstiques présente des ressemblances avec celle de l'Holocène ancien de la Pedra Furada. Le problème de la corrélation entre la présence humaine et cette faune est donc posé.

Abstract : Radiocarbon largely contributed to the first synthesis on the São Raimundo Nonato archaeological Area (Piaui, Brazil), where about 400 archaeological sites were recognized ; two third of them are painted rock-shelters of lower and middle Holocene age.

The Toca do Boqueirão da Pedra Furada yielded a chronological sequence beginning at more than 50000 + 5 000 years BP with a rich lithic industry and 156 hearths and combustion features. This site is hence a key for our knowledge of the peopling of America. The succession of two different cultural phases is to be observed through the sequence : Pedra Furada phase is a Pleistocene one, dating from more than 50000 up to 11000 years BP ; the following, of lower holocene age (11000 to 5000 BP), is the Serra Talhada phase, characterized by a large increase of the sites number, the development of rock painting, a more intensive landscape use and a more sophisticated lithic industry.

Such sedimentological and cultural results were correlated with other sites of the Area, namely Toca do Garrincho and Toca da Janela da Barra do Antonião. These karstic sites yielded a mamalian fauna whose nature, biodiversity and abundance lead us to date from the Upper Pleistocene. The lithic industry associated with the fauna resembles the lower Holocene industry from Pedra Furada, setting the problem of the correlation between that fauna and human presence.

Mots-clés : Datation radiocarbone, Piauni-Brésil, premier peuplement, Holocène, Pléistocène supérieur.

Key-words : Radiocarbon dating, Piauni-Brazil, early peopling, Holocen, Upper Pleistocene.

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I - INTRODUCTION

Le peuplement humain des régions éloignées du «berceau» africain intéresse depuis longtemps les préhistoriens. Celui du continent américain fait l'objet, pour ses modalités et surtout pour sa chronologie, de controverses remontant au siècle dernier. Alors que des découvertes récentes en Australie et en Indonésie ranimaient le débat sur l'expansion de l'Homme au delà de la ligne de Wallace et obligeaient à une révision des chronologies proposées, on assistait pour les Amériques au développement malheureux d'une polémique sur les méthodes de reconnaissance et la nature des témoins archéologiques des premières occupations humaines. Dans ce contexte la séquence archéologique du Sud-Est du Piaui, essentiellement fondée sur les datations au radiocarbone du site de référence de la Pedra Furada, est un argument majeur pour étayer la théorie du peuplement pléistocène de l'Amérique du Sud.

II - L'AIRE DE SÃO RAIMUNDO NONATO ET SES SITES ARCHÉOLOGIQUES

Dans un milieu aujourd'hui semi-aride de savane arbustive épineuse (Caatinga), la région de São Raimundo Nonato dans le Sud-Est du Piaui (Nordeste brésilien) constitue une enclave à haute densité de gisements archéologiques, dans un continuum géographique d'occupations humaines bien établi à partir au moins du début de l'Holocène (Guidon *et al.*, 1994).

Près de 400 sites archéologiques y ont en effet été découverts. Plus des deux tiers sont des sites à art rupestre (Guidon, 1984 ; Pessis, 1987). Une dizaine ont fait l'objet de fouilles ou sondages importants. Plusieurs ont livré des niveaux archéologiques pléistocènes, dont deux ont fait l'objet de datations au radiocarbone : la Toca do Sitio do Meio, dont le remplissage est daté entre 12200 ± 600 et 14300 ± 400 BP et surtout la Toca do Boqueirão do Sitio da Pedra Furada (fig. 1).

La Pedra Furada, comme la plupart des gisements de l'Aire archéologique de São Raimundo Nonato, se situe en domaine gréseux ; la nature acide des terrains n'autorise pas la conservation des fossiles pléistocènes. Mais depuis 1986 plusieurs sites ont été découverts à faible distance des précédents dans un contexte géologique tout à fait différent, constitué de massifs de calcaire infracambrien métamorphisé (fig. 1). Ils ont de ce fait la particularité de renfermer une riche faune pléistocène, associée à des artefacts lithiques. Ces gisements en domaine karstique sont la Toca de Janela da Barra do Antonião, la Toca de Serrote do Artur, la Toca da Cima dos Pilão et la Toca do Garrincho (Guérin *et al.*, 1993).

III - LA SÉQUENCE CHRONOSTRATIGRAPHIQUE ET CULTURELLE DE LA PEDRA FURADA

L'abri de la Pedra Furada a fait l'objet de fouilles périodiques (dirigées par N.G.) entre 1978 et 1987. Une grande campagne continue (sous la direction de F.P.), achevée en 1988, a complété les recherches archéologiques dans le gisement (Parenti, sous presse).

La Pedra Furada est un vaste abri-sous-roche qui se situe à la base de la formation Serra Grande, d'âge silurien, constituée de grès grossiers et de poudingues. Dans le secteur, elle atteint son épaisseur maximale, soit environ 150 m. L'ensemble, affecté d'un pendage moyen de 15° vers le NW, forme une cuesta dominant un vaste pédiment d'où émergent des inselbergs.

La partie inférieure, qui repose sur des micaschistes précambriens, est formée de grès moyens à grossiers, siliceux, à stratification entrecroisée de faible développement. Ces grès sont surmontés par une série conglomératique pouvant atteindre 50 m d'épaisseur. Les

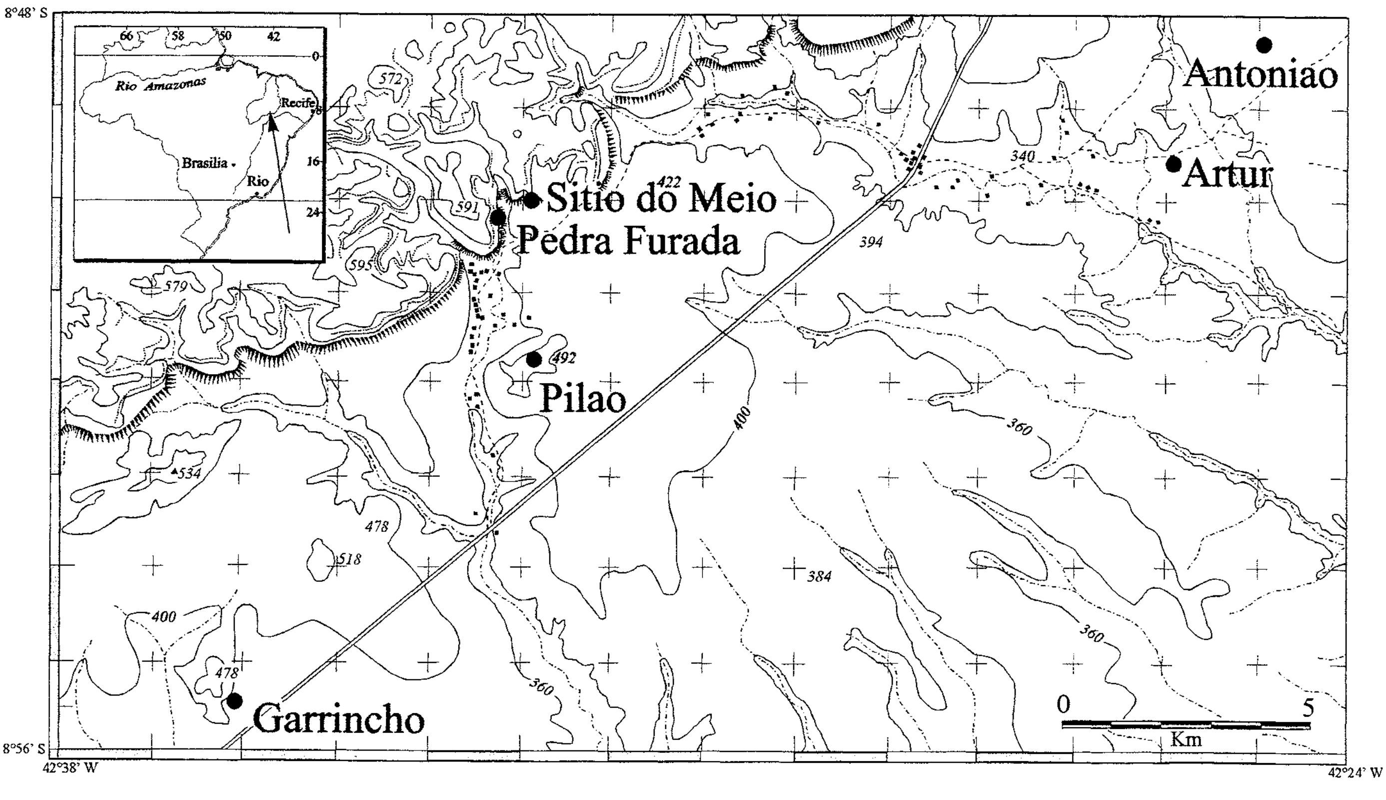

Fig. 1 : Localisation des principaux sites pléistocènes de l'Aire archéologique de São Raimundo Nonato (Brésil).

galets (quartz, quartzite, grès, parfois roches basiques), hétérométriques, montrent une granulométrie décroissante de la base au sommet de la série. Les plus gros peuvent atteindre 30 à 40 cm de longueur. Progressivement, on passe à des grès moyens à grossiers avec des intercalations conglomératiques.

L'abri de la Pedra Furada se trouve à la base d'une falaise sub-verticale d'environ 150 m de hauteur au pied de laquelle se trouve de puissants éboulis liés à son recul. Celui-ci a été favorisé par l'intersection des deux principaux réseaux de fractures, qui ont induit l'orientation des falaises limitant l'abri à l'Ouest et vers le Nord et se recoupant au niveau d'un axe de drainage bien marqué, la cascade du caldeirão. Celle-ci fait partie des 4 cascades qui drainent les eaux tombant au-dessus de l'abri et qui ravinent les niveaux conglomératiques supérieurs.

L'abri s'est formé par érosion différentielle entre les grès et des niveaux plus silteux. Ceux-ci forment généralement des zones en creux, parfois creusées de petites cavités peu profondes. La partie abritée est due à un surplomb de la falaise avançant de 19 m à la hauteur de la coupe de référence. Le substratum suit une pente moyenne de 10° conforme au pendage général. La zone la plus déprimée de l'abri se trouve au niveau du ruisseau issu du caldeirão, qui a toujours recueilli les eaux de ruissellement provenant de la partie Est du gisement.

Le remplissage atteint 5 m d'épaisseur, il est d'âge pléistocène (trois niveaux) et holocène (trois niveaux). La majeure partie des éléments fins est issue de la dégradation des parois. Cette dernière est facilitée par la faible cimentation de la plupart des niveaux. Les agents responsables d'une érosion continuelle ont sans doute varié au cours des temps : altération chimique lors des phases humides, haloclastie et/ou vent lors des phases plus sèches. Les plaquettes, plaques et blocs de grès correspondent à des phases de desquamation de la paroi. Cela est particulièrement net dans les sédiments les plus proches de la paroi. Les éléments siliceux grossiers sont issus des niveaux conglomératiques. Ils ont été sédimentés lors des périodes de pluie. L'essentiel des galets a été apporté par les cascades, et aussi par des drains moins importants situés le long de la paroi à l'aplomb de l'abri.

Après le dernier recul de la falaise à l'origine du talus de blocs fermant l'abri vers le Sud, les premiers sédiments issus de la paroi et du conglomérat supérieur ont nivelé les creux existants en suivant la pente naturelle formée par le talus ou le substratum. Ces sédiments sont accompagnés de blocs de grès marquant une régularisation de la falaise. Ensuite, la sédimentation s'est poursuivi avec un gradient granulométrique d'Est en Ouest et du Sud vers le Nord pour les éléments provenant des niveaux conglomératiques, du Nord vers le Sud pour les sédiments issus de la paroi. Les dépôts présentant à l'origine une pente marquée vers le NW voient ensuite celle-ci se réduire.

Dans cette dynamique sédimentaire assez monotone, il faut souligner la présence de niveaux de galets plus gros qui pourraient traduire des épisodes plus humides augmentant la compétence des ruisseaux et des cascades. Mais ils peuvent aussi résulter de l'érosion d'une lentille plus grossière dans le conglomérat. Une partie des gros galets n'a pu se sédimenter naturellement : aucun agent géodynamique, en l'occurence l'eau ou la gravité, n'a pu apporter des éléments de grande taille au milieu de sédiments de faible granulométrie et présentant une pente réduite. Il faut admettre l'intervention anthropique pour expliquer leur présence dans l'abri à l'intérieur de la ligne de pluie.

Les niveaux pléistocènes montrent une association spatiale entre des foyers, des galets chauffés, des charbons de bois et des industries lithiques (Guidon *et al.*, 1995 ; Parenti, sous presse). L'acidité du remplissage n'a pas permis la conservation de fossiles plus vieux que 8000 ans.

Le remplissage contient 156 structures (surtout des foyers) dispersées dans toute son épaisseur, dont 86 d'âge pléistocène ; certaines ont conservé des témoins de combustion, notamment des charbons de bois et des galets qui ont été chauffés à plus de 450° C. On y observe une succession de deux phases culturelles, la Phase Pedra Furada, pléistocène (plus de 50 000 et 11000 BP), et la phase Serra Talhada, d'âge holocène inférieur (11 000 - 5 000 BP). Cette dernière est caractérisée par une forte augmentation du nombre des sites, par l'affirmation de la pratique picturale et par une utilisation plus intensive du territoire, ainsi que par un travail de la pierre de plus en plus élaboré.

Parmi plus de 7000 pièces lithiques incontestables, environ 600 proviennent des niveaux pléistocènes. Des conglomérats à galets de quartzites couronnant la falaise au-dessus de l'abri, un effort tout particulier a été fait pour établir un distingo entre les galets à cassures anthropiques et ceux à fracturations naturelles, dont les paramètres ont été établis expérimentalement. Les industries pléistocènes sont des galets taillés de quartz et de quartzite, des fragments utilisés, des éclats corticaux, des racloirs, de rares perçoirs et denticulés. Des éclats de taille et des fragments d'origine naturelle ont été aussi repris et utilisés (Guidon *et al.*, 1996 ; Parenti, sous presse).

Les parois de l'abri portent de nombreuses peintures (Guidon, 1984 ; Pessis, 1987) appartenant pour la plupart à la tradition Nordeste, qui date de l'Holocène ancien. Un fragment de paroi portant deux lignes parallèles rouges fait partie de la bordure d'un foyer daté de 17 000 ± 400 BP et pourrait bien démontrer que la pratique picturale a commencé avant le début de l'Holocène.

55 datations radiométriques ont été réalisées (tab. 1) par trois laboratoires différents (Gif-sur-Yvette, Beta Analytic et Fortaleza) à partir de charbons de bois provenant des foyers ; 9, pour des raisons diverses (Parenti, sous presse), sont douteuses ; parmi les 46 datations retenues, 32 sont pléistocènes (au delà de 10 400 BP) et 14 holocènes. Cet ensemble constitue un remarquable cadre chronostratigraphique ; l'âge le plus ancien est supérieur à 50 000 BP. Notons qu'il s'agit de datations non calibrées et que les âges réels des niveaux les plus anciens se situent donc un peu au-delà de 50 000 ans.

IV - LES AUTRES GISEMENTS

a - Toca do Sitio do Meio

Il s'agit d'un abri-sous-roche en contexte gréseux, à 1000 m environ au NE de la Pedra Furada. La paroi porte de nombreuses peintures typiques de la tradition Nordeste (dont l'âge est de 12 000 à 6 000 BP).

Un premier sondage de reconnaissance avait été réalisé en 1978. En 1980 les fouilles, qui avaient permis de dater un foyer de 14 300 ± 400 BP, ont révélé d'énormes blocs effondrés recouvrant les niveaux archéologiques. Ces blocs de plusieurs mètres cubes ont dû être retirés ou débités sur place ; en dessous se trouve la couche archéologique supérieure, qui contient de nombreux foyers construits avec des blocs tombés des parois et des grands galets apportés de l'extérieur du site. Dans ces foyers se trouvent des charbons, des cendres, une grande quantité

site	datation	date calibrée	laboratoire	remarques
Pedra Furada	6150 +/- 60	- 7175 - 6886	GIF 8108	tranchée E, niveau 1, foyer 2 (SW)
Pedra Furada	6160 +/- 130	- 7289 - 6736	GIF 5863	secteur W, niveau V
Pedra Furada	7220 +/- 80	- 8137 - 7824	GIF 8390	tranchée E, niveau 1, foyer 1
Pedra Furada	7230 +/- 80	- 8146 - 7830	GIF 7242	secteur W, niveau III, foyer 124
Pedra Furada	7640 +/- 160	- 8945 - 8O22	GIF 4928	secteur W, niveau X, foyer 116
Pedra Furada	7750 +/- 80	- 8941 - 8388	GIF 6161	secteur W, niveau II, foyer 153
Pedra Furada	8050 +/- 170	- 9375 - 8458	GIF 4625	secteur W, niveau XII
Pedra Furada	8080 +/- 120	- 7420 - 6605	GIF 6157	secteur W, niveau XIX
Pedra Furada	8170 +/- 80	- 7423 - 6817	GIF 6436	couche I
Pedra Furada	8450 +/- 80	- 7578 - 7302	GIF 6162	couche VII
Pedra Furada	8600 +/- 60	- 9830 - 9442	GIF 8350	secteur E, niveau 2, foyer 4
Pedra Furada	9506 +135 - 132	- 10969 - 10210	FZ 436	secteur W, niveau VII
Pedra Furada	9800 +/- 60	- 11320 - 10626	GIF 8351	secteur E,niveau 4, foyer 12
Pedra Furada	10040 +/- 80	- 11935 - 11OO5	GIF 8389	secteur W, niveau VII, foyer 137
Pedra Furada	10050 +/- 80	- 11952 - 11007	GIF 8352	Secteur E, niveau 4, foyer 18
Pedra Furada	10400 +/- 180	- 11699 - 11222	GIF 5862	sondage 2
Pedra Furada	10454 +/- 113	- 10689 - 10005	FZ 430	Secteur W, niveau VI
Pedra Furada	10540 +/- 350	- 11206 - 9046	BETA 22859	Secteur E, niveau 5
Pedra Furada	13989 +/- 165	- 15252 - 14382	FZ 433	Secteur W, niveau XIX
Pedra Furada	14300 +/- 210	- 17635 - 16625	GIF 6159	secteur W, niveau XVIII
Pedra Furada	17400 +/- 400	- 21732 - 19565	GIF 5397	secteur W, bloc peint n° 0153
Pedra Furada	18310 +/- 190	- 22433 - 21294	BETA 22086	secteur W, niveau I
Pedra Furada	19320 +/- 200		GIF 8125	Secteur E, niveau 5, foyer 19
Pedra Furada	21400 +/- 400		GIF 6160	Secteur W, niveau XVII
Pedra Furada	23500 +/- 390		GIF 6158	Secteur W, niveau XIX
Pedra Furada ;	> 25000		GIF 5398	Secteur W, de - 2,03 m à - 2,10 m
Pedra FuradaX	> 25000		GIF 5648	Secteur W, de -1,92 m à - 2,03 m
Pedra Furada	25200 +/- 320		GIF 6147	secteur W, niveau XX
Pedra Furada	25600 +/- 450		GIF 8353	secteur E, niveau 5, foyer 20
Pedra Furada	26300 +/- 600		GIF 5963	Secteur W, niveau XIX
Pedra Furada	26300 +/- 800		GIF 6309	Secteur W, niv. XIX, bloc peint n° 2429
Pedra Furada	26400 +/- 500		GIF 5962	Secteur W, niveau XIX
Pedra Furada	27000 +/- 800		GIF 6308	Secteur W, niveau XIX
Pedra Furada	28600 +/- 600		GIF 6654	couche XXV
Pedra Furada	29740 +/- 650		GIF 8354	Secteur E, niveau 7
Pedra Furada	29860 +/- 650		GIF 6651	Secteur W, niveau XIX
Pedra Furada	31500 +/- 950		GIF 6041	Secteur W, niveau XIX
Pedra Furada	31700 +/- 830		GIF 6652	Secteur W, niveau XXI
Pedra Furada	31860 +/- 560		BETA 22085	Secteur W, - 2
Pedra Furada	32160 +/- 1000		GIF 6653	Secteur W, niveau XXIII
Pedra Furada	> 35000		GIF 9018	Secteur E, niveau 13, foyer 59
Pedra Furada	> 37350		BETA 22831	Secteur E, niveau 3
Pedra Furada	> 38000		GIF-TAN 8124	tranchée 6, foyer 49
Pedra Furada	> 39200		BETA 22858	Secteur W, niveau 3, foyer 150
Pedra Furada	39500 +/- 1600		GIF-A- 89357	Secteur E, niveau 14
Pedra Furada	40800 +4420 - 1850		GIF 7619	Secteur W, niveau -3 m
Pedra Furada	41000 + 3000 - 22000		GIF 8355	Secteur Est, niveau 13
Pedra Furada	41500 + 4200		GIF 7681	Secteur W, niveau - 4 m
Pedra Furada	42400 +/- 2600		GIF -TAN 8997	Esc. central, phase 14
Pedra Furada	> 42600		GIF-A- 89354	Secteur E, niveau 13
Pedra Furada	44800 +/- 1400		GIF (LSM) 9020	Secteur E, niveau 13
Pedra Furada	>/= 45000		GIF (LSM) 9021	Secteur E, niveau 13
Pedra Furada	>/= 47000		GIF-TAN 89098	tranchée 6, niveau 9
Pedra Furada	> 48000		GIF-A-89265	Secteur E, niveau 14
Pedra Furada	>/= 50000		GIF (LSM) 9019	Secteur E, niveau 13

site	datation	date calibrée	laboratoire	remarques
Sitio do Meio	8100 +/- 90	- 7307 - 6701	GIF 9409	foyer
Sitio do Meio	8800 +/- 60	- 8007 - 7590	BETA 47494	ultime chute de blocs
Sitio do Meio	8960 +/- 70	- 8087 - 7911	BETA 47493	céramique
Sitio do Meio	9110 +/- 80	- 8340 - 7984	GIF 9407	foyer niveau 15
Sitio do Meio	9200 +/- 60	- 8399 - 8069	BETA 65856	hache polie
Sitio do Meio	9270 +/- 100	- 8586 - 8063	GIF 9408	foyer sect. 2 niveau 16
Sitio do Meio	9400 +/- 60	- 8842 - 8259	GIF 9027	foyer
Sitio do Meio	9400 +/- 70	- 8846 - 8213	BETA 65349/CAMS 8994	foyer berge ruisseau
Sitio do Meio	12200 +/- 600	- 14089 - 10963	GIF 4628	niveau V
Sitio do Meio	12440 +/- 230	- 13373 - 11974	GIF 5403	niveau XV
Sitio do Meio	12640 +/- 210	- 13619 - 11260	GIF 9541	foyer
Sitio do Meio	12870 +/- 40	- 13549 - 12927	GIF 9540	foyer
Sitio do Meio	13100 +/- 50	- 13901 - 13335	GIF 9410	foyer
Sitio do Meio	13900 +/- 300	- 15441 - 13915	GIF 4927	niveau VI
Sitio do Meio	14300 +/- 400	- 16090 - 14197	GIF 5399	niveau XVIII
Sitio do Meio	20280 +/- 450		BETA 65350	foyer berge ruisseau
Sitio do Meio	25170 +/- 140		GIF 9542/LSM 9542	foyer
Cima dos Pilão	2290 +/- 60	- 409 - 192	GIF 7810	sépulture
Cima dos Pilão	10390 +/- 80	- 10570 - 9985	BETA 27345	niveau 2
Garrincho	5900 +/- 135	- 5194 - 4462	GIF 9334	tranchée 2
Garrincho	6360 +/- 120	- 5520 - 5050	GIF 9363	charbon
Garrincho	7410 +/- 130	- 6461 - 5975	GIF 9333	carré I, décapage 8-10
Garrincho	10020 +/- 290	- 10593 - 8462	GIF 9335	charbon
Serrote do Artur	6890 +/- 60	- 5849 - 5608	GIF 1015	dent de pécari
Serrote do Artur	8490 +/- 120	- 7867 - 7266	GIF 10516	coupe EE'
Barra do Antonião	240 +/- 40	+ 1529 + 1954	GIF 8671	charbon
Barra do Antonião	985 +/- 65	+ 899 + 1217	BETA 28832 ETH 4814	charbon
Barra do Antonião	1920 +/- 130	- 196 + 412	GIF-TAN 900-38	dents de caïman
Barra do Antonião	6270 +/- 140	- 5443 - 4853	GIF 7374	niveau II
Barra do Antonião	9670 +/- 140	- 9241 - 8412	GIF 8712	sépulture*

Tab. 1 : Principales datations au radiocarbone dans l'Aire archéologique de São Raimundo Nonato (Brésil). Les dates calibrées sont données selon notre ère.

de macrorestes végétaux, des restes fossilisés d'animaux holocènes et des artefacts lithiques. L'industrie lithique comprend à la fois des pièces très élaborées et d'autres de type archaïque (pebble-tools). Des morceaux de paroi peinte ont été aussi trouvés, ainsi qu'une bonne quantité de pigment rouge préparé sous forme de poudre déposée dans un petit creux de rocher. La partie supérieure des foyers a été datée de 8800 ± 60 BP (BETA 47494).

La couche archéologique supérieure repose sur une autre couche de blocs ; une troisième couche de blocs, la plus ancienne, est à la base du remplissage.

Il existe donc trois couches archéologiques à l'extérieur de l'abri-sous-roche, au niveau du surplomb, qui correspondent chacune à un effondrement de la falaise. Ces effondrements ont constitué un talus haut d'environ 2 m qui a isolé l'abri du contexte extérieur.

A l'intérieur de l'abri, près de la paroi, se trouvent deux unités stratigraphiques :

- la supérieure, constituée de sédiments meubles, dans laquelle abondent les foyers avec des industries, des charbons, des cendres, des vestiges organiques divers (5 niveaux archéologiques) ;
- l'inférieure, plus argileuse et compactée, où les structures de combustion n'ont conservé que les charbons. Une douzaine de pièces lithiques sur quartz a été recueillie. Deux datations ont été réalisées dans cette unité : 13 180 ± 130 BP et 13 660 ± 130 BP. A la base de la séquence on observe les traces d'un passage d'eau, limité à l'extrémité ouest du site et daté de 20 280 ± 450 BP.

A tous les niveaux ont été trouvés des blocs tombés de la paroi, dont certains portent des vestiges de peintures de la tradition Nordeste.

La genèse du gisement peut être envisagée de la façon suivante :

- Pendant une première phase qui s'achève il y a une vingtaine de milliers d'années, lors d'une période très humide, un torrent coulait dans la vallée et a creusé l'abri-sous-roche ;
- des éboulements du surplomb séparent ensuite l'abri de la vallée ;
- l'Homme s'installe dans l'abri, qu'il occupe de manière sporadique ; il taille à ce moment de rares outils sur galet semblables à ceux du Pléistocène de la Pedra Furada ;
- vers 12 000 / 10 000 BP, le climat devient semi-aride ;
- à l'Holocène, la présence humaine devient beaucoup plus régulière. Les niveaux holocènes contiennent une industrie lithique abondante et de nombreux restes fossilisés d'animaux et de plantes appartenant tous à des espèces actuelles.

Les structures de combustion sont réparties dans toutes les couches du gisement ; vers l'extérieur de l'abri, au niveau de la plus ancienne chute de blocs, on trouve encore de petits foyers, délimités par des blocs posés à plat, à côté desquels on observe de façon constante des plaquettes de silt, portant des traces d'utilisation comme enclume ; à proximité des foyers la densité des pièces lithiques est plus importante ; il n'y a pas de structures près de la paroi du fond.

Un tesson de céramique a été trouvé dans l'unité stratigraphique inférieure. Son âge est de 8960 ± 70 BP. En 1992 trois autres tessons ont été découverts, associés à des foyers de même âge. Un de ces derniers a aussi livré un très beau collier en graines de Graminées. En 1993 nous avons découvert une hache polie avec rainure de fixation, associée à un foyer daté de 9200 ± 60 BP. L'existence au Sitio do Meio de poteries anciennes et d'une industrie en pierre polie confirme les récentes découvertes de A. Roosevelt *et al.*, (1991) en Amazonie.

b - Toca da Janela da Barra do Antonião

Situé au Nord d'un petit affleurement de calcaire précambrien métamorphisé, ce vaste abri-sous-roche orienté au Nord se trouve légèrement en contre-bas de la surface d'altération qui nivelle une partie du calcaire. Il est large de 180 m et profond de 28 m, le remplissage atteint environ 8 m de puissance ; on observe un pendage régulier vers l'Est. Découvert en 1986, ce gisement a été fouillé jusqu'en 1990 sur une surface de 750 m2 (Guérin *et al.*, 1993).

L'étude préliminaire du sédiment et de la topographie actuelle, ainsi que quelques observations taphonomiques, permettent d'avancer l'hypothèse d'une double origine du remplissage, à savoir une sédimentation en régime lacustre, avec enfouissement rapide des cadavres d'animaux dont la plupart sont morts sur les lieux où ils venaient boire, et un remplissage en régime de haute énergie, favorisé par une intense circulation karstique.

Les fouilles ont montré au moins 4 horizons principaux de distribution des vestiges osseux. Parmi des milliers de restes, environ 1500 pièces ou ensembles de grands mammifères ont été déterminés. Des artefacts ont aussi été recueillis, en partie mélangés aux restes fauniques, dans les mêmes niveaux. Ils présentent des analogies avec l'industrie des niveaux pléistocènes de la Pedra Furada. L'homme a utilisé massivement les galets, qui sont ici exogènes.

En juillet 1990 les restes d'un squelette humain datant d'environ 9700 BP ont été découverts dans les niveaux supérieurs sous d'énormes blocs effondrés.

c - Toca da Cima dos Pilão

Situé sur le versant ouest du principal affleurement calcaire précambrien qui domine la vallée d'environ 90 mètres, ce site fouillé de 1986 à 1990 est composé de différentes unités morphologiques et de plusieures aires de fréquentation préhistoriques. On y distingue deux unités :

- Une série d'abris-sous-roche, riches en artefacts lithiques. Ces derniers sont comparables aux industries du niveau Serra Talhada de l'abri de la Pedra Furada (Parenti, sous presse).
- Deux grottes communiquantes, qui ont subi plusieures phases d'évolution morphoclimatique et dont le remplissage est riche en faune. Dans la moins profonde, des restes de foyers et d'industrie lithique ont été datés de 10390±80 ans BP.

d - Toca do Garrincho

Il s'agit d'une grotte creusée dans le calcaire précambrien, à 15 km au NE de São Raimundo Nonato. Un étroit couloir s'enfonce au dessous de l'entrée et débouche dans une vaste salle. Le couloir et la salle présentent la même stratigraphie que l'entrée : une épaisse couche de sédiments sablo-argileux rougeâtres surmonte un plancher stalagmitique ; sous ce plancher un amas de galets de différentes tailles est riche en fossiles, intacts et parfois en connexion anatomique ; ils ont le même type de fossilisation et la même couleur que ceux trouvés lors d'une récolte de sauvetage qui a été effectuée il y a quelques années après que le propriétaire de la grotte en ait fait vider l'entrée (le remplissage atteignait 8 m d'épaisseur) pour y installer un réservoir d'eau. C'est dans ce matériel qu'un fragment de pariétal humain a été découvert ; sa patine et sa minéralisation sont identiques à celles de la mégafaune.

Une fouille systématique a été entreprise à partir de novembre 1991. Le site a livré plus de 1500 restes ou groupes de restes de macromammifères déterminés. En 1992 deux dents humaines ont été trouvées en stratigraphie, associées aux animaux fossiles, sous un plancher stalagmitique daté de 10 020 ± 290 BP (Peyre *et al.*, 1998).

e - Toca do Serrote do Artur

C'est une vaste grotte creusée dans les calcaires métamorphisés du Précambrien où un sondage réalisé en 1987 par N. Guidon avait révélé une faune prometteuse. Une première campagne de fouilles a été effectué en 1995. Elle a permis de recueillir une riche faune, bien différente de celles des autres sites de la région ; plus proche de la faune actuelle, avec bien moins de biodiversité que les faunes pléistocènes, elle est plus récente, ce que confirment deux datations au radiocarbone (tab. 1).

V - LES FAUNES ET LEURS IMPLICATIONS PALÉOÉCOLOGIQUES ET BIOSTRATIGRAPHIQUES

Plus de cinquante espèces de mammifères, plus de trente espèces d'oiseaux, des reptiles et des amphibiens ont été recueillies. L'ensemble de la faune de mammifères témoigne d'un paysage de savane à buissons entrecoupée de zones forestières, sous un climat bien plus humide que l'actuel (Guérin *et al.*, 1993).

Plusieurs des genres présents dans nos gisements sont considérés par L.G. Marshall *et al.*, (1984) comme de bons marqueurs chronologiques du Pléistocène final : il s'agit du Paresseux géant *Eremotherium, Equus* et du Mastodonte *Haplomastodon* auxquels nous ajouterons un autre Paresseux géant, *Catonyx.* D'autres genres ne semblent pas connus en Amérique du Sud avant l'âge Lujanien (Pléistocène moyen récent et Pléistocène supérieur) : ce sont les deux Pécaris *Dicotyles* et *Tayassu,* le Cervidé *Mazama*, et peut-être le Rongeur *Galea*. Le Canidé *Speothos* et le Notongulé Toxodontidé *Mixotoxodon* sont à ranger dans la même catégorie. A.L. Cione & E.P. Tonni (1995) considèrent la présence de l'Equidé *Equus neogaeus* et l'apparition des Rongeurs *Holochilus brasiliensis* et *Calomys* comme caractéristiques de la «zone à Equus neogaeus», du Lujanien supérieur.

Notons que pour L.G. Marshall *et al.*, (1984), *Scelidodon* (pris au sens large, c'est-à-dire incluant *Catonyx*) et sans doute *Palaeolama* avaient disparu depuis longtemps des régions à climat tempéré, comme l'Argentine, mais ont survécu jusqu'au début de l'Holocène dans les zones tropicales et intertropicales du continent, notamment au Brésil. La faune de l'Aire archéologique de São Raimundo Nonato ne peut donc être plus ancienne que le Lujanien, et il est hautement probable qu'elle est du Lujanien supérieur. De plus sa richesse en individus et sa grande diversité excluent un âge plus récent : il n'est pas vraisemblable qu'une faune de l'extrême début de l'Holocène soit aussi abondante et variée, comme nous avons pu le constater (Guérin, 1993) à la Lagoa da Pedra (Conceição das Creoulas).

CONCLUSION

Dans l'état actuel des connaissances, plusieurs points peuvent être établis à partir de l'étude régionale que nous menons :

1) la présence de l'homme dans le Pléistocène du Nordeste du Brésil est prouvée indirectement par une remarquable quantité de vestiges archéologiques découverts dans plusieurs gisements : Pedra Furada, Sitio do Meio et Antonião. Les restes humains de la grotte de Garrincho ont plus de 10 000 ans. Une fois de plus il faut remarquer que ce que nous considérons valable est avant tout la présence simultanée de plusieurs types de vestiges anthropiques (industries et structures de combustion) au même moment dans plusieurs sites datés.

2) l'association temporelle et spatiale entre homme et faunes éteintes, pas encore datée, est documentée dans plusieurs gisements. Bien qu'elle semble s'étendre jusqu'au premier tiers de l'Holocène, elle paraît essentiellement située dans le Pléistocène supérieur et final.

3) les vestiges archéologiques analysés pour la phase Pedra Furada indiquent une évolution très lente à la fin de laquelle - début Holocène - intervient une nette rupture culturelle. Il se peut que l'on retrouve ici les traces de plusieurs vagues de peuplement, analogues à celles qui ont été évoquées à l'occasion d'études récentes dans les domaines de la morphologie crânienne, de la linguistique et de la génétique.

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LES DATES RADIOCARBONE DE LA PÉRIODE FORMATIVE (OU DES PREMIÈRES CIVILISATIONS) DANS LES ANDES CENTRALES : UNE MISE EN GARDE

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Résumé : D'après une évaluation d'environ 600 dates ^{14}C associées à la période Formative des Andes centrales, nous avons détecté plusieurs problèmes liés à leur obtention. Parmi les plus importants : la mauvaise association archéologique, des séries de dates en contradiction avec la stratigraphie, la présence de matériel peu fiable pour les datations (par exemple coquillages), une grande marge d'erreur (jusqu'à ± 900 !!) ou l'absence de celle-ci, des dates nécessitant une réévaluation des conditions de leur obtention (absence de normalisation $\partial^{13}C$ par exemple).
D'autres problèmes sont également liés au traitement des dates : une mauvaise présentation dans les publications, des confusions entre les dates et les codes des laboratoires, la transformation arbitraire en années av. J.-C. sans passer par la calibration, l'absence dans la discussion, de l'erreur de probabilité à 1 ou 2 sigma, etc.
Dans le cas où les dates ont été calibrées, les résultats son présentés de manière aléatoire. Or, les dates calibrées peuvent montrer une marge de probabilité très large sur la courbe de calibration.
Nous pensons donc que la discussion sur la périodisation du Formatif doit être révisée et vérifiée à l'aide d'un meilleur niveau d'association archéologique.

Abstract : According to an estimation of about 600 ^{14}C dates associated with the Formative period in Central Andes, we found several problems in relation with the way they were obtained. Among the most important : a bad archaeological association, some series of dates in contradiction with the stratigraphy, the presence of material that can be hardly trusted (shells, for instance), a great margin of error (up to about 900 !), some dates requiring a re-estimation of the way they were obtained.
There are other problems in relation with the way dates are processed : a bad presentation in the publications, some confusions between the dates and the codes used by the laboratories, the arbitrary change into B.-C. years without any calibration, etc.
When the dates are calibrated, the results are presented in a random way ; and the calibrated dates can sometimes show a great interval on the calibration curve.
Therefore, we believe that the discussion on the periodization of the Formative must be reviewed and checked up with a higher archaeological fiability.

Mots-clés : Période Formative, datation radiocarbone, Andes centrales, calibration.

Key-words : Formative period, radiocarbon dating, Central Andes, calibration.

Cet article présente une évaluation d'environ 600 dates ^{14}C provenant des Andes centrales, qui ont généralement été attribuées à la Période formative et aux périodes qui la délimitent : l'Archaïque final et les premières phases de la Période des Développements régionaux.

1 - FORMATIF ET LA CHRONOLOGIE

Le Formatif est une période fondamentale dans le développement culturel du Pérou préhispanique. Elle est en effet définie par l'apparition de la céramique, la multiplication des grandes pyramides et la complexification des sociétés. C'est durant cette période que se développent, entre autres, les cultures de Chavín, Paracas et Cupisnique.

Dans le tableau chronologique (tab. 1), nous avons inclus les deux types de sériation chronologique utilisés pour les Andes centrales. L'une est définie en fonction de critères économiques (colonne 1) et l'autre en fonction du développement et de l'extension temporelle et géographique des styles céramiques (colonne 2) avec horizons et périodes intermédiaires. L'utilisation de cha-

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Chronologie socio-économique	Chronologie "spatio-temporelle "	styles représentatifs	Dates BC données par les archéologues
	PERIODE 1 INTERMEDIAIRE ANCIEN	Nasca 1	100 AD (Silverman, 1991, 352)
	10	Ocucaje 10	
FORMATIF FINAL		Kotosh Higueras	1 AD
		Salinar	200 BC (Onuki, 1994, 91)
----------------		Janabarriu/Capilla	390 BC 200 BC (Burger, 1988, 110)
FORMATIF MOYEN	HORIZON ANCIEN	Ocucaje 3-4	800 BC (Silverman, *ibid.*)
			500 BC (*ibid.* : 378)
----------------	1		
FORMATIF ANCIEN	PERIODE INITIALE	Kotosh-Kotosh	700 BC (Onuki, 1994, 74)
		Erizo	
		Wayrajirca	1800 - 1500 BC (plusieurs auteurs)
ARCHAIQUE FINAL	PRE-CERAMIQUE TARDIF	Mito	2000 BC (Onuki, *ibid.*)

Tab. 1 : Séquence chronologique du Formatif.

que séquence dépend de la tendance théorique de chaque archéologue. Ces deux sériations sont valides et nous pensons, tout comme beaucoup d'archéologues, que leur utilisation en parallèle est utile à partir du moment où leurs divisions principales ne sont pas employées comme termes équivalents. Dans notre cas, nous donnons la priorité à la terminologie socio-économique.

Dans l'archéologie sud-américaine et particulièrement andine il est très courant d'établir des séquences chronologiques très précises en années BC, à partir des datations ^{14}C. La période formative des Andes centrales n'échappe pas à cette tendance.

Dans les années 60, époque durant laquelle les dates ^{14}C étaient converties automatiquement en années solaires en enlevant 1950, une chronologie comprise entre 2000 - 1800 BC et 100 AD a été établie pour la Période initiale et l'Horizon ancien (l'Horizon ancien comprenant 10 phases). Ces dates ont été adoptées pour représenter les limites du Formatif. Les dates apparaissant dans le tableau 1 sont celles généralement acceptées mais ne sont pas forcément calibrées, d'où leur présentation en années BC (non calibrées).

Pour le non spécialiste, l'utilisation de cette terminologie en phases et dates est compliquée et prête à confusion, même pour certains archéologues spécialistes de la région. A cette situation déjà complexe s'ajoutent d'autres terminologies, une diversité de «conceptions théoriques», et une méconnaissance de la problématique des datations ^{14}C.

1.2 - LES PRINCIPAUX PROBLÈMES DES DATES ^{14}C ET LA CHRONOLOGIE

Pour l'Archaïque final, le problème principal se situe dans l'utilisation de l'absence de céramique comme marqueur principal. Ainsi certains sites, ou phases d'occupation, ont été attribués à la période «pré-céramique» en raison de l'absence de ce matériel dans les fouilles, y compris dans celles réduites à des sondages (les fameux « test-pits » nord-américains). Pour la période de transition entre le Précéramique et le Formatif ancien l'absence, dans les stratigraphies, de corrélations claires entre les datations radiocarbones et les contextes archéologiques, est également à mettre en évidence. Il n'existe pratiquement pas de sites côtiers comprenant une bonne séquence stratigraphique corrélée à des dates ^{14}C, entre la Période archaïque et le Formatif.

Des sites très importants pour cette période comportent des problèmes liés aux datations. C'est le cas de Las Haldas et de Pampa de las Llamas sur la côte nord et nord-centrale du Pérou, ou El Paraiso au nord de Lima (classé comme pré-céramique puisque la céramique est absente dans une grande partie du site, avec des dates qui oscillent vers 3400 B.P.). A Las Haldas (Pozorski et Pozorski, 1992, 849 ; Grieder, 1975), pour les couches sans céramique, cinq dates sont comprises entre 3960±80 (UGa-4531) et 3140±80 (Tx-648). Pour la Période initiale, une série de 10 dates, entre 3595±75 (UGa-4534) et 2520±60 (TK-122), coïncident avec les dates attribuées au Précéramique. Dans cet ensemble, une séquence de trois dates associées à la céramique et provenant d'une même unité d'excavation (Unité 2) sont en contradiction (Pozorski et Pozorski, 1987, 23 ; Burger, 1992) : UGa-4532 3460±75 dans une couche récente, UGa-4533 3140±75 dans une couche profonde et UGa-4534 3595±75 au fond de l'excavation. Ces dates sont présentées (*ibid.*) sans être discutées et comme références pour les corrélations.

De ce fait, les généralisations servant à établir des limites précises de transition, par exemple entre le Précéramique et la Période initiale, ou l'établissement de séquences chronologiques pour les différents processus sociaux, risquent d'être peu cohérentes.

Sur la côte nord, les premiers vestiges d'architecture monumentale sont représentés par le site pré-céramique d'Aspero. Ce site a été daté approximativement entre

Code Lab.	V-900:	V-899	V-721
Date B.P.	2705±?	2609±?	2254±?
Site	Puerto Nuevo	Puerto Nuevo	Paracas Necrópolis

Tab. 2 : Dates ^{14}C sans marge d'erreur (probablement à cause d'une instabilité au laboratoire de Victoria (Bermingham, 1966, 507).

Code Lab.	TK-42	N-90	UCLA-1808D	TK-345	TX-5606
Date B.P.	3900±900	3360±760	2200±430	2010±380	3320±270
Site	Kotosh	Chanapata	Waywaka	Huacaloma	La Galgada

Tab. 3 : Dates ^{14}C présentant une marge d'erreur très grande.

Code Lab.	C-315	UCLA-729A	UCLA-729B
Date B.P	3572±220	3400±100	2640±90
Site	Huaca Prieta	Sechín Alto	Sechín Alto

Tab. 4 : Dates ^{14}C obtenues sur des coquillages.

Date B.P.	Référence telle que publiée par quelques archéologues	Code réel
3800±80	"Engel, 1966, 82" Las Haldas Précéramique	NZ-212
3430±80	"Grieder, 1975, 99 Las Haldas Période Initiale	TX-631
3600±95	"Matsuzawa, 1978, 666" Las Haldas Période Initiale	GaK-4456
3150±90	"Matsuzawa, 1978, 666" Las Haldas Période Initiale	GaK-4455
2590±80	"Matsuzawa, 1978, 666" Las Haldas Période Initiale	TK-123
2520±60	"Matsuzawa, 1978, 666" Las Haldas Période Initiale	TK-122
3400±100	"Carlevato, 1979, 155-7" Sechín Alto, Période Initiale	UCLA-729A
2640±90	"Carlevato, 1979, 155-7" Sechín Alto, Période Initiale	UCLA-729B
2070±100	"Radiocarbon Dates Association, Inc.n.d." Chankillo	Gif 2482
2720±60	"Radiocarbon Dates Association, Inc.n.d." Cerro Sechín	TK-106

Tab. 5 : Liste partielle de dates ^{14}C généralement présentées sans code de laboratoire ou seulement avec une référence bibliographique.

4300 et 3900 B.P. (Feldman, 1985, 71) et cette datation pourrait montrer qu'il existait déjà ce type d'architecture bien avant l'arrivée de la céramique. Parallèlement, dans la cordillère, des dates aussi anciennes marquent l'apparition de la céramique : 4090±120 (GX-2198) à Pampa de Lampas (Bischof, 1979, 339), 4075±115 (ZK-333) à Pandanche (Kaulicke, 1981, 373), ou, pour une couche immédiatement antérieure à l'apparition de la céramique, 4470±110 (Gif-4837) à 3680±100 (Gif-4835) à Telarmachay (Lavallée, 1985, 57).

Le site de Huaca de los Reyes sert à caractériser le Formatif ancien sur la côte nord. Cependant, les raccords entre les couches et leur contexte pourraient être problématiques. Ce site a été classé comme «pré-Chavin» (Burger, 1992, 92, d'après Pozorski, 1975) et une date moyenne de 1511 BC lui a été attribuée (Burger, *ibid.*). Huaca de los Reyes reste comme l'exemple typique de l'architecture monumentale antérieure à Chavin et appartiendrait à la culture Cupisnique. Pourtant l'association archéologique des dates publiées, s'étalant entre 3680±80 B.P. (Tx-1974) et 2800±60 B.P. (Tx-2180) pour la première phase constructive (Pozorski, 1975, 247), est douteuse. Nous avons trouvé également une autre date, très tardive, probablement associée au même contexte, mais non publiée sous la référence précédemment citée : 1560±120 (Tx-2181, *in* : Valastro *et al.,* 1978, 268). De plus, d'après d'autres spécialistes (Kaulicke, 1992, 35), ce site ne peut pas être attribué, par comparaison stylistique, à une période Cupisnique «pré-Chavin».

Le Formatif moyen est une période très controversée tant en ce qui concerne les datations que sa définition. Des propositions ont été élaborées à partir de datations ^{14}C, comme par exemple V-900, V-899 (tab. 2) pour lui donner des limites. Elles lui donnent une durée précise de 190 années : 390 BC à 200 BC (Burger, 1988, 110). Cependant, les dates ^{14}C de cette période coïncident en grande partie avec le «plateau Hallstatt» de la courbe de calibration (fig. 1 : voir entre 420 à 750 et entre 200 à

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RADIOCARBON AGES AT MURRAY SPRINGS, Arizona, AND THE INFLUENCE OF CLIMATE CHANGE ON CLOVIS MAN

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Abstract : Radiocarbon dating can now be calibrated through the last glacial transition, due to improved calibrations using tree rings, corals and also marine varved sediments. Lake sediments also provide additional support for changes in the calibration. This means we can now compare the previously relative radiocarbon date of a given cultural strata with climatic information from other records, such as the climatic record in ice cores.
The return to colder climate after the end of the glacial, the Younger Dryas event, is marked in records in many parts of the world. This can be expressed in different ways in different parts of the globe. For example, in Chinese loess, oscillatory behavior is observed during this time. In the southwestern USA, there has always been a good stratigraphic relationship between the end of the Clovis culture at about 10,900 ^{14}C yr BP and subsequent evidence for a wetter climate, expressed by algal mat deposits, which dates during the period of the Younger Dryas cold event. We will discuss the correlation of archaeological and climatic events in North America, and the interaction of man and climate using more precise age estimates of these events.

Résumé : Les datations par le radiocarbone peuvent être calibrées pour la transition glaciaire-interglaciaire, grâce aux améliorations apportées à la courbe de calibration par l'emploi des cernes de croissance des arbres, des coraux et aussi des sédiments marins. Les sédiments lacustres peuvent aussi apporter un support supplémentaire pour les changements en calibration. Cela signifie que nous pouvons maintenant comparer la date radiocarbone, autrefois relative, d'un niveau culturel donné, avec les informations climatiques obtenues sur d'autres profils, tels que, par exemple, les variations climatiques répertoriées dans les carottes glaciaires.
Le retour du climat froid après la fin du glaciaire, à la période du "Dryas récent", est marqué dans de nombreuses coupes, dans beaucoup de régions du monde. Suivant celles-ci, il peut se traduire de différentes manières. Par exemple, dans le loess de Chine, on a observé une tendance oscillatoire pendant cette période. Au sud-ouest des Etats-Unis, il y a toujours eu une bonne relation statigraphique entre la fin de la culture Clovis, aux environs de 10 900 BP, et pour la période immédiatement postérieure où l'on observe un climat plus mouillé, qui se traduit par le dépôt d'une couche dite 'algal mat' dont l'âge correspond à la période froide du Dryas récent. On discutera de la corrélation entre les évènements archéologiques et climatiques en Amérique du Nord, et aussi de l'interaction homme/climat, en utilisant les dates les plus précises de ces évènements.

Key-words : Radiocarbon dating, climatic changes, Clovis, Youger Dryas

Mots-clés : Datation par le radiocarbone, changements climatiques, Clovis, Dryas récent.

INTRODUCTION

The interaction of man with his environment suggests that early man must have had to adapt to drastic changes in climate. This adaptation could have taken many forms, with expansion, contraction or elimination of a specific culture. Over geologic time, we know the earth's climate changes from glacial to interglacial due to the effects of astronomical parameters as well as ocean circulation. Also, other effects such as solar effects, volcanic emissions and large meteorites could also have caused short-term climatic changes.

The end of the last Glacial period was followed by warming during the Bölling-Alleröd. A short return to colder climate during the Inter-Alleröd Cold Period (IACP) was followed in much of the world by the Younger Dryas event, which is marked in ice (Alley *et al.*, 1993) and coral records (Bard *et al.*, 1990 ; Edwards *et al.*, 1993), as well as other expressions in many parts of the world. This can be expressed in different ways in different

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parts of the globe. The most spectacular record is in the ice cores collected from central Greenland, discussed by Alley *et al.* (1993), which show evidence for a rapid onset at about 12,900 years BP and termination of this cold event about 11,000 years ago. In Chinese loess, oscillatory behavior from dry and cold to warmer and wetter is observed during this time (Zhou *et al.,* 1996, 1997). In the southwestern USA, there has always been a good stratigraphic relationship between the end of the Clovis culture at about 10,900 ^{14}C yr BP (about 12,800 calibrated years BP) and subsequent evidence for a wetter climate, expressed by algal mat deposits, which dates during the period of the Younger Dryas cold event (see Haynes, 1991, 1993).

Radiocarbon dating can now be calibrated through the last glacial transition, due to improved calibrations using tree rings, corals and marine varved sediments. Developments in radiocarbon dating of corals coupled with U-Th dating (Bard *et al.,* 1990 ; Edwards *et al.,* 1993 ; Burr *et al.,* 1998) have allowed us to extend the period of time where precise age estimates can be determined. Previously, the radiocarbon time-scale was calibrated only by tree-ring chronologies. The earliest tree-ring samples date to about 11,500 calendar years BP (cal. BP). The coral and tree-ring chronologies are consistent. Other age estimates based on lake-varve chronologies (e.g. Hajdas *et al.,* 1995 ; Wohlfahrt, 1997) can also be use to show as substantial offset between radiocarbon and absolute time-scales of about 1,000 years around 11,000 cal BP, which increases with age during the Younger Dryas period and into the Alleröd. The latter chronologies often have other sources of variations, so consistent results with tree rings or corals are not always obtained. Most recently, Hughen *et al.* (1998) have reported on a new chronology based on marine varves from the Cariaco basin. This record, like the corals, assumes the marine correction was similar to today at 400 yr BP. Kitagawa and van der Plicht (1998) have also discussed a continuous lake-varve chronology from Lake Sugietsu, Japan which suggests large variations in 14C in the period before 20,000 yr BP. There is good agreement between these records and corals from about 15,000 to 10,000 yr BP.

A consequence of all these studies is that it is now possible to take a radiocarbon measurement and correlate the time period with climatic signals in other records, such as ice cores (Alley *et al.,* 1993) and timing of sea level rise (Edwards *et al.,* 1993).

In this paper, we report on some new radiocarbon measurements of algal mat deposits at the Clovis mammoth kill site of Murray Springs, located in southern Arizona, close to Sierra Vista, about 140 km south-east of Tucson. We also discuss these results in the light of new interpretations of the exact timing of the arrival of Clovis man in the new world and how climatic records can show the possible causes of his arrival and disappearance in the archaeological record.

RADIOCARBON MEASUREMENTS

We collected new samples of algal mat deposits, which overly the Clovis surface at Murray Springs, Arizona. This site was originally excavated by Haynes and others from 1966 to 1971 (Hemmings, 1970 ; Haynes, 1987), who found a mammoth kill site, an extensive bison kill site, with many bison skeletons, and a Clovis encampment with many stone tools. The Clovis-age charcoal dated to 11,100 to 10,900 ^{14}C yr BP (Haynes, 1991 ; Goebel *et al.,* 1991). These deposits are indicative of a change from warm-dry to cooler and wetter conditions for this area, which is today very arid (Haynes, 1991). Haynes and others have previously speculated that the end of the Clovis period was concomitant with drought-like conditions which were followed by the wetter periods. This oscillatory behavior in the younger Dryas, which is normally considered to be cold and wet, is also observed in other locations. For a very different example, Zhou *et al.* (1996, 1997) have documented similar behavior at a similar time in loess deposits in central China.

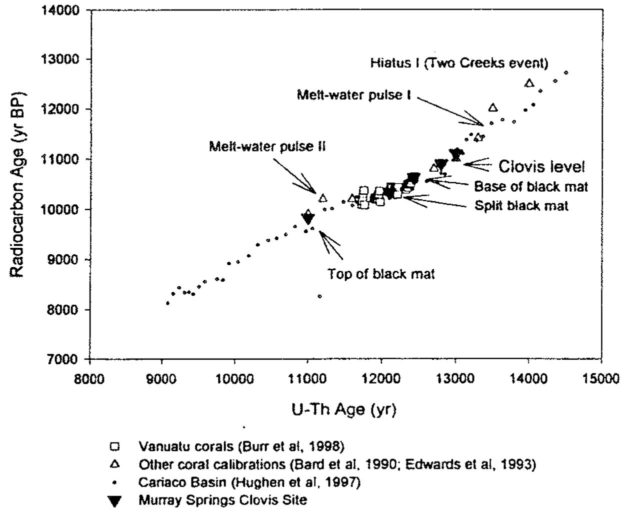

Fig. 1 : Detail of sampling locations in the Murray Springs algal mat layer (Haynes, 1984, 1991). The Clovis occupation level are immediately below this layer.

Fig. 1 : Détail des points d'échantillonnage dans la couche 'algal mat' à Murray Springs. Le gisement d'occupation Clovis est immédiatement sous ce niveau.

Location	^{14}C age (BP)	
#2	9,823±46 years BP	AA-26210
#3, top	10,325±44 years BP	AA-26211
#3, lower	10,628±60 years BP	AA-26212
Clovis Horizon	11,100-10,900 years BP	Haynes, 1991

Table 1 : Radiocarbon measurements of algal mat deposits overlying the Clovis level at Murray Springs, Arizona.

Results of sampling of 2 different locations at the original mammoth kill discovery were made in July 1997. We sampled on area with a single algal mat layer approximately 2-3 mm thick and another (#3) where the carbon-rich layers had separated into two discrete layers ~3 cm apart (see figure 1). The results are shown in table 1. Repeated AMS measurements were performed to obtain high-precision dates on these samples. The mammoth kill and Clovis artifacts were all recovered from a horizon immediately below, but in no case transgressing, the algal mat layers. In some cases, multiple mat layers are known to exist. Similar stratigraphy is also observed at other Paleoindian sites in the southwestern USA (Haynes, 1991).

These radiocarbon ages on the algal mats clearly fall into the period of the younger Dryas "cold event", which dates to approx. 11,000 to 10,000 ^{14}C yr BP (Wohlfahrt, 1997). As already mentioned, the possibility of oscillatory climatic behavior during this time has been noted. In the European chronology, Amman and Lotter (1989) place the Alleröd-younger Dryas boundary in European samples at 10,900±140 ^{14}C yr BP. Hughen *et al.* (1998) place it at approximately the same time. This suggests strongly that much of the Clovis expansion occurred in the Alleröd warm period, and that we can likely associate the Clovis "drought" of Haynes (1991) with the Intra-Alleröd cold period (IACP) which occurred about 11,400 to 11,100 14C yr BP and was followed by a short warmer epoch before the rapid onset of the Younger Dryas at 10,900 14C yr BP. Fiedel (1998) has also discussed this concept in much greater detail.

Further, we can compare these radiocarbon ages to the estimates of sea level rise determined by Bard *et al.* (1990) in Barbados coral and Edwards *et al.* (1993) in the South Pacific. In either case, the algal mat deposits which post-date Clovis, and all Clovis radiocarbon measurements (Haynes, 1984, 1991, 1992) fall between these two sea-level rise events. We can show this correlation in graphical form in figure 2. The Clovis expansion starts after the first melt-water pulse and the algal mat occurs in the center of the flat region of reduced slope (hiatus II) of the radiocarbon vs. calibrated-age curve shown. A previous hiatus (I) occurs about 12,200 ^{14}C yr BP, associated with a change in atmospheric CO_2 volume. Edwards *et al.* (1993) demonstrated convincingly that the hiatus during the younger Dryas is caused by a dramatic drop in $\Delta^{14}C$ during this time. These authors asserted this drop was too rapid to be caused solely by changes in cosmic-ray production rate (Bard *et al.*, 1990) or CO_2 volume and oceanic ventilation must also have played a role.

In table 2, we list the timing of many important climatic and archaeological events in the new world. This table shows clearly that Clovis falls between the two melt-water pulses and that the Folsom period transgresses the second sea level rise. The second sea-level rise of about 60 m would have flooded the Bering Strait and thus would have finally cut off the new world from Asia. We also note that the radiocarbon dates on wood artifacts at the Monte Verde site in Chile, which now appears to be a possible very early settlement in South America (Meltzer *et al.*, 1997), come just after the end of the full Glacial and are likely coincident with the first radiocarbon «hiatus» at about 12,200-12,400 ^{14}C years BP. It is not clear at this point how this very early site might be related to the Clovis expansion in North America at a later time.

	Radiocarbon Age	**Calibrated Age**	**References**
Bone/Ivory artifacts (?), Alaska (isolated evidence)	15,800 yr BP	~18,000 yr	Holmes *et al.* (1996); Ackerman (1996)
End of full Glacial Period (ice cores)	~12,400 yr BP	~14,000 yr	Alley *et al.* (1993)
Possible early Monte Verde occupation	12,300-12,700 yr BP	~14,000 yr	Meltzer *et al.* (1997)
Hiatus in ^{14}C age curve	12,200-12,400 yr BP	~14,000 yr	Kalin, Jull *et al.* (unpublished) Leavitt *et al.*
(Two Creeks event)			
(change in atmospheric CO_2 volume)			
Good evidence for Alaskan sites	~12,000 yr BP	~13,600 yr	Hopkins (1996)
Melt-water pulse I, Barbados coral	12,000 yr BP	~13,500 yr	Bard *et al.* (1990)
Melt-water pulse I, Pacific coral	11,000-11,500 yr BP	~13,000-13,500 yr	Edwards *et al.* (1993)
Clovis expansion	11,400-10,900 yr BP	13,300-12,800 yr (coral)	Haynes (1991)
		13,100-12,800 yr (lakes)	Goslar *et al.* (1995); Hajdas *et al.* (1995b)
Inter-Alleröd Cold Period	11,400-11,100 yr BP	13,300-13,000 yr	Hajdas *et al.* (1995b) Hughen *et al.* (1998)
Mass Pleistocene Extinctions (ref)	11,000 yr BP	12,600-13,000 yr (hiatus II)	Haynes (1991); Martin *et al.*
Younger Dryas cold event	**11,000-10,200 yr BP**	12,900-11,600 (coral)	Edwards *et al.* (1993) Bard *et al.* (1990)
		12,900-11,000 (lakes)	Goslar et al. (1995); Hajdas *et al.* (1995b)
(second hiatus in ^{14}C age coincident with YD period)			
(second change in atmospheric CO_2 volume)			
beginning of Folsom period	10,800 yr BP	12,600-12,900 yr	Haynes (1991)
wet climatic period in SW USA	~10,650 yr BP	12,700-12,900 yr	Haynes (1991)
Folsom-like (Fell's Cave) points in Argentina	10,700-10,500 yr BP	12,800-12,500 yr (during hiatus II)	Flegenheimer (1987)
end of Folsom periods	10,200 yr BP	11,600-12,200 yr (during hiatus II)	Haynes (1991)
Period of reduced melting	10,200-9,900 yr BP	12,300-11,000 yr	Edwards *et al.* (1993)
Melt-water pulse II, Barbados coral	~10,200 yr BP	~11,200 yr	Bard *et al.* (1990)
Melt-water pulse II, Pacific coral	~10,000 yr BP	~11,000 yr	Edwards *et al.* (1993)
End of $\delta^{18}O$ anomaly in GISP ice core	----	10,700±150 yr	Alley *et al.* (1993)
Holocene begins	~10,000 yr BP	~11,000 yr	

Table 2 : Correlation of Archaeology and Paleoclimatic events.

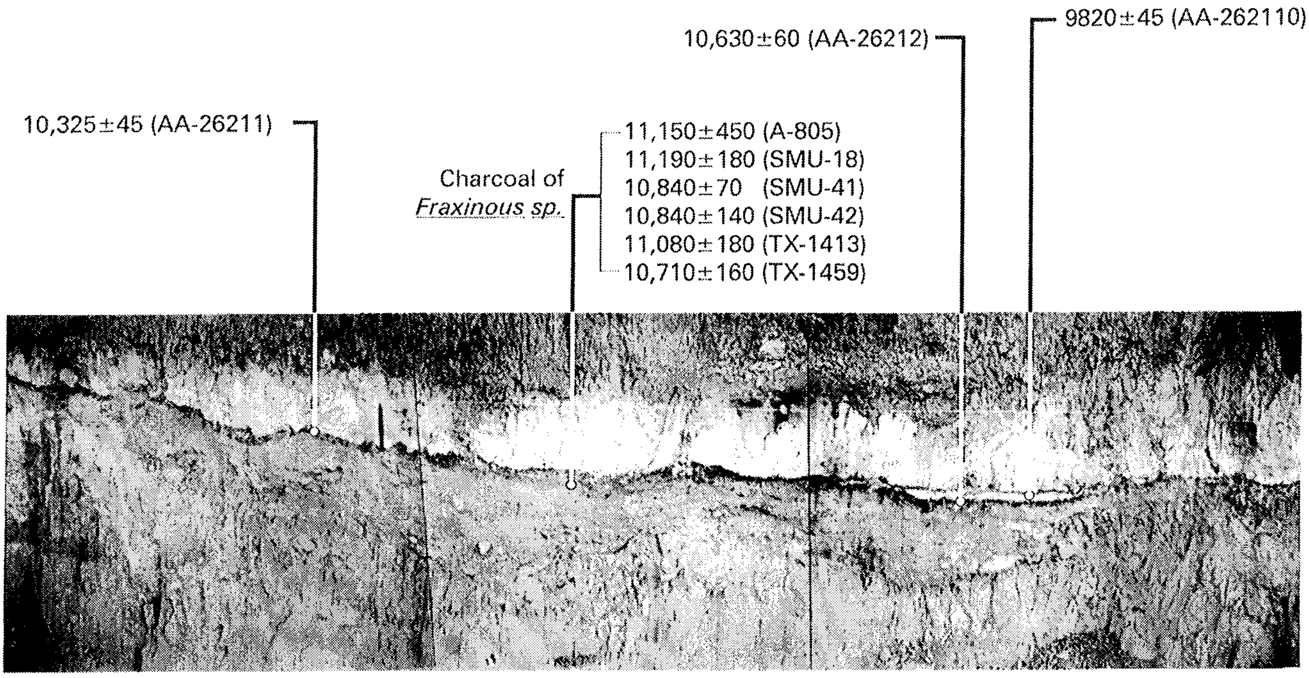

Fig. 2 : A comparison of radiocarbon ages of deposits at Murray Springs, Arizona. Calibrated ages determined from the coral chronology (Bard *et al.*, 1990 ; Edwards *et al.*, 1993 ; Burr *et al.*, 1998) and Cariaco basin varved sediments (Hughen *et al.*, 1998).
Fig. 2 : Comparaison des âges radiocarbone des gisements de Murray Springs (Arizona). Les âges calibrés sont déterminés avec la chronologie des coraux (Bard et al., 1990 ; Edwards et al., 1993 ; Burr et al., 1998) et des sédiments marin du bassin Cariaco (Hughen et al., 1998).

CONCLUSIONS

Cross-correlations of radiocarbon age records with climatic records based on absolute chronologies are now possible, due to the extension of the radiocarbon time scale with corals and other records. This allows us to understand the chronology of man's interaction with his environment during this time. The rapid Clovis expansion in the new world can be understood to be driven by climate.

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L'AGE DU FER DANS LA MOYENNE VALLÉE DE L'OGOOUÉ (Gabon) : CHRONOLOGIE PAR LE RADIOCARBONE

Richard OSLISLY, Michel FONTUGNE** et Christine HATTÉ***

Résumé : Cet article présente l'avènement et le développement de la métallurgie du fer dans la moyenne vallée de l'Ogooué (Gabon). On constate la présence d'un Age du Fer ancien (2500-1400 BP) avec deux groupes culturels et un important hiatus (1400-800 BP) qui précède l'arrivée de nouveaux métallurgistes de l'Age du Fer récent à partir de 800 BP.

Abstract : This article present the advent and development of iron metallurgy in the middle Ogooué valley (Gabon). We establish the presence of an Early Iron Age (2500-1400 BP) and an important gap (1400-800 BP) which precedes the arrival of the new ironworkers of the Late Iron Age.

Mots-clés : Gabon, moyenne vallée de l'Ogooué, Age du Fer, hiatus, datations.

Key-words : Gabon, middle Ogooué valley, Iron Age, hiatus, datings.

INTRODUCTION

En Afrique centrale atlantique, les chercheurs s'accordent à rattacher la diffusion des techniques réductrices du fer aux mouvements migratoires de l'expansion Bantou, depuis le Cameroun à travers le bloc forestier du Gabon jusqu'aux espaces ouverts du Congo (fig. 1). La métallurgie du fer est connue *ca* 2600 BP au Nord Cameroun dans les Monts Mandara (Mac Eachern, 1996), également dans la zone de Yaoundé au Sud-Cameroun (Essomba, 1989) ; elle est attestée *ca* 2500/2400 BP dans le centre du Gabon sur la moyenne vallée de l'Ogooué (Oslisly et Peyrot, 1992), et à partir de 2100 BP au Congo (Lanfranchi, 1991).

La synthèse des travaux menés depuis une décennie sur la métallurgie du cours moyen de l'Ogooué permet actuellement de différencier deux Ages du Fer, (ancien et récent) séparés par un important hiatus (Oslisly, 1998).

1 - L'AGE DU FER ANCIEN (2500-1400 BP)

Située à cheval sur la ligne équatoriale, la moyenne vallée de l'Ogooué est caractérisée par des paysages ouverts de savanes et de forêts galeries sur une aire de 1000 km^2 enclavés dans la forêt sempervirente. C'est à partir de 2300 BP que l'on assiste à une nette expansion des fondeurs du groupe céramique Okanda, précisément dans sa partie orientale l'Okanda-Lopé. Ils s'établissent de préférence en savane sur les sommets collinaires et construisent des fours de réduction du fer qui se distinguent par une structure d'argile, circulaire, haute de plus d'un mètre avec des tuyères disposées à la base (Oslisly, 1993). Ils confectionnent aussi une poterie qui présente des récipients campanulés au profil à courbure continue et des appendices de préhension comme les tenons et les anses. Le décor du cercle concentrique estampé à la base de ces anses est le plus significatif et il apparaît comme le marqueur typologique des potiers de la tradition Okanda. Ce sont d'ailleurs ces mêmes cercles concentriques que l'on retrouve dans l'iconographie de l'art rupestre régional, riche de 2000 gravures qui ont été exécutées à l'aide de pointes burinantes de fer (Oslisly, 1997). La présence de ces métallurgistes dans la région est attestée pour la dernière fois *ca* 1400 BP.

Une nouvelle vague de métallurgistes atteint *ca* 1900 BP la moyenne vallée de l'Ogooué mais dans la zone occidentale d'Otoumbi-Epona. Ces populations réduisent le fer selon le même procédé que le groupe Okanda. Elles sont rattachées au groupe céramique Otoumbi qui se substitue et se démarque du précédent

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par des récipients à panse sphérique et de taille moyenne à bords ouverts au méplat marqué d'une ligne cannelée. Les décors plus diversifiés et mieux définis, se disposent généralement sur l'encolure et la partie supérieure de la panse des récipients. La présence de ces métallurgistes est attestée pour la dernière fois *ca* 1400 BP, plus au sud en forêt ombrophile, à proximité d'importantes zones à brûlis, vraisemblablement traces d'une agriculture sur brûlis (Oslisly et Dechamps, 1994). Ces pratiques sont révélatrices de populations agro-forestières qui traversent la forêt grâce à la maîtrise d'un outillage de fer.

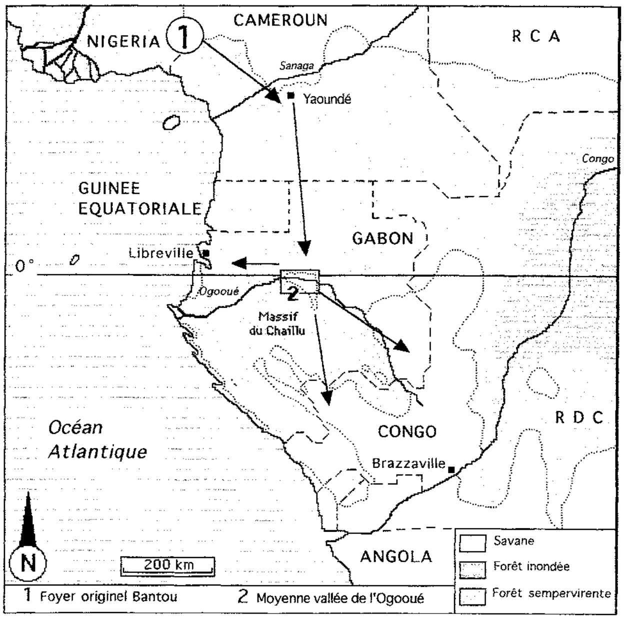

Fig. 1 : Carte de la diffusion des techniques de la réduction du fer dans la partie occidentale de l'Afrique centrale atlantique, par l'hinterland à travers le bloc forestier depuis le Cameroun vers le Gabon et le Congo.
Fig. 1 : Map of the diffusion of ironworking technics in the west atlantic central Africa, using hinterland countries across the forest block from Cameroon to Gabon and Congo.

2 - LE HIATUS (1400-800 BP)

Alors que la présence de populations de l'Age du Fer est bien confirmée de 2500-1400 BP dans la région (fig. 2), les mesures radiochronologiques indiquent qu'à partir de 1400 BP, la moyenne vallée de l'Ogooué semble ne pas avoir connu de peuplements humains jusqu'à 800 BP (Oslisly, 1993, 1995). En effet pour cette période de 1400/800 BP, aucune datation ne figure sur le tableau chronologique régional pourtant riche actuellement de plus de 100 dates. Durant cette longue période de près de six siècles, l'absence de groupes humains n'apparaît pas spécifique à cette seule région, car en tenant compte des très rares dates obtenues pour cette période, l'ensemble du territoire gabonais semble aussi affecté par ce hiatus. Cette absence de mesures radiométriques entre 1400/800 BP aurait pu s'expliquer par un accident majeur dans la courbe de calibration dendrochronologique du ^{14}C mais tel n'est pas le cas, la courbe est linéaire avec de petites oscillations et ne présente pas de plateau notoire (Stuiver et Becker, 1993).

3 - L'AGE DU FER RÉCENT (de 800 BP à l'Actuel)

De nouvelles populations métallurgistes réapparaissent dans la moyenne vallée de l'Ogooué *ca* 800 BP. L'analyse céramique distingue des récipients sub-sphériques avec un décor unique, fait de tout petits motifs circulaires disposés en arêtes de poissons et réalisés à l'aide d'une roulette végétale. Cette tradition céramique de l'Age du Fer récent est reconnue jusqu'au début de ce siècle. Les fours de réduction du fer se présentent sous la forme d'une simple excavation qui ne dépasse pas un mètre de profondeur avec de grosses et longues tuyères disposées en biais pour pouvoir atteindre et insuffler l'air à la base de la fosse.

Cette particularité est remarquable car elle nous permet ainsi de distinguer pour l'Age du Fer ancien l'utilisation de four de réduction avec une superstructure élevée en argile et pour l'Age du Fer récent l'emploi du four en fosse.

4 - CONCLUSION

On constate donc que depuis *ca* 2500 BP, l'histoire des populations des Ages du Fer dans la moyenne vallée de l'Ogooué est discontinue avec d'importantes ruptures culturelles (Oslisly et Fontugne, 1993) ; elle semble aussi s'inscrire dans le phénomène migratoire occidental de l'expansion Bantou. Cet important fractionnement culturel est probablement dû à la localisation géographique de cet espace-savane au milieu de la grande forêt, permettant ainsi l'escale (plus ou moins longue) de ces groupes immigrants.

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Laboratoire numéro	Radiocarbone age (B.P.)	Age Calibré (Cal) 2 Sigma	Sites	Association
		AGE DU FER ANCIEN		
Beta 14834	2640 ± 70	- 961 / - 559	Otoumbi 2a	Four
Gif 9860	2510 ± 70	- 796 / - 417	Lopé 5/b	Four
Gif 10326	2450 ± 60	- 765 / - 404	Lopé 5/f	Four
Gif 7130	2400 ± 50	- 752 / - 401	Otoumbi 2a	Four
Gif 7774	2310 ± 70	- 736 / - 203	Lopé 10	Four
Gif 9959	2270 ± 55	- 401 / - 193	Lopé 5/e	Four
		Tradition céramique OKANDA		
Beta 15067	2260 ±120	- 740 / - 38	Otoumbi 5	Fosse, Céramique
Beta 15063	2130 ±110	- 390 / + 72	Lopé 4	Four, Céramique
Gif 6909	2130 ± 60	- 358 / - 24	Okanda 1	Niveau, Céramique
Gif 8741	2130 ± 60	- 358 / - 24	Epona	Four, Céramique
Gif 7776	2110 ± 70	- 355 / + 60	Okanda 2	Niveau, Céramique
Gif 8140	2010 ± 40	- 112 / + 64	Mingoué 1	Four, Céramique
Beta 15066	1980 ± 80	- 184 / + 199	Otoumbi 4	Four, Céramique
Gif 9858	1970 ± 50	- 66 / + 194	Okanda 2a	Four, Céramique
Gif 10437	1950 ± 40	- 37 / + 143	Okanda 5 F1	Fosse, Céramique
Gif 8138	1910 ± 40	+ 5 / + 199	Lindili 1	Fosse, Céramique
Gif 7524	1840 ± 60	+ 39 / + 324	Okanda 5	Fosse, Céramique
Gif 10436	1890 ± 50	+ 21 / + 243	Lindili 1 F6	Fosse, Céramique
Gif 10102	1790 ± 50	+ 128 / + 383	Okanda 1/b	Niveau, Céramique
		Tradition céramique OTOUMBI		
Gif 6423	1970 ± 70	- 151 / + 190	Otoumbi 2b	Niveau, scories
Beta 15068	1900 ± 90	- 104 / + 323	Otoumbi 5	Fosse, Céramique
Gif 6908	1860 ± 60	+ 19 / + 310	Otoumbi 1a	Four
Gif 8051	1850 ± 60	+ 29 / + 317	Elarmekora 3	Niveau, Céramique
Gif 9965	1780 ± 70	+ 88 / + 416	Lefob 1	Fosse, Céramique
Beta 14835	1740 ± 60	+ 140 / + 410	Otoumbi 1a	Four
Gif 7775	1730 ± 60	+ 146 / + 417	Mingoué 5	Four, scories
Gif 7197	1700 ± 50	+ 225 / + 426	Otoumbi 5	Fosse, Céramique
Gif 7430	1640 ± 70	+ 244 / + 560	Otoumbi 8	Fosse, Céramique
Gif 7196	1630 ± 50	+ 270 / + 537	Otoumbi 5	Fosse, Céramique
Gif 8740	1600 ± 60	+ 281 / + 584	Anzem 1	Four, scories
Gif 7777	1420 ± 50	+ 540 / + 673	Mbama 1	Fosse, Céramique
		H I A T U S		
		AGE DU FER RECENT		
Gif 10278	860 ± 40	+1046 / +1276	HVLélédi 4	Four, Céramique
Gif 10327	820 ± 60	+1046 / +1293	Lopé 15	Ferrier, Céramique
Gif 10205	705 ± 50	+1239 / +1395	Oumoundo	Four, Céramique
Gif 10104	700 ± 50	+1248 / +1396	Lélédi 2	Four, Céramique
Beta 15064	660 ± 80	+1215 / +1414	Lopé 5	Niveau, Céramique
Gif 8050	500 ± 30	+1398 / +1442	Otoumbi 3	Four, Céramique
Gif 9966	450 ± 40	+1408 / +1619	LeFob 2	Niveau, noix
Gif 9964	410 ± 45	+1430 / +1634	Lélédi 2	Four, Céramique
Gif 9862	250 ± 40	+1623 / +1808	Lopé 10	Niveau, Céramique
Gif 9963	210 ± 40	+1641 / +1819	Lélédi 1	Four, Céramique
Gif 10325	200 ± 50	+1643 / +1884	HVLélédi 2	Four, Céramique
Gif 9967	80 ± 60	+1677 / +1941	HVLélédi 1	Niveau, noix
Gif 6425	Age moderne	-	Obaka 1	Niveau, Céramique
Gif 7526	Age moderne	-	Otoumbi 11	Fosse, Céramique
Gif 10279	Age moderne	-	Mitendi 1	Niveau, Céramique

Fig. 2 : Tableau des datations radiocarbones de l'Age du Fer de la moyenne vallée de l'Ogooué (état des connaissances au 1er Mars 1998).
Fig. 2 : Table of Iron Age radiocarbon dates in the middle reaches of the Ogooué valley (state of knowledge at the first March 1998).

Actes du colloque « C14 Archéologie », 1998, p. 349-353.

SYNTHÈSE RADIOCHRONOMÉTRIQUE CONCERNANT LA SÉQUENCE NÉOLITHIQUE AU MAROC

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Résumé : Les sites néolithiques du Maroc ont fait l'objet de fouilles anciennes souvent imparfaitement publiées et, sauf exception, sans que des datations absolues aient été réalisées : Les Idoles, Mugharet et Alya, Oued Tahadart, Gar Kahal, Kaf taht el Ghar, Dar Soltane, Témara Les Contrebandiers, El Kiffen, Toulkine.
En 1982, La Mission Préhistorique Française et l'Institut National des Sciences de l'Archéologie et du Patrimoine du Maroc sont convenus de développer un programme de datations absolues. Tous les sites ont été révisés et échantillonnés tandis que certaines fouilles étaient reprises (Gar Kahal, Kaf taht el Ghar) et d'autres ouvertes (Témara, El M'nasra). Afin de palier au manque de matériaux charbonneux et osseux fiables, on a recouru à la datation directe des céramiques (thermoluminescence, Laboratoire de Physique Corpusculaire de l'Université de Clermont-Ferrand II) et des sédiments encaissants (T.L./O.S.L., Université de Londres).
A plusieurs reprises il a été possible d'opérer des croisements méthodologiques à même de renforcer la fiabilité des résultats obtenus : ^{14}C/T.L. sur céramique/O.S.L. à Skhirat-Rouazi ; ^{14}C/T.L./O.S.L. à l'Oued Tahadart ; ^{14}C/T.L. à Kaf taht el Ghar. En outre dans deux cas (Skhirat-Rouazi et Kaf taht el Ghar) il a été procédé à la mesure du taux de racémisation des acides aminés de coquilles marines (*Patella*, *Mytilus*) et de gastéropodes continentaux (*Helix*) issus de niveaux archéologiques et faisant concurremment l'objet d'une datation par le radiocarbone. Les résultats sont cohérents et en bon accord avec la position stratigraphique des échantillons ouvrant ainsi de nouvelles perspectives de datation.

Abstract : The ancient excavations of the neolithic sites of Morocco are often imperfectly published and, with a few exception, without any radiocarbon dates : Les Idoles, Mugharet et Alya, Oued Tahadart, Gar Kahal, Kaf taht el Ghar, Dar Soltane, Témara Les Contrebandiers, El Kiffen, Toulkine.
Therefore, in 1982, the Mission Préhistorique Française and the Institut National des Sciences de l'Archéologie et du Patrimoine du Maroc decided to launch a program of absolute dates.
All sites were reviewed and sampled while some excavations were reopened (Gar Kahal, Kaf taht el Ghar) and other opened (Témara, El M'nasra). When there was no reliable charcoal or bones, direct datings of ceramic (T.L. by the Laboratoire de Physique Corpusculaire of the University of Clermont-Ferrand II) and embedding sediments (T.L.or /O.S.L. by the University of London) were performed.

Mots-clés : Maroc, Néolithique, Protohistoire, datations abolues, sériation chrono-culturelle.

Key-words : Morocco, Neolithic, Protohistorry, absolute datations, chrono-cultural seriation.

INTRODUCTION

Jusqu'à une date proche les recherches concernant la Préhistoire récente et la Protohistoire du Maroc sont demeurées tributaires de modèles induits des travaux conduits en Europe occidentale et dans les contrées avoisinantes du Maghreb ou de la Péninsule ibérique. La plupart des données de terrain étaient issues de la zone saharienne et, en l'absence d'ensembles cohérents de datations numériques, il était impossible de tenter une sériation typochronologique fondée sur la reconnaissance d'ensembles régionaux issus de fouilles rigoureuses. Seules, entre 1923 et 1975, les activités conduites dans la Péninsule tingitane par H. Koehler, M. Tarradell, A.

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Jodin, M. Ponsich, G. Camps, H. Camps-Fabrer et A. Gilman, permirent de distinguer une phase ancienne rapportable au Cardial (Ve millénaire av. J.-C.) d'une autre, récente, attribuable au Campaniforme (IIIe millénaire av. J.-C.) mais sans que des composantes locales et une chronologie détaillée soient établies.

Dès 1984, la Mission Préhistorique Française au Maroc (programme «Néolithique du littoral nord-atlantique») a engagé, en collaboration avec l'Institut National des Sciences de l'Archéologie et du Patrimoine, à Rabat, et le Laboratoire de Physique Corpusculaire de l'Université Blaise Pascal de Clermont-Ferrand, la vérification systématique des sites connus entre Tanger et Casablanca. Ces travaux ont donné l'occasion de réviser les stratigraphies, de contrôler les associations, de prélever des échantillons naturalistes (sédimentologie, palynologie, zoologie....) et des matériaux (charbons, restes humains, céramiques, coquilles marines et terrestres, sédiments incluant des quartz) propres à obtenir des datations fondées sur des croisements méthodologiques : radiocarbone (Daugas *et al.*, 1989) thermoluminescence de céramiques (Ousmoi, 1989), O.S.L. (Smith *et al.*, 1990), racémisation des acides aminés sur coquilles (Occhietti *et al.*, 1998, même ouvrage). A cette occasion des prospections ont été conduites dans la région de Tétouan et de nouveaux gisements en grotte ont été découverts, tel Kaf Boussaria (travaux A. El Idrissi).

Les sites concernés sont les grottes de Kaf taht el Ghar et de Kaf Boussaria (Dar ben Karrich, environs de Tétouan), de Gar Kahal (El Bioutz, secteur de Ceuta), d' El Khil A, B et C, des Idoles (Cap Achakar, alentours de Tanger), de l'habitat de plein-air de l'Oued Tahadart (Gzanaïa, Had Gharbia, environs d'Asilah) dans la Péninsule tingitane. Dans la mesetta côtière il s'agit des grottes de Dar es Soltan 2 (Rabat) d'El Harhoura 2, des Contrebandiers, (Témara) et de la nécropole de Rouazi (Skhirat). Dans l'arrière pays montagnard, ce sont la grotte funéraire d'Ifri ou Berid (Azrou) ainsi que l'abri de Toulkine (Amzri), (Daugas *et al.*, 1998).

Les résultats, convergents et recoupés, sont présentés dans le tableau 1 et permettent désormais de présenter une chronométrie intercalibrée de la séquence néolithique et protohistorique du Maroc septentrional :

1 - NÉOLITHIQUE ANCIEN RÉGIONAL ACÉRAMIQUE (?) VERS 9000 AV. J.-C. (?)

Les fouilles de 1989-1994 dans la grotte de Kaf taht el Ghar (J.-P. et C. Daugas, A. Mikdad, *publication en cours*) ont permis d'établir une séquence stratigraphique complétant et corrigeant les données anciennes (Tarradell, 1958) : à la base du Néolithique ancien cardial et reposant sur un dépôt paléontologique (US 1029) d'âge épipaléolithique (Ly-7289 = 13300 ± 180 BP, 14467/13325 av J.-C.), deux dépôts anthropiques (US 1038 et 1039) ont été datés de la seconde moitié du Xe millénaire (Ly-7695 = 9865 ± 75 BP, 9522/9004av. J.-C. Ly-7287 = 9910 ± 50 BP, 9623/9033 av. J.-C.). L'analyse carpologique (Ph. Marinval, CNRS-EHESS, Toulouse, *publication en cours)* a révélé la présence de très nombreuses graines attribuables à trois espèces de blé (l'amidonnier, *Triticum dicoccum* ; l'engrain, *T. monococcum* ; le froment/blé dur *T. aestivum/T. durum*) et à la gesse ocre (*Lathyrus cf. ochrus*) comestible et cultivée qui confèreraient donc un caractère néolithique à ces formations n'ayant toutefois livré aucun vestige céramique. Le fait que cette phase est marquée par une lacune de sédimentation peut impliquer que des éléments asynchrones co-existent sur une même surface palimpseste, ou de cumul.

Afin de tenter de valider cette donnée une datation AMS directe est en cours sur l'un de ces carpes.

2 - NÉOLITHIQUE ANCIEN CARDIAL, VERS 5450 À 4400 AV. J.-C.

La reprise des fouilles de Kaf taht el Ghar (*cf. supra*), l'échantillonnage de Ghar Kahal, d'Ell Khil C, des Idoles, de Tahadart, d'El Hahroura 2 et des Contrebandiers a, tout à la fois, permis de caler dans le temps la séquence cardiale du Maroc et de préciser l'extension géographique de cette culture jusqu'à la latitude de Rabat.

Après une première occupation cardiale sporadique (US 1027 à 1024) la grotte de Kaf taht el Ghar est le siège d'un habitat permanent et structuré dont l'attribution au Cardial récent (deuxième moitié du VIe/début du Ve millénaire av. J.-C.) est fondée sur deux dates au radiocarbone, (Ly-3821 et 7288), quatre mesures de T.L. sur céramique (Cler 126 à 129 et par une mesure du taux d'épimérisation de l'isoleucine sur des coquilles d'*Hélix* (US 1004. Occhietti *et al.*, 1998, même ouvrage).

Dans la grotte d'El Khil C, deux tessons cardiaux collectés à la base de la couche C (Jodin, 1958), en octobre 1987, à la faveur de la dosimétrie de site, ont été datés de la charnière entre le le IVe et le Ve millénaire av. J.-C. (Cler TL 118 et 119).

La grotte des Idoles à Achakar étant désormais en partie détruite et, pour le reste, polluée par l'égout d'un établissement touristique a donné lieu à un échantillonnage parmi les collections du fonds Koehler conservées au musée de Rabat : l'occupation cardiale est située au début du Ve millénaire par la thermoluminescence d'un tesson impressionné (Cler 120). *A contrario*, la datation de charbons notés par le fouilleur comme provenant de la couche C (Néolithique récent à céramique rouge et figurines féminines) a également fourni un âge de la première moitié du Ve millénaire, ce qui implique des remaniements stratigraphiques.

Le site de plein-air de l'Oued Tahadart, découvert en 1972 et régulièrement prospecté par G. Hadacek lui a livré, comme à de nombreux amateurs tangérois, un très abondant mobilier céramique cardial associé à des foyers aménagés régulièrement mis au jour par la déflation du cordon dunaire reposant au toit d'un pseudo-karst de sable grèsifié. La découverte de nombreuses vertèbres de thon, dont certaines aménagées en grains d'enfilage, permettent d'évoquer une aire de pêche spécialisée. Un sondage implanté en mai 1984 a permis de collecter des échantillons céramiques, à 1,60 m de profondeur, au sein d'un niveau archéologique associant de la faune et des coquilles marines, tout en effectuant une dosimétrie de site. En juin 1988, deux prélèvements de sédiment ont été effectués, à la même cote dans ce sondage, en vue d'une datation par O.S.L. Les résultats obtenus convergent pour situer l'occupation cardiale au milieu du Ve millénaire avant J.-C. et dont on notera le bon classement stratigraphique (*cf.* tab. 1 : ^{14}C sur coquille marine UQ 1556 ; TL sur céramique Cler 122 à 125 ; OSL sur sable dunaire Ox 726 aII et Ox 726 bII).

Jusqu'en 1989, la présence du Néolithique ancien dans la région de Rabat n'était attestée que par la double sépulture de la grotte d'El Harhoura 2 créditée d'un âge de 5400 ± 290 BP, 4898/3636 av. J.-C. - Gif. 5519, Debénath et Lacombe, 1986). Cette attribution a été confirmée par une date sur coquille de *Patella* collectée en 1987 (UQ 1601 = 5800 ± 150 BP, 4865/3612 av. J.-C). En revan-

SITES	14 C					T.L.					O.S.L.				
	Matériau	U.S.	N° labo.	B.P.	av.J.-C.	Matériau	U.S.	N° labo.	avant 1980	av.J.-C.	Matériau	U.S.	N° labo.	B.P.	av.J.-C.
EL KHIL C						poterie	C Cardial	Cle 118	6400±500	4420					
						poterie	C Cardial	Cle 119	5950±350	3970					
ACHAKAR Idoles						poterie	Cardial	Cle 120	6900±600	4920					
	charbon	Cardial	Gif A 92332	5630±80	4696 4356										
TAHADART	coquille marine	Cardial	UQ 1556	5600±200	4890 4010										
						poterie	Cardial	Cle 122	6490±560	4510					
						poterie	Cardial	Cle 123	5047±580	3067					
						poterie	Cardial	Cle 124	6710±510	4730					
						poterie	Cardial	Cle 125	6850±520	4870					
											sable dunaire	Cardial	Ox 726bII	5900±800	3920
											sable dunaire	Cardial	Ox 726aII	6200±800	4220
GAR KAHAL						poterie	Bronze	Cle 130	3880±300	1900					
						poterie	Bronze	Cle 131	2200±250	220					
KAF TAHT EL GHAR						poterie	1005 Cardial	Cle 126	6780±550	4800					
						poterie	1005 Cardial	Cle 127	6350±600	4370					
						poterie	1005 Cardial	Cle 128	5800±750	3820					
						poterie	1005 Cardial	Cle 129	7200±750	5220					
	charbon	1006 Cardial	Ly 3821	6050±120	5221 4675										
	charbon	1018 Cardial	Ly 7288	6520±80	5565 5287										
	charbon	1038 Néo ancien ac.	Ly 7695	9865±75	9522 9004										
	charbon	1039 Néo ancien ac.	Ly 7287	9910±50	9581 9040										
	charbon	1029 Epipal.	Ly 7289	13300±180	14467 13325										
DAR ES SOLTANE 2						poterie	Néo.	Cle 132	5000±350	3020					
EL HARHOURA I	os humain	Sép. coll. Néo.	Gif 5519	5400±290	4898 3636										
EL HARHOURA II	os humain	Sép. ind. Néo. ancien	Ly 2149	5980±210	5230 4354										
	coquille marine	Néo. ancien	UQ 1601	5800±150	4865 3612										
						poterie (recuite)	Néo.	Cle 133	1780±350	200 AD					
						poterie (recuite)	Néo.	Cle 134	2200±400	220					
TEMARA Contrebandiers						poterie	Néo. (Cardial)	Cle 136	6600±600	4620					
						poterie	Néo.	Cle 135	4200±350	2200					
SKHIRAT Rouazi											sable dunaire	encaissant	Ox 725aII	8100+3100-2700	6120
	mat. org.	paléosol	Ly 4097	7710±180	7012 6176										
	coquille marine	delta	UQ 1557	4950±150	4069 3388										
	os Rhino.	delta	Ly 3087	4481±190	3618 2637										
	charbon	kjökken	Ly 4096	4560±150	3616 2898										
						poterie	kjökken T1	Cle 137	5260±350	3280					
						poterie	kjökken T1	Cle 138	5500±1500	3520					
						poterie	kjökken T2	Cle 139	4400±650	2420					
	os humain	S.61	UQ 1868	5350±150	4466 3828										
						poterie	S.35	Cle 140	5400±450	3420					
TOULKINE						poterie	Néo.	Cle 141	4400±450	2420					
						poterie	Néo.	Cle 142	4000±350	2020					
						poterie	Néo.	Cle 143	4300±400	2320					
IFRI OU BERID	os humain	sépulture proto.	OxA-7424 Lyon 597	2370±50	743 284										

Tab. 1 : Corpus des datations numériques obtenues par le programme mixte franco-marocain «Néolithique du littoral nord-atlantique» entre 1989 et 1997 (C. DAUGAS *del*).

che, la mesure de la thermoluminescence d'un tesson de technologie et à décor de style cardial n'a indiqué qu'une date de 1780 ± 350 av. 1980 (Cler 133) du fait du rechauffage de cette poterie dans un foyer en fosse, récent. Enfin une date obtenue sur un tesson de type cardial, échantillonné en 1987 dans les séries issues des fouilles de 1955 (Roche, 1963) dans la grotte des Contrebandiers, à Témara, confirme ce diagnostic : Cler 136 = 6600 ± 600 BP, 4620 av. J.-C. Depuis lors, la découverte d'un micro-vase cardial, entier, dans la grotte d'El M'nasra (ex Casino) est venue souligner l'ampleur de cette occupation méridionale (Lacombe *et al.*, 1991).

3 - NÉOLITHIQUE MOYEN, VERS 4300 AV. J.-C.

Cet épisode n'est actuellement inféré que par l'âge obtenu sur les ossements humains de la sépulture collective d'El Hahroura 1 (grotte Zouhrah) fouillée en 1977 et 1978 à Témara : Gif 5519 = 5400 ± 290 BP, 4898/3636 av. J.-C. (Debénath et Alaoui, 1979).

Seule la reprise des études sur des découvertes isolées comme celles de l'Oued Mellah (Mohammedia. Labouret et Lesven, 1929) ou de la série céramique de la grotte de l'Oued Merzeg (Dar Bouâzza. Capitant et Mieg de Boofzheim, 1953) permettrait, éventuellement, d'abonder cette hypothèse de travail.

4 - NÉOLITHIQUE MOYEN-RÉCENT, DE 4000 À 2900 AV. J.-C.

Cette phase est fondée sur l'identification du *style céramique de Skhirat* au terme de la fouille de la nécropole de Rouazi (J.-P. et C. Daugas, F.-Z. Sbihi-Alaoui. *Publication en cours*. Etude anthropologique J.-P. Lacombe), où abondent les décors peignés en bande sur des formes d'urnes à fond cônique ou rond, et de jattes ovalaires ou à fond plat. Les tombes, attenantes à une aire domestique avec foyers à coquilles marines (*kjökkenmödding)*, sont situées dans la première moitié du IVe millénaire av. J.-C. par un croisement de dates radiocarbone (charbons et os humains) et T.L. (poterie). L'encaissant est situé au VIIe millénaire par la matière organique d'un paléosol (Ly-4097) et par O.S.L. sur sable dunaire (Ox 725 aII. Rhodes, 1990).

Depuis lors, l'extension de ce style a été reconnue dans la région de Rabat (Kaf el Baroud à Benslimane, Mikdad, 1998 ; Dar es Soltane 1 ; Dar es Soltane 2, fouilles Debénath, Cler TL 132 = 5000 ± 350 av. 1980., 3020 av. J.-C. ; El Hahroura 2, El M'nasra, Les Contrebandiers) mais aussi dans les environs de Tanger (grottes A, B et C d'El Khil ; Mugharet el Alia, Mugharet as Safiya Gilman 1975 ; Les Idoles) et de Tétouan (Gar Kahal, Kaf taht el Ghar, Kaf Boussaria). De même, l'étude des séries du fonds Glory de l'I.P.H à Paris et provenant de ses fouilles dans l'abri de Toulkine (Amzri, Haut-Atlas. Bayle des Hermens *et al.*, 1984) a permis d'isoler des éléments du style Skhirat et de les dater du IIIe millénaire av. J.-C. (Cler 141 à 143).

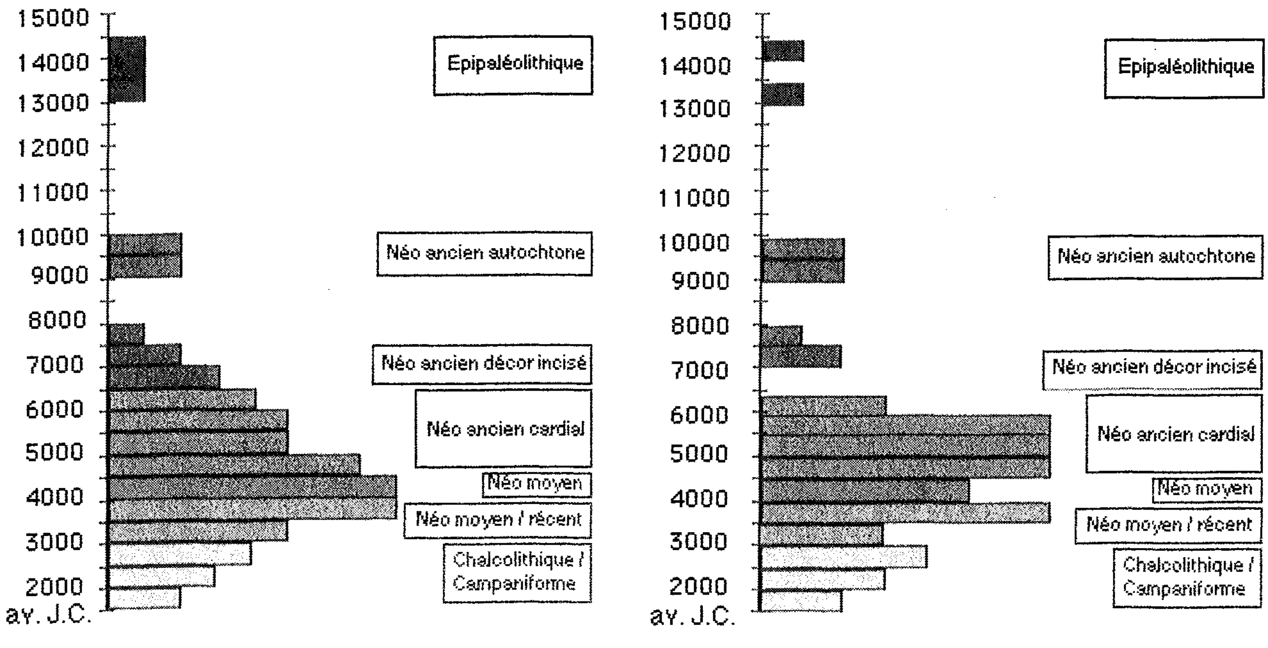
5 - CAMPANIFORME

Aucune datation absolue ne porte actuellement sur des campaniformes marocains. La fourchette 2900/1900 av. J.-C. peut être déduite, d'une part du *terminus post quem* fourni par le style de Skhirat qui intervient comme composante génétique du Campaniforme ibérique, d'autre part des dates attribuées aux pointes de *La Palmela*, nombreuses en contexte campaniforme au Maroc.

On notera cependant que les investigations récentes à Kaf taht el Ghar, Ghar Kahal et Kaf Boussaria ont permis d'enrichir considérablement le *corpus* céramique et le mobilier d'accompagnement (brassards d'archer, haches et ciseau en cuivre...).

6 - AGE DU BRONZE, À PARTIR DE 2900 AV. J.-C.

En octobre 1987 et en avril-mai 1988, l'ouverture d'importants sondages sur le site de Gar Kahal a permis d'établir que l'ensemble de la stratigraphie observée par M. Tarradell correspond au remplissage d'un four à chaux d'âge historique directement implanté dans la diaclase du secteur A de la cavité. Dès lors la succession chrono-



Tab. 2 : Histogrammes de répartition des dates calibrées. A droite : par classes de 500 ans. A gauche : nombre de plages de dates calibrées par classes de 500 ans (P. CHEVET *del*).

culturelle établie par cet auteur doit-elle être considérée comme caduque même s'il demeure avéré que la cavité a été occupée à l'Epipaléolithique, au Cardial, au Néolithique récent, au Campaniforme, à l'Age du Bronze et à l'époque historique. Plus particulièrement, l'attribution d'une céramique peinte au Néolithique ancien (Tarradell, 1954, 1958) doit-elle être définitivement abandonnée.

Par contre la datation par thermoluminescence d'un ensemble de tessons d'une poterie noire, lisse et brillante a permis d'identifier, pour la première fois au Maroc, une production céramique de l'Age du Bronze : Cler 130 et 131, entre 1900 et 220 av. J.-C. Depuis, le même matériel a été isolé en grand nombre à Kaf taht el Ghar (US 1002 et 1003) ainsi qu'à Kaf Boussaria (US 1051/1052 et 1059/1062) évoquant, en particulier, des formes de petites urnes globulaires à fond rond.

7 - PHASE PROTOHISTORIQUE À CÉRAMIQUE TOURNÉE, À COMPTER DE 600 AV. J.-C.

Le petit aven funéraire d'Ifri ou Berid (environs de la maison forestière d'Aïn Kahla, région d'Azrou), s'ouvrant sur un étroit joint de stratification, a été découvert en 1980 par B. LIPS, spéléologue (Revel, 1987, p. 123, FA 12, Kef el Ras). Une intervention d'échantillonnage anthropologique a eu lieu en 1985 (travaux J.-P. Lacombe) et un vase entier, monté au tournassin, a été recueilli en association avec le dépôt funéraire. Une date radiocarbone sur os humains Ly-597/Oxa-7424 = 2370 $\pm$ 50 BP., 743/284 av. J.-C.) permet désormais de fournir une limite haute, pour la fin de l'Age du Bronze et l'apparition des techniques protohistoriques. Ce *terminus* est en bon accord avec les données historiques relatives au Maroc.

La présentation, sous forme d'histogrammes (tab. 2), de ce cortège de dates réparties par classes de 500 ans traduit bien la cohérence du cadre chronologique proposé. Il sera désormais plus aisé de définir et de suivre l'évolution des groupes régionaux dont le catalogue mobilier est en voie d'élaboration, sur la base des études monographiques en cours.

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RELATIONS CHRONOLOGIQUES ENTRE HABITATS, MODES DE VIE ET FLUCTUATIONS CLIMATIQUES HOLOCÈNES SUR LES DHARS TICHITT ET OUALATA (Mauritanie Sud-Orientale)

Sylvie AMBLARD-PISON et Alain PERSON***

Résumé : Au Néolithique, sur les falaises (dhars) du Hodh et du Tagant ont été bâtis de nombreux villages en pierres sèches. A leurs pieds, dans l'étroite dépression (baten) où subsistent des dépôts stratigraphiques, des habitats non construits attestent également une densité humaine importante. Les populations de cette région pratiquaient l'agriculture, l'élevage et le stockage. Les datations ^{14}C situent l'occupation humaine entre 4000 et 2000 BP, leur majorité étant focalisée entre 3500-2500 BP. Celles relevant du paléoenvironnement se répartissent du début de l'Holocène à 2000 BP. Les histogrammes, obtenus par une méthode de traitement graphique appliquée à l'ensemble des données ^{14}C, précisent les relations entre les modes de vie et l'évolution de l'environnement de ces populations installées dans un contexte d'environnement-refuge.

Abstract : During the Neolithic period, many drystone villages have been built on the cliffs (dhars) of the Hodh and Tagant areas. At their foot, Holocene stratigraphic deposits are preserved in a narrow trough (baten). A large human density is also evidenced by many non-built settlements. The populations of this area have been practised agriculture, herding and storage. ^{14}C datings demonstrate that the human settlement has occurred between 4000 and 2000 BP ; most of them are centred on the millenium 3500-2500 BP. Those from paleoenvironmental evidences range from the beginning of the Holocene to 2000 BP. The histograms obtained by graphical ^{14}C data-processing are specifying the relations between the ways of life and the evolution of the environment of these Neolithic populations living in an environmental context of refuge.

Mots-clés : ^{14}C, habitat néolithique, agriculture, paléoenvironnement, Mauritanie.

Key-words : ^{14}C, Neolithic settlement, agriculture, palaeoenvironment, Mauritania.

1 - DONNÉES ARCHÉOLOGIQUES ET PALÉOENVIRONNEMENTALES

La région du Hodh et du Tagant, entre 7° et 9°50' de longitude ouest et 17°18' et 18°35' de latitude nord, est située entre les isohyètes 100 et 50. Elle se caractérise par une série de falaises gréseuses, les *Dhars*, de 100 à 350 m de haut. Ils s'étendent en arc de cercle sur plus de 800 km, séparant deux grands ergs : la Majabat al-Koubra, au Nord, et l'Aouker, au Sud. Leur sommet surplombe une dépression large de quelques centaines de mètres à quelques kilomètres : le *Baten*. Des dépôts stratigraphiques, postérieurs à la fin du Pleistocène, y subsistent (Hugot, 1977 ; Miskovsky *et al.*, 1988 ; Person *et al.*, 1995, 1996), maintenus à l'affleurement par l'activité des circulations éoliennes liées au relief de la falaise. La nature des sédiments non éoliens (diatomitiques, palustres et pédologiques) et l'importance des séries sableuses éoliennes sont compatibles avec l'existence au pied des Dhars de plans d'eau, alimentés par des nappes phréatiques enrichies aux périodes plus humides de l'Holocène. Les falaises de Tichitt et Oualata commandent donc l'organisation du système hydrologique régional devenu endoréïque depuis la fin de la première période humide holocène. Elles ont joué le rôle de «zone-refuge», dans la seconde moitié de l'Holocène et permis à l'une des cultures les plus originales du Néolithique saharien de se développer à une période où, ailleurs, l'aridification trop prononcée ne permettait plus aux hommes de vivre.

Cette région, actuellement désertique, compte, selon les années, de 1 à 9 habitants pour 100 km^2. Pourtant, l'abondance des vestiges préhistoriques traduit une

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occupation humaine particulièrement intense marquée par les ruines de centaines de villages sur les Dhars et les nombreux sites d'occupation du Baten (Mauny, 1951 ; Munson, 1971 ; Amblard, 1984 ; Holl, 1986). Construits en pierres sèches, les villages constituent un ensemble exceptionnel dont l'uniformité, très nette au niveau des techniques architecturales employées, se retrouve aussi dans l'outillage taillé, les décors et formes des céramiques et les manifestations artistiques. Le village v.72 (fig. 1), qui s'étend sur quelques 15 hectares, en est l'un des plus beaux exemples. Souvent en vue les uns des autres, ces villages sont localisés sur une étroite bande de terrain de quelques kilomètres de large mais de plusieurs centaines de kilomètres de long, correspondant au rebord de la falaise et à ses pentes. Ils sont constitués de concessions, aires d'occupation familiale délimitées par des murs épais, séparées par des espaces destinés à la circulation. A l'intérieur, parmi l'important mobilier archéologique, céramique et matériel de broyage abondent. Divers éléments attestent la pratique de l'élevage et de l'agriculture (champs et jardins ; Amblard, 1996). Données architecturales et mobilières témoignent de la sédentarité de ces populations. L'association de pratiques agricoles et de nombreux vestiges de stockage de vivres et d'eau (Amblard-Pison, 1996) plaident en faveur d'une prise en charge par ces populations de la gestion de leur environnement limité par les phénomènes naturels.

Notre propos est de discuter de l'apport du ^{14}C dans la compréhension de l'apparition et de la succession des grands évènements survenus dans ces sociétés. Ainsi, les villages des Dhars sont-ils contemporains des habitats du Baten et du plateau ? Constituent-ils un ensemble chronologiquement homogène ? Toutes les parties du village ont-elles été occupées conjointement ? Ces grands évènements, tels sédentarité, agriculture et stockage sont-ils, dans cette région, en relation avec l'évolution des géo-écosystèmes ?

2 - DONNÉES RADIOCHRONOLOGIQUES

Les données radiochronologiques obtenues ces dernières années ont permis d'affiner la vision préalable du mode de vie et de l'environnement des populations de cette région à l'Holocène. Jointes à celles obtenues par d'autres auteurs, elles forment un corpus de 80 dates ^{14}C, réalisées depuis une vingtaine d'années, à la suite de différents programmes, par dix laboratoires : Laboratoire du Radiocarbone, IFAN, Dakar (Sénégal) ; LODYC, Paris (F) ; Teledyne isotopes (USA) ; Laboratories of Geochron, Inc. and Isotopes, Cambridge (USA) ; Centre de Datations et d'Analyses Isotopiques, Lyon (F) ; Laboratoire de Radioactivité appliquée (Monaco) ; Centre des Faibles radioactivités, Gif-sur-Yvette (F) ; Institut des Radio-Isotopes, Niamey (Niger) ; Laboratoire d'Hydrologie et de Géochimie Isotopique, Orsay (F). Les matériaux archéologiques datés sont constitués essentiellement par des poteries (44 %) et des charbons de bois (43 %) ; viennent ensuite les données sur ossements animaux (déchets de cuisine) ou humains. Les datations sur céramique ont été obtenues par la méthode basée sur la mesure du ^{14}C de la matière organique carbonisée provenant des dégraissants végétaux inclus dans les poteries (Gabasio, 1987 ; Saliège et Person, 1991). Les matériaux paléoenvironnementaux datés sont des traces paléohydrologiques (tests de mollus-

Fig. 1 : Le village v.72, construit sur le rebord du plateau du Dhar Tichitt, avec ses 210 concessions délimitées par des murs en pierres sèches et son réseau de rues et de places (levé S. Amblard).
Fig. 1 : The v.72 village, built on the edge of the Dhar Tichitt plateau, with its 210 compounds bordered by stone walls ans its network of streets and open spaces (S. A.).

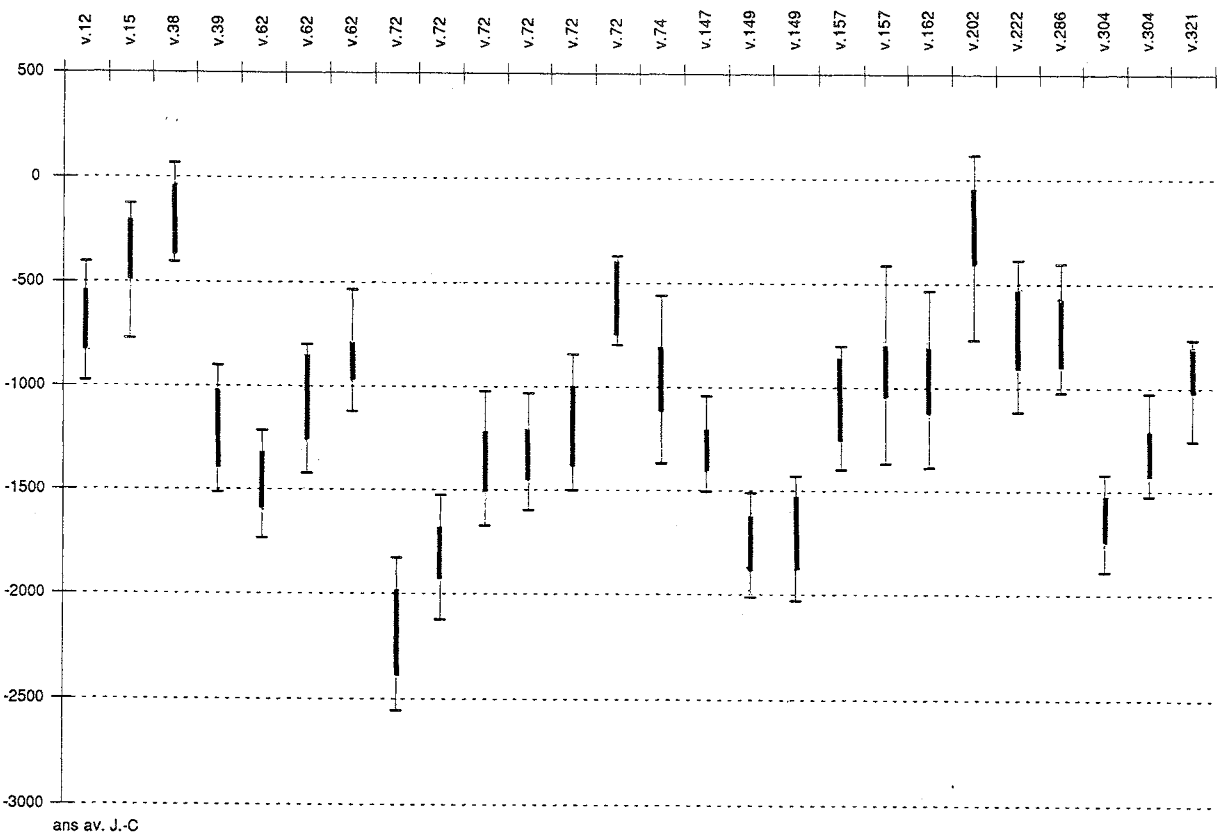

Fig. 2 : Distribution d'Ouest en Est, sur les Dhars, des dates ^{14}C calibrées (1 et 2 sigmas) de l'occupation en villages.
Fig. 2 : Distribution of calibrated ^{14}C datings (1 and 2 sigmas) for the Dhar villages from West to East.

ques d'eau douce, sédiments carbonatés) ou paléopédologiques (concrétions racinaires, matières organiques).

Les dates archéologiques indiquent une occupation de la région continue dans le temps, entre 4000 et 2000 BP. Les dates paléoenvironnementales se répartissent entre 9500 et 2000 BP.

3 - INTERPRÉTATION CHRONO-ARCHÉOLOGIQUE

3.1 - LES HABITATS

Les villages des Dhars ont été datés entre 3776 ± 120 BP (2399-1983 av. J.-C.) et 2170 ± 105 BP (375-47 av. J.-C.) (fig. 2). Les intervalles de confiance obtenus après calibration des dates indiquent que de nombreux villages ont pu être occupés simultanément, tout au moins à un moment de leur histoire.

Dans le village v.72, les dates fournies par trois échantillons prélevés selon un axe NO/SE traversant le village, sembleraient indiquer au cours des temps, une expansion des zones construites ou un déplacement des zones habitées du rebord de la falaise vers l'intérieur du plateau. Ceci en accord avec les données architecturales : les murs des concessions les plus récentes prenant appui sur les plus anciennes. Les dates les plus anciennes correspondent à l'extrême bordure sud (3500 ± 100 BP, 1936-1683 av. J.-C.) et à une concession proche (3400 BP). Près de la bordure sud-ouest du village, des charbons ont donné un âge de 3100 ± 105 BP (1446-1216 av. J.-C.) et d'autres, d'une concession de la partie nord-est, ont fourni une date plus récente (2430 ± 80 BP, 763-397 av. J.-C.).

Les sites non architecturés du Baten, au mobilier apparenté à celui des villages, ont été datés entre 3590 ± 80 BP (2032-1780 av. J.-C.) et 2610 ± 110 BP (838-559 av. J.-C.). Cette occupation néolithique du Baten serait même plus ancienne, si l'on retient la date de 3830 ± 260 BP (2611-1891 av. J.-C.) réalisée sur os par le Laboratoire de Gif-sur-Yvette, mais dont la marge d'erreur est importante. Pour les rares habitats de plateau, de même type que ceux du Baten, identifiés lors des dernières missions, nous ne disposons que d'une seule date : 2120 ± 100 BP (352-1 av. J.-C.).

Le fait que l'ensemble des datations «villages» soit contemporain de celui des datations «Baten» ne préjuge pas forcément de la contemporanéité d'un site «village» géographiquement associé à un site «Baten». Pour avoir une idée plus précise de cette chronologie relative entre villages des Dhars et habitats de Baten voisins, nous avons procédé, avec notre collègue N.E. Saoudi, à des prélèvements d'échantillons couplés. Les résultats ont montré pour le village v.39 (daté de 3000 ± 120 BP, 1400-1021 av. J.-C.) et le site de Baten qui s'étend à ses pieds (2800 ± 120 BP, 1116-818 av. J.-C.) une possibilité de contemporanéité. Par contre, pour le village v.147 (daté de 3060 ± 80 BP, 1410-1204 av. J.-C.) et le site de Baten qui lui est le plus proche (3590 ± 80 BP, 2032-1780 av. J.-C., les moments d'occupation ne semblent pas coïncider, et ceci même après calibration à 2 sigmas. Le nombre limité de dates obtenues pour ces sites nous conduit à envisager des datations complémentaires, d'autant plus que l'occupation d'un même village peut perdurer près d'un millénaire.

3.2 - LES «INNOVATIONS» RÉGIONALES

L'avantage de la méthode de datation à partir de tessons de céramique, réside dans le fait qu'elle permet de dater également la pratique, ou tout au moins la connaissance, de l'agriculture par les artisans qui ont fabriqué ces récipients. L'abondant dégraissant végétal, mêlé à l'argile par les potiers, a laissé des empreintes sur les parois des récipients. Certaines ont été identifiées (Jacques-Félix, 1971 ; Amblard et Pernès, 1989) comme appartenant à du mil cultivé (*Pennisetum americanum* K. Schum). L'agriculture du mil remonte ainsi dans la région au moins à 3500 ± 100 BP (1936-1683 av. J.-C.).

L'importance de la pratique du stockage par les villageois des Dhars est soulignée par l'abondance de vestiges de greniers sur pilotis et de tessons de jarres. L'ancienneté de cette pratique est attestée, sur grenier, dès 3420 ± 120 BP (1882-1527 av. J.-C.), par des poteries gisant entre les pilotis d'un grenier du village v.149 et, en jarre, par un tesson du village v.72 qui a fourni un âge de 3500 ± 100 BP (1936-1683 av. J.-C.).

La comparaison des datations les plus anciennes concernant ces grands évènements survenus sur les Dhars peut indiquer leur probable contemporanéité d'apparition dans la région. Mais si l'on pouvait établir, en augmentant le corpus de dates, qu'il existe une réelle antériorité des habitats par rapport à ces différents faits, l'on aurait un argument de plus pour considérer cette région comme un réel lieu d'innovations : agriculture et stockage n'étant alors pas encore dans les habitudes des premiers arrivants sur les Dhars.

4 - HABITATS ET FLUCTUATIONS CLIMATIQUES

L'ensemble des données ^{14}C, présentées en BP afin de pouvoir être confrontées, a permis d'obtenir des histogrammes distincts (fig. 3). Le fait que les dates soient sensiblement distribuées de façon égale entre objets archéologiques et paléoenvironnementaux permet une réelle comparaison. Ces dates correspondent à des échantillons prélevés tout au long des Dhars dans des zones où sites archéologiques et témoins paléoenvironnementaux se côtoient. Toutes les dates ont été portées sur ce diagramme quelle que soit la nature du matériau daté, mais elles n'ont été retenues qu'après analyse critique des matériaux supports de datation.

Les dates paléoenvironnementales se répartissent sur l'ensemble de l'Holocène. Cependant des concentrations indiquent que les faciès lacustres et palustres sont mieux représentés dans la région à certaines périodes. Par exemple, autour de 8000 BP, où elles correspondent à l'optimum climatique de l'Holocène inférieur. Les données recueillies sur le terrain montrent cependant que ces faciès restent d'extension limitée. Des périodes apparaissent par contre plus arides, notamment entre 5500-5000 et 4500-3800, où l'on note une absence d'informations chronologiques.

Les dates relatives à l'occupation humaine couvrent la période 4000 à 2000 BP, mais la majorité apparaît focalisée sur le millénaire 3500-2500 BP, témoignant d'une occupation intense de la région, qui peut évoquer une véritable «explosion» démographique au vu du vide humain antérieur.

L'on constate, en rapprochant ces deux diagrammes que l'ensemble archéologique recouvre en fait la dernière période humide holocène dans la région. Il ne s'agit pourtant pas d'un optimum climatique très intense, mais bien d'une phase où les dépôts attestent de conditions à peine plus confortables que celles qui existent aujourd'hui pour les habitants des cités actuelles de Tichitt et Oualata. Il apparaît également une absence de vestiges archéologiques liés aux épisodes favorables de l'Holocène inférieur. Elle peut traduire soit un réel vide humain pour cette période, soit simplement des modes de vie radicalement différents, sous une forme beaucoup plus dispersée, avec des habitats temporaires qui restent encore à retrouver (Person *et al.*, 1995).

Les premières dates archéologiques apparaissent à un moment où les dates paléoenvironnementales sont absentes. Cela peut correspondre à une lacune de conservation du matériel sur le terrain ou à l'éventualité d'une installation des hommes à la fin d'une phase encore aride, néanmoins moins forte que celle affectant les autres zones du Sahara méridional à la même époque, en raison de la propre nature du géo-écosystème des Dhars (Person *et al.*, 1996) : par exemple, grâce à la présence de sources au pied des falaises transformant déjà cette région en «zone-refuge».

La fin de la période d'occupation est en relation avec une diminution des possibilités en eau ; l'équilibre est rompu ; la pression anthropique est devenue trop forte sur l'environnement. Ce contexte environnemental refuge, même bien géré par les populations, est devenu insuffisant.

CONCLUSION

Les histogrammes (fig. 3), reprenant le bilan chronologique des recherches réalisées depuis une vingtaine d'années, confirment les résultats acquis au cours de nos dernières missions de terrain et précisent donc les relations entre les modes de vie des populations néolithiques et l'évolution de l'environnement dans cette région.

Les dates archéologiques indiquent que cette société des Dhars a su évoluer et perdurer pendant plus d'un millénaire sur cette étroite bande de terre disponible entre deux grandes étendues sableuses. Dans ce contexte environnemental refuge, ces hommes ont su s'adapter à un environnement déjà fragile lors de leur arrivée en le prenant en charge : entre autres, par la pratique de l'agriculture du mil et du stockage des vivres et de l'eau.

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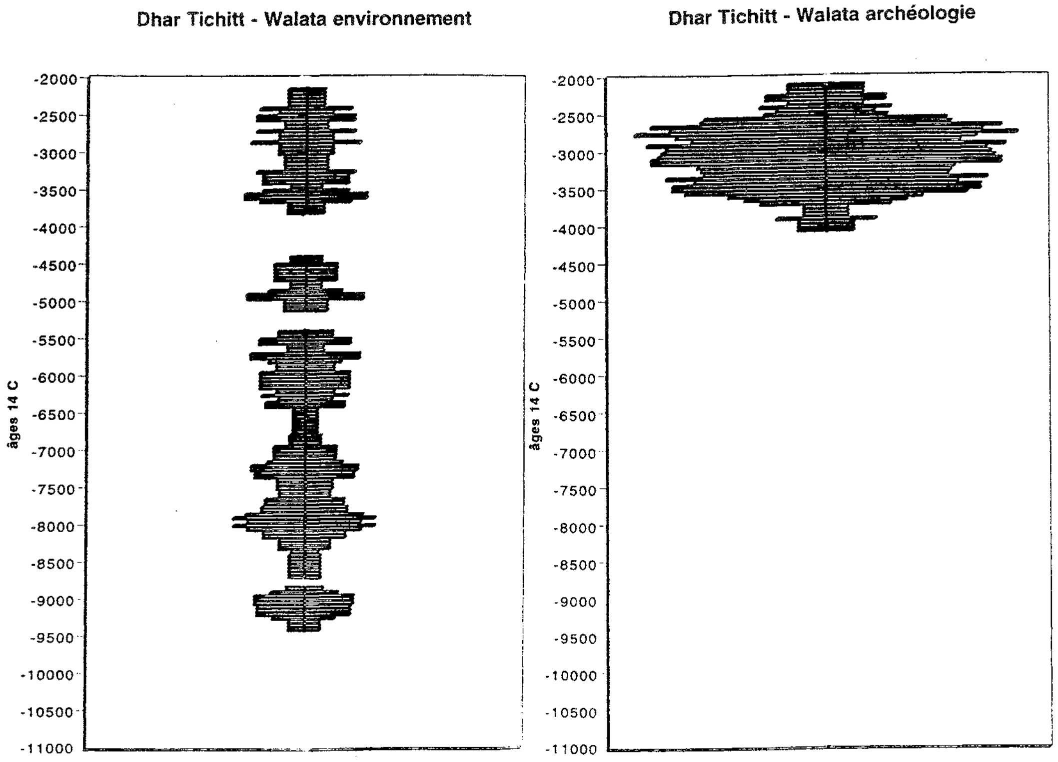

Fig. 3 : Histogrammes des données ^{14}C paléoenvironnementales et archéologiques.
Fig. 3 : Histograms of paleoenvironmental and archaeological ^{14}C data.

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DATATIONS RADIOCARBONE ET ÉVOLUTION CHRONOCULTURELLE DES SITES ARCHÉOLOGIQUES (HABITATS ET MÉGALITHES) DU NORD-OUEST DE LA RÉPUBLIQUE CENTRAFRICAINE

*Etienne ZANGATO**

Résumé : Les travaux archéologiques effectués dans la région de Bouar au nord-ouest de la République Centrafricaine ont permis de réaliser de nombreuses datations (92 au total). Cet article expose les aspects méthodologiques d'échantillonnage des charbons de bois par type de sites de la localité de Ndio, de dosages du carbone radioactif et suggèrent que l'interprétation du contexte chronoculturel régional (Néolithique, Age du fer et la période sub-actuelle) dépend de la fiabilité de ces deux méthodes.

Summary : Archaeological excavations carried out in the north-western Bouar region of the Central African Republic have allowed us to produce sixty carbon datings. These datings must however undergo critical review prior to any chronological interpretation. After producing a quick analysis of the datings already published, this article explains our sampling strategy. This strategy mainly consisted in systematically choosing to study charcoal at various stratigraphic levels. It has also become the basis for a sound chronocultural sequence put forward for the Ndio region (The Central African Republic).

Mots-clés : Centrafrique, datations sites.

Key-words : Centrafrica, datations and sites.

INTRODUCTION

Le nord-ouest de la République Centrafricaine est connu pour sa forte concentration mégalithique qui s'étend d'ouest en est, sur plus de 1500 km, entre Djohong au Cameroun et Bouar en Centrafrique. Dans les années soixante-dix la connaissance de l'évolution chronoculturelle de la région de Bouar reposait sur un corpus de 36 dates issus des fouilles de 11 mégalithes et de 3 sites villageois. Les datations des mégalithes en particulier suscitaient une vive polémique entre ceux qui attribuaient ces monuments au VIIe millénaire avant J.-C. et ceux qui les situaient dans les périodes récentes, autour du IVe siècle après J.-C. (en datation calibrée) (Vidal, 1969, 1982, 1987 ; David, 1982, 1983 ; David et Vidal, 1977 ; de Bayle des Hermens et Vidal, 1971 ; de Bayle des Hermens, 1975 ; Vidal, de Bayle des Hermens et Menard, 1983). C'est en fait l'interprétation d'une plage chronologique toujours large obtenue pour chaque datation de mégalithe qui était à l'origine de la divergence entre les différents auteurs.

Lorsque nous avons repris les fouilles dans la zone de Ndio à 40 km au nord de Bouar, seuls deux monuments avaient été fouillés par Nicolas David (1982, 1983). Comprise entre 15° 15' et 15° 31' de longitude est d'une part, 5° 54' et 6° 11' de latitude nord, la zone de Ndio est le point d'attache de la dorsale oubanguienne qui forme l'extrémité est de l'Adamaoua. Elle est partagée par la ligne de crête qui sépare la cuvette tchadienne, au nord, de la cuvette congolaise, au sud. Les altitudes sont comprises entre 800 m et 1040 m au sud, avec des points culminants au mont *K. Ngao* (1090 m) et au mont *Yolé* (1055 m), tandis qu'elles sont comprises entre 1000 et 1120 m au nord. La zone est donc caractérisée par un relief de hauts plateaux entaillés par un réseau hydrographique très dense. Il existe néanmoins des contrastes :

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dans la cuvette congolaise, les pentes sont accusées avec des vallées encaissées et l'érosion très vive dégage des dômes rocheux. Les sols sont jeunes, peu épais et décapés (lithosols, sols pénévolués). Au contraire, sur les aplanissements à pente très faible de la cuvette tchadienne, le drainage est souvent médiocre, les sols ferralitiques sont anciens, profonds, souvent indurés en carapace ou cuirasse, engendrant un modelé figé (Boulvert, 1985, 301-309). Aujourd'hui, la région connaît de fortes précipitations (de l'ordre de 1600 mm par an), avec 8 mois de saison humide (d'avril à novembre) et 4 mois de saison sèche (de décembre à mars) (Boulvert, 1985, 1986, 1995). Le milieu naturel est caractérisé par une savane boisée de type soudano-guinéen à *Burkea africana, Lophira lanceolata, Daniellia oliveri* avec une strate herbacée à *Andropogon gayanus, Hyparrhenia welwistschii, Hyparrhenia familiaris* et par l'existence de lambeaux forestiers qui sont des formes dégradées de forêt primaire et de galeries forestières avec des faciès à *Anogeissus leiocarpus, Albizia zygia* (Boulvert, 1986). Dans ces dernières, il existe aujourd'hui des essences identifiées de forêt tropicale humide telles que *Alstonia, Uapaca, Symphonia* et de forêt montagnarde telle que *Hagenia* (Zangato, 1991, 186-192).

Notre problématique de recherche étant d'aborder le phénomène mégalithique dans une optique régionale, nous avons privilégié des stratégies de terrain permettant d'acquérir un corpus de sites et de données archéologiques représentatives (Zangato, sous presse). Cette région s'est révélée très riche en sites archéologiques puisque nos prospections ont permis de recenser plus de 92 sites. 36 d'entre eux ont été fouillés (11 sites villageois, 15 monuments mégalithiques à vocation non funéraire, 4 tombes mégalithiques, 35 structures cinéraires, 24 tombes en pleine terre et 28 structures métallurgiques).

Une telle analyse régionale nécessitant à notre sens, d'établir la coexistence, dans le temps et l'espace, des différents types de sites. Il nous a fallu donc établir un véritable cadre chronoculturel qui manquait pour cette région. Plusieurs motivations ont ainsi guidé l'établissement d'une stratégie de datations radiométriques : outre le débat sur l'ancienneté présumée des mégalithes centrafricains, celui sur l'occupation néolithique et celui sur la mise en place de la métallurgie du fer en Afrique centrale.

MÉTHODES DE FOUILLES ET DE PRÉLÈVEMENTS DES CHARBONS DE BOIS

La fouille extensive avec relevés en plan des vestiges archéologiques et des structures, selon un carroyage d'un mètre de côté, a été privilégiée dans de nombreux cas pour les différentes catégories de sites (village, monument mégalithique, site métallurgique, site funéraire). Cette technique présente l'avantage d'offrir une représentation de la structuration spatiale intra-site permettant d'identifier les aires d'activités dans les villages ou encore la fonction des monuments, de faire éventuellement la part des différents processus (naturels ou humains) qui ont pu influencer les conditions de mise en place et de conservation des vestiges archéologiques. Ce point est particulièrement pertinent dans le cas des monuments mégalithiques et des sites métallurgiques pour lesquels la question de l'intégrité des structures est importante pour l'obtention de datations fiables. Tous les sédiments ont été systématiquement tamisés à sec et à l'eau. Les monuments mégalithiques se présentent sous forme de buttes anthropiques sur lesquelles des pierres ont été dressées, leurs fouilles tantôt partielles, tantôt intégrales, ont été menées à la truelle par niveaux successifs de 10 cm, en suivant la couche humifère, puis la couche de couverture. Seul le démontage des pierres de remplissage du niveau sous-jacent a été effectué à la serfouette. C'est la nécessité de comprendre la relation entre le contenant et le contenu qui a présidé au choix d'une telle approche des architectures mégalithiques. En ce qui concerne les prélèvements des charbons de bois, ils ont été réalisés en tenant compte de la caractéristique de chaque site et du contexte archéologique. Dans les mégalithes, les charbons contenus dans les matériaux de construction ne datent pas, à notre sens, le monument, mais peuvent, en revanche, situer un *terminus post quem* (Zangato, 1993). C'est pourquoi les échantillons destinés à dater la construction des monuments ont toujours été prélevés, lorsqu'ils existent, dans les structures fiables tels que les foyers, les coffres et les chambres (Zangato 1995, 1996, sous presse). En outre, d'autres échantillons ont été recueillis dans chaque couche stratigraphique, à l'intérieur du monument, afin de confronter les deux catégories de dates et apporter ainsi des éléments de discussion au problème de l'ancienneté des mégalithes centrafricains. Dans les sites de villages, ateliers métallurgiques et les cimetières, le décapage a également été conduit à la truelle et, dans certains cas, à l'aide d'outils plus fins. Contrairement aux sites mégalithiques, les sites de village destinés à être l'objet de fouilles extensives ont été sélectionnés en fonction des résultats des sondages (richesse du matériel, datations). Dans chaque cas, une surface d'un seul tenant a été ouverte, accompagnée d'une série de sondages pour déterminer l'extension du site. Dans les sites de crémation, les charbons ont généralement été prélevés dans les jarres cinéraires. Dans les sites métallurgiques, ils ont été récoltés dans les fours (datant la dernière utilisation) et dans chacune des couches stratigraphiques composant l'amas de déchets de réduction généralement associé à ces structures (permettant de mesurer la durée d'utilisation de ce type de site). Dans les sites de village enfin, les échantillons ont été prélevés dans chaque couche, voire lorsqu'ils ont été reconnus, dans chaque horizon, ainsi que dans toutes les structures de foyer.

Les différentes datations ont systématiquement été effectuées sur des échantillons significatifs, c'est-à-dire comprenant entre 20 et 30 morceaux d'un diamètre supérieur ou égal à 3 cm, ce afin d'éliminer des échantillons d'origine douteuse.

LE CADRE CHRONOCULTUREL RÉGIONAL

Le corpus ainsi obtenu comprend 92 dates : 40 pour les sites villageois, 31 pour les monuments à vocation non funéraire, 9 pour les sites funéraires et 14 pour les ateliers métallurgiques (David, 1982, 1983 ; David et Vidal, 1977 ; de Bayle des Hermens et Vidal, 1971 ; de Bayle des Hermens, 1975 ; Vidal, de Bayle des Hermens et Menard, 1983 ; Zangato, sous presse ; Zangato et Saliège, à paraître). Ce corpus est actuellement le plus important d'Afrique centrale puisqu'il couvre une longue séquence chronologique allant de 4500 avant J.-C. à 1900 après J.-C., sans hiatus archéologique (fig. 1).

Dans l'état actuel des travaux, les phases d'évolution culturelle sont documentées par les niveaux d'occupation de deux sites villageois (*Balimbé* site 68 et *Gbabiri 1* site 77) qui ont fourni de longues séquences stratigraphiques datées. Trois dates ont été obtenues dans un niveau du site villageois *Balimbé* daté de 7500 à 1200 av. J.-C.

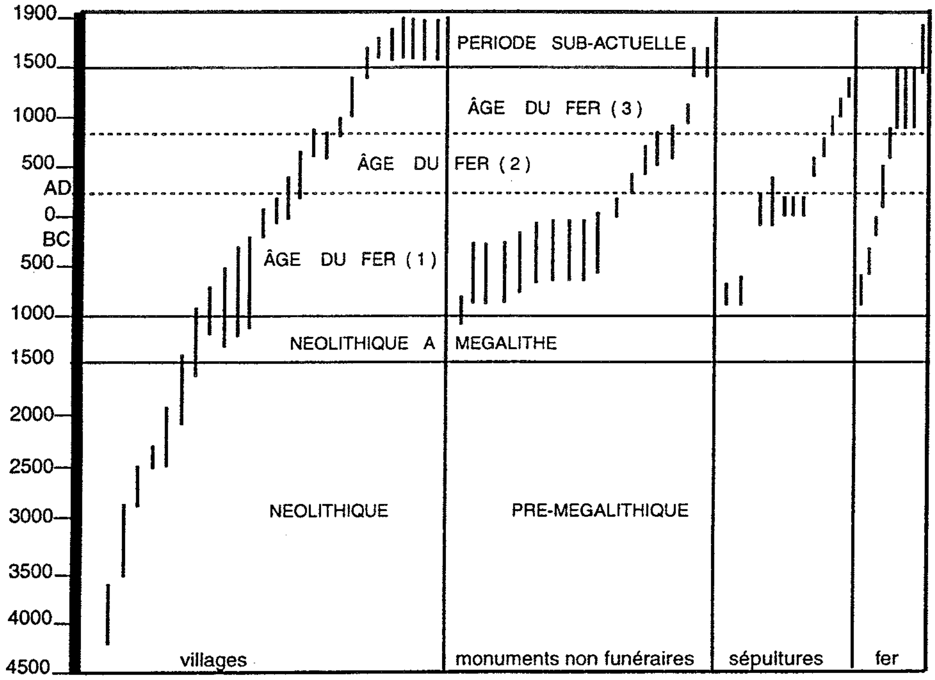

Fig. 1 : Sites et datations radiocarbone.

Néolithique pré-mégalithique (de 4500-1500 avant J.-C.)

Elle est caractérisée par une industrie à débitage laminaire et à éclat où dominent les têtes de flèche à pédoncule, les trapèzes et les grattoirs. Cette industrie lithique est associée à une production céramique réalisé aux colombins avec des parois parfois très épaisses et décorée des motifs aux caractères grossiers.

Néolithique à mégalithes (de 1500 à 1000 avant J.-C.)

Sur ce fond culturel qui est resté pratiquement inchangé durant toute la période, apparaissent, entre 1500 et 1000 avant J.-C., un Néolithique à mégalithes caractérisé par la présence de constructions mégalithiques à vocation non funéraire et de nombreuses haches polies et pierres percées ou « Kwé ». La céramique reste la même que précédemment. Cette céramique a été également collectée dans plusieurs sites de surface et dans les trois monuments mégalithique de cette phase culturelle.

Mise en place de la métallurgie du fer (entre 1000 et 400 avant J.-C.)

La phase suivante voit la mise en place de la métallurgie du fer entre 1000 et 400 avant J.-C. : 7 dates ont été obtenues pour le premier niveau d'occupation du site villageois *Gbabiri* 77 contenant des structures et des objets métalliques et 3 dates issues des structures de réduction du fer en fosse situées à 2 et 3 km du village *Gbabiri*. Pendant cette phase on note également la présence des tombes mégalithiques et des tombes en pleine terre datant de la même séquence culturelle.

Le développement du fer se matérialise dans la région par l'apparition des bas fourneaux entre le V^{e} et le IV^{e} siècle avant J.-C. Il faut ajouter à cette nouvelle configuration socio-économique l'apparition des structures cinéraires vers 450 avant J.-C. qui va perdurer jusqu'au VIII^{e} siècle après J.-C. période correspondant à la multiplication des sites villageois et à l'intensification de la production du fer caractérisée par l'apparition des hauts fourneaux à partir de 850 après J.-C.

Enfin, c'est durant la phase subactuelle qui précède la période moderne que disparaissent les mégalithes.

Les dates obtenues dans l'état actuel des travaux, pour l'ensemble des sites archéologiques étudiés constituent une base de données intéressantes de la connaissance de l'évolution chronoculturelle des anciennes sociétés de la région, du Néolithique à la période sub-actuelle.

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RADIOCARBON DATINGS OF LATE PALAEOLITHIC, EPIPALAEOLITHIC AND NEOLITHIC SITES IN NORTHEASTERN MOROCCO

Jochen GÖRSDORF and Josef EIWANGER***

Summary : Chronological problems of the Maghreb (Morocco) have been under intensive investigation during the last years. The excavations of the archaeological sites "Ifri el-Baroud", "Hassi Ouenzga-Plein Air" and "Hassi Ouenzga-Abri" were performed with the aim of obtaining a better knowledge of the Late Glacial and Early Holocene development in the region of Maghreb (Morocco).
In more detail we present the results of the cave "Ifri el-Baroud" and the cave site "Hassi Ouenzga-Abri". The cave "Ifri el-Baroud" is located in Morocco about 50 km south-west of Nador and the coast. Layers from Ibéromaurusien to Bronze Age were excavated. Samples from all these layers were dated. The dating material was charcoal. We present the dating results. The results allow us a better understanding of the regional development in connection with the surroundings.
In the nearby cave site of "Hassi Ouenzga-Abri" an important stratigraphy of the Holocene was excavated. It yielded cardial and bell beaker pottery levels and, for the first time in Northwestern Africa, decorated pre-cardial pottery dating back to the 7th and 6th millennia BC.

Résumé : Depuis plusieurs années, on mène des recherches sur les problèmes liés à la chronologie du Maghreb (Maroc). Les fouilles des sites archéologiques d'Ifri el-Baroud, de Hassi Ouenzga-Plein Air et de Hassi Ouenzga Abri ont été effectuées dans le but de mieux comprendre le développement du Glaciaire tardif et de l'Holocène récent dans la région du Maghreb (Maroc).
Nous présentons ici de façon détaillée les résultats des fouilles de la grotte d'Ifri-el-Baroud et du site de Hassi Ouenzga-Abri.
La grotte d'Ifri el-Baroud se situe au Maroc, à 50 km environ au sud-ouest de Nador et de la côte. La stratigraphie présente des niveaux allant de la période Ibéro-mauresque à l'Age du Bronze. Tous les échantillons provenant de ces périodes ont été datés (charbons de bois). Nous en présentons ici les résultats qui nous permettent de mieux comprendre le développement de cette région et de ses environs.
Sur le site de Hassi Ouenzga-Abri, proche d'Ifri el-Baroud, des niveaux Holocène ont été fouillés. On y a découvert, pour la première fois en Afrique nord-occidentale, de la céramique décorée pré-cardiale datant des 7ème et 6ème millénaires av. J.-C.

Key-words : Radiocarbon dating, Late Paleolithic, Epipaleolithic, Neolithic, Northeastern Morocco.

Mots-clés : Datation radiocarbone, Paléolithique supérieur, Epipaléolithique, Néolithique, Maroc nord-oriental.

INTRODUCTION

In 1994 the Kommission für Allgemeine und Vergleichende Archäologie des Deutschen Archäologischen Instituts (KAVA), Bonn" and the Institut National des Sciences de l'Archéologie et du Patrimoine (INSAP), Rabat" have established a joint project of archaeological research in northeastern Morocco. Archaeological research in Morocco since colonial times has been concentrated more or less in the environs of the bigger cities (Casablanca, Fes, Rabat etc.). The main objective of the cooperation is the exploration of a landscape still unknown in its archaeological aspects. The survey area has been defined between Oued Bou Frah, Oued Moulouya and the mediterranean coastline, enclosing a total surface of nearly 10000 square km. The landscape varies from high mountain environments in the west to hilly and plain areas in the east and the Moulouya valley in the south. In this area the cooperation tries to establish a concise settlement pattern and stratigraphical sequence from earliest times until the beginning of Antiquity. From the geographical point of view we expect new data concerning the interaction between the Maghreb and Saharan Africa in the course of time. Some two

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hundred sites have been discovered until 1997, most of them caves, rock-shelters and tumuli, but also some open air settlements. The time range extends from middle palaeolithic material to protohistoric sites. Five important and some minor sites have been excavated during the field campaigns 1995-1997. The three important sites of Hassi Ouenzga Plein Air, Hassi Ouenzga Abri and Ifri el-Baroud have been dated during 1995-1997.

METHODS

Chemical pretreatment of wood samples was done by A-A-A treatment (Mook and Streuerman, 1981) or by leaching with 10 % ammonium hydroxide solution in a Soxhlet-extractor and leaching with 5 % hypochloric acid (Kohl and Quitta, 1978). The dating was performed with gas proportional counters of the Houtermans-Oeschger type, using methane at 133.3 kPa pressure as filling gas (Kohl and Quitta, 1978). Measurement control and data processing were done with the help of computers (Görsdorf, 1990 ; Görsdorf and Bojadziev, 1996). The $\delta^{13}C$-measurements were done by H. Erlenkeuser and colleagues (Leibniz-Labor, University of Kiel) and are reported with respect to PDB-standard.

RESULTS

We present the dating results together with AMS-results from the Leibniz-Labor, University of Kiel[(1)] sorted after age (tab. 1 and 2). The tree-ring count of charcoal samples

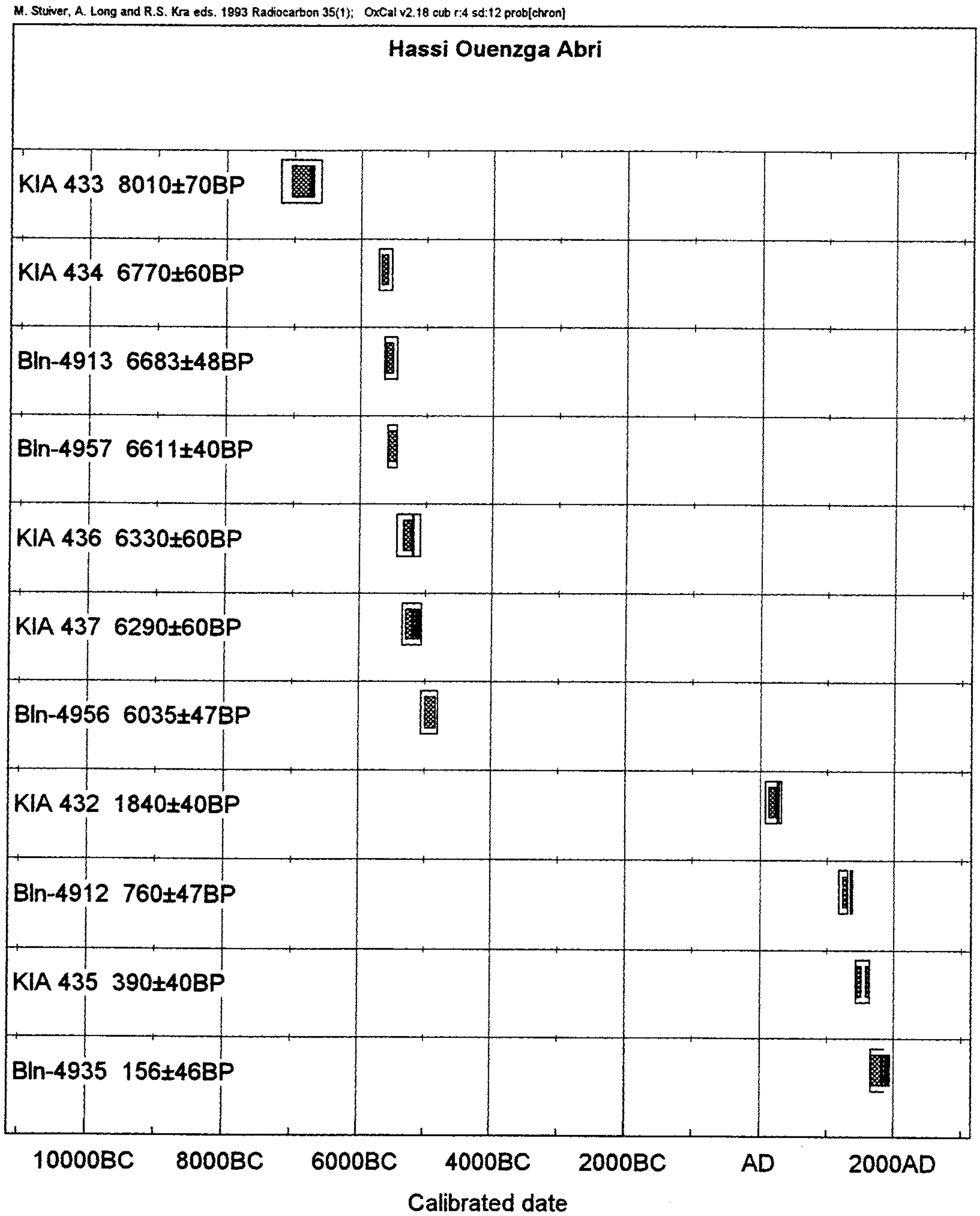

Fig. 1 : Calibrated dating results of Hassi Ouenzga Abri. The confidence limit of the hatched boxes is 68.2 % and of the unfilled boxes is 95.4 %.

(1) The publication of the AMS-datings by the Leibniz-Labor of the University of Kiel (KIA) is by permission of Prof. Grotes, whom we thank cordially for this.

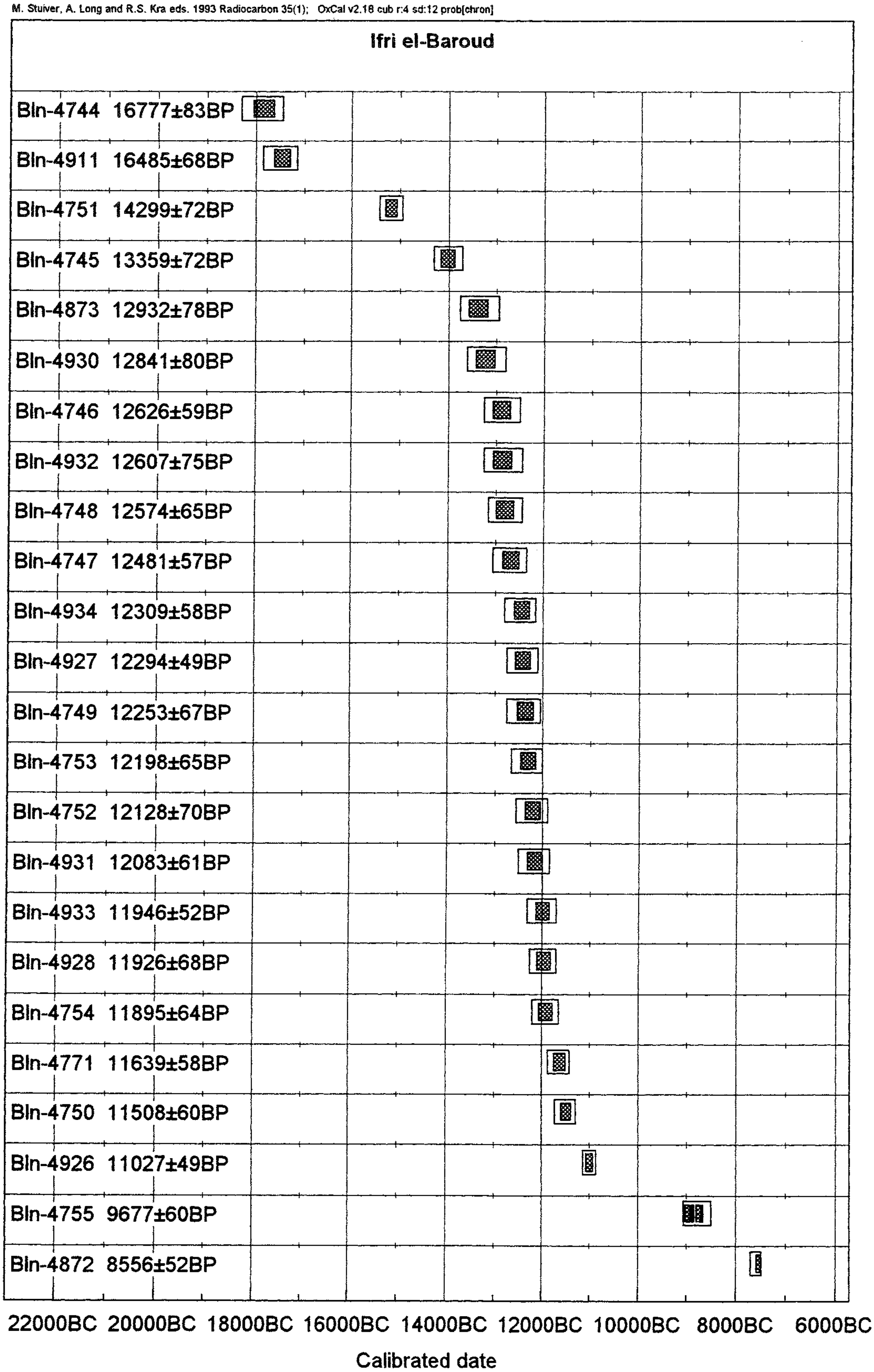

Fig. 2 : Calibrated dating results of Ifri el-Baroud. The confidence limit of the hatched boxes is 68.2 % and of the unfilled boxes is 95.4 %.

could not be determined. In the calibration program (Ramsey, 1995) we used the bidecadal calibration curve (Bard *et al.,* 1993) as a first approximation.

Fig.1 shows the calibrated dating results of Hassi Ouenzga Abri. The lowest holocene level dates back to the late 8th/early7th millennium, the precardial phase to the 6th and the cardial level to the late 6th/5th millennium B.C. The late neolithic and bell beaker levels are disturbed by antique and islamic activities.

Fig. 2 shows the calibrated dating results of Ifri el-Baroud. According to the archaeological levels we can observe a clear division into early, middle and late Ibéromaurusien.

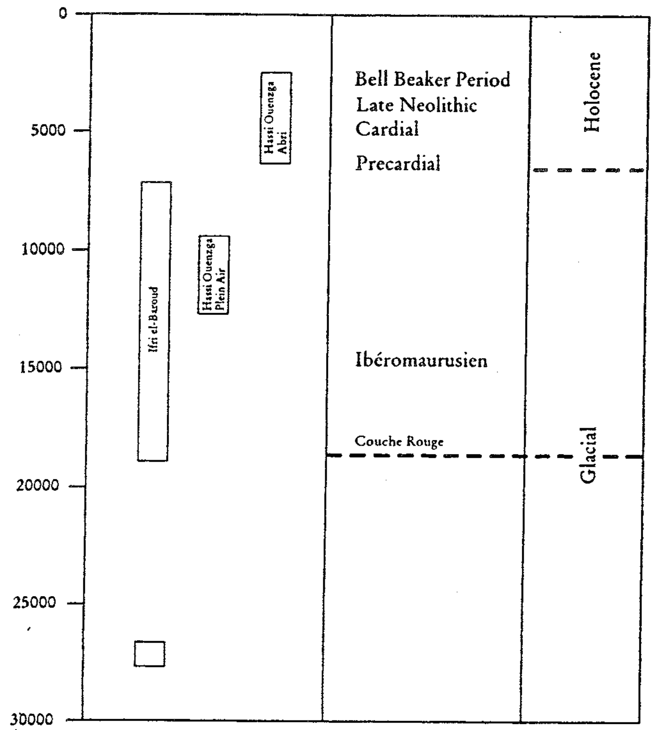

Fig. 3 : Archaeological sequence in the excavation places together with the absolute timemarks.

Old-Ibéromaurusien : 19 000 - 14 500 cal BC
Middle-Ibéromaurusien : 14 500 - 11 000 cal BC
Late-Ibéromaurusien : 11 000 - 8 000 cal BC

CONCLUSION

Fig. 3 presents the archaeological sequence in the different excavation places together with the absolute timemarks. The middle and younger Palaeolithic periods are well represented in the cave site of Ifri el-Baroud („powder cave") and in the open air site of Hassi Ouenzga. The combined stratigraphical column of the two sites ranges from approximately 20000 B.C. to 3500 B.C. It covers the transition from middle palaeolithic to Ibéromaurusien (younger palaeolithic) deposits as well as the final phase of the Ibéromaurusien. Beside the artefacts large quantities of carbonised material and animal bones have been recovered from the deposits. They will allow a reconstruction of environment and its change from Late Glacial to Early Holocene times.

The Holocene sequence is represented by the sites of Hassi Ouenzga Abri. In the small rockshelter Hassi Ouenzga Abri an important stratigraphy has been discovered and investigated in 1996 and 1997. The upper layer yielded bell-beaker pottery until now unknown in Eastern Morocco. Below this deposit an important layer containing neolithic cardial pottery was uncovered. Below the cardial remains we found pottery in "neolithic" layers which fall into the gap between the end of the Epipalaeolithic (ca. 8000 B.C.) and the first "Neolithic" in the Maghreb (ca. 5000 B.C.). These layers date back to the 7th and 6th millenia B.C. The profusely decorated pottery resembles in some way undated materials from the Algerian Oranais.

Hassi Ouenzga Plein Air (34° 42′ N, 3° 17′ E)

Bln-4756 charcoal	profile west, HO 95-A		10571 ± 77 BP 10660 - 10430 cal BC

Hassi Ouenzga Abri (34° 42′ N, 3° 17′ E)

KIA 433 charcoal	HO 96 4f, pos.108	-17.46 ‰	8010 ± 70 BP 7040 - 6710 cal BC
KIA 434 charcoal	HO 96 (4), pos.62	-21.12 ‰	6770 ± 60 BP 5680 - 5580 cal BC
Bln-4913 charcoal	HO 96-D neolithic layer, containing cardial pottery	-19.29 ‰	6683 ± 48 BP 5600 - 5505 cal BC
Bln-4957 charcoal	HO 96-H early neolithic layer		6611 ± 40 BP 5570 - 5450 cal BC
KIA 436 charcoal	HO 96 IV (4e), pos.102	-22.36 ‰	6330 ± 60 BP 5310 - 5230 cal BC
KIA 437 charcoal	HO 96 IV (4e), pos.103	-23.04 ‰	6290 ± 60 BP 5280 - 5140 cal BC
Bln-4956 charcoal	HO 96-C neolithic layer, containing cardial pottery	-21.70 ‰	6035 ± 47 BP 4990 - 4840 cal BC
KIA 432 charcoal	HO 96 pos 30	-21.95 ‰	1840 ± 40 BP 128 - 240 cal AD
Bln-4912 charcoal	HO 96-A young material in late neolithic layer	-22.53 ‰	760 ± 47 BP 235 - 1290 cal AD
KIA 435 charcoal	HO 96 (4), pos.15	-23.39 ‰	390 ± 40 BP 1440 - 1630 cal AD
Bln-4935 charcoal	HO 96-B young material in neolithic layer	-22.82 ‰	156 ± 46 BP 1670 - 1950 cal AD

Tab. 1 : Results for Hassi Ouenzga.

Ifri el-Baroud (34° 46′ N, 3° 19′ E)			
Bln-4744 charcoal	trench II, profile west, IB 95-A	-22.09‰	16777 ± 83 BP 18050 - 17640 cal BC
Bln-4745 charcoal	trench II, profile east, IB 95-C	-22.60‰	13359 ± 72 BP 14160 - 13870 cal BC
Bln-4746 charcoal	trench II, profile west, IB 95-D	-23.09‰	12626 ± 59 BP 13060 - 12710 cal BC
Bln-4747 charcoal	trench II, profile west, IB 95-E	-23.05‰	12481 ± 57 BP 12850 - 12510 cal BC
Bln-4748 charcoal	trench II, profile west, IB 95-F	-23.07‰	12574 ± 65 BP 12990 - 12630 cal BC
Bln-4749 charcoal	trench II, profile west, IB 95-H	-22.49‰	12253 ± 67 BP 12530 - 12200 cal BC
Bln-4750 charcoal	trench II, profile west, IB 95-L	-22.40‰	11508 ± 60 BP 11590 - 11380 cal BC
Bln-4751 charcoal	trench II, profile west, IB 95-M		14299 ± 72 BP 15310 - 15070 cal BC
Bln-4752 charcoal	trench III, profile east, IB 95-P		12128 ± 70 BP 12360 - 12050 cal BC
Bln-4753 charcoal	trench III, profile east, IB 95-Q	-22.23‰	12198 ± 65 BP 12460 - 12140 cal BC
Bln-4754 charcoal	trench III, profile east, IB 95-R	-22.76‰	11895 ± 64 BP 12060 - 11780 cal BC
Bln-4755 charcoal	trench III, profile east, IB 95-S	-22.42‰	9677 ± 60 BP 9020 - 8670 cal BC
Bln-4871 charcoal	trench IV, IB 96-A, Nr. 41	-22.92‰	11639 ± 58 BP 11740 - 11510 cal BC
Bln-4872 charcoal	trench IV, IB 96-B, Nr. 97	-22.29‰	8556 ± 52 BP 7580 - 7500 cal BC
Bln-4873 charcoal	trench IV, IB 96-C, Nr. 88		12932 ± 78 BP 13560 - 13180 cal BC
Bln-4911 charcoal	trench IV, IB 96-68	-21.89‰	16485 ± 68 BP 17630 - 17300 cal BC
Bln-4926 charcoal	trench IV, IB 96-4	-22.43‰	11027 ± 49 BP 11060 - 10920 cal BC
Bln-4927 charcoal	trench IV, IB 96-5	-22.65‰	12294 ± 49 BP 12580 - 12260 cal BC
Bln-4928 charcoal	trench IV, IB 96-21	-22.61‰	11926 ± 68 BP 12100 - 11820 cal BC
Bln-4929 charcoal	trench IV, IB 96-38	-22.78‰	12172 ± 61 BP 12420 - 12110 cal BC
Bln-4930 charcoal	trench IV, IB 96-49		12841 ± 80 BP 13420 - 13030 cal BC
Bln-4931 charcoal	trench IV, IB 96-51	-21.92‰	12083 ± 61 BP 12300 - 12000 cal BC
Bln-4932 charcoal	trench IV, IB 96-83		12607 ± 75 BP 13050 - 12670 cal BC
Bln-4933 charcoal	trench IV, IB 96-94		11946 ± 52 BP 12120 - 11850 cal BC
Bln-4934 charcoal	trench IV, IB 96-96	-22.59‰	12309 ± 58 BP 12600 - 12280 cal BC

Tab. 2 : Results for Ifri el-Baroud.

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DATATIONS PAR LE RADIOCARBONE DES CULTURES PRÉHISTORIQUES EN RELATION AVEC L'ENVIRONNEMENT DANS L'EST DU MAROC

Luc WENGLER, Georgette DELIBRIAS**, Jacques EVIN*** et Michel FONTUGNE***

Résumé : Depuis une quinzaine d'années, des recherches conduites aussi bien en Préhistoire qu'en Géologie du Quaternaire ont fourni des données diverses et un matériel archéologique important qu'il était nécessaire de situer dans le temps. Les âges obtenus grâce à une soixantaine de datations ^{14}C effectuées à partir de matériaux variés seront discutés en fonction des données disponibles. Ils permettent de proposer un cadre chronologique des 25 derniers millénaires pour les cultures préhistoriques s'échelonnant de la fin du Paléolithique moyen, avec l'Atérien, jusqu'aux temps néolithiques en relation avec les paléoenvironnements. Ces dates apportent notamment des précisions sur la fin du Paléolithique supérieur, représenté par l'Ibéromaurusien auquel succède dans la région étudiée un épipaléolithique proche du Kérémien. D'autres données concernent les phases moyennes à récentes du Néolithique avec des informations sur ces populations de pasteurs nomades.

Abstract : For about fifteen years, prehistoric and quaternary geological researches have given many different data and a lot of archaeological material which had to be dated. About sixty radiocarbon datings obtained from various materials will be discussed according to available informations. They allow to suggest a chronological frame of the latest 25 millennium from the end of Middle Palaeolithic with Aterian to the neolithic times in relation with the paleoenvironments. These datings particularly give some informations about the end of Late Palaeolithic, the Iberomaurusian and its evolution into an Epipalaeolithic culture looks like the Keremian. Other data concern middle and recent Neolithic with informations about these populations of nomadic shepherds.

Mots-clés : Datations radiocarbone, chronologie, Paléolithique, Epipaléolithique, Néolithique moyen, paléoenvironnements, terrasse alluviale, Maroc oriental.

Key-words : Radiocarbon datings, chronology, Palaeolithic, Epipalaeolithic, Middle Neolithic, palaeoenvironments, alluvial terrasse, Eastern Morocco.

Les premiers prélèvements pour obtenir des datations ^{14}C au Maroc ont été effectués en 1952 par l'Abbé J. Roche dans la grotte de Taforalt au Maroc oriental. Les résultats furent publiés en 1959 et 1961 (Olson *et al.*, 1959, 1961). Depuis, une vingtaine de datations seulement ont été obtenues dans cette région (Delibrias *et al.*, 1964, 1982 ; Delibrias et Roche, 1976 ; Choubert et Faure-Muret, 1971 a, b) alors que moins de 200 ont été comptabilisées sur l'ensemble du Maroc jusqu'en 1985 (Evin et Miallier, 1985).

Depuis le début des années 80, des recherches sont conduites sur les paléoenvironnements du Pléistocène récent et les cultures préhistoriques de l'Oriental. Elles ont permis l'identification et l'étude des systèmes de glacis-terrasse alluviale et des remplissages de plusieurs abris sous roche dans les zones montagneuses (Wengler, 1993). Ces formations ont fourni des données diverses et un matériel archéologique important qu'il était nécessaire de situer dans le temps. Pour les formations et les cultures récentes, la méthode de datation par le ^{14}C était un moyen particulièrement intéressant pour constituer une échelle chronologique compte tenu de la variété des matériaux disponibles contenant du carbone. Une soixantaine de dates s'échelonnant sur les vingt derniers millénaires ont été obtenues sur différents sites géologiques et archéologiques (fig. 1) et seront discutées en fonction des données disponibles.

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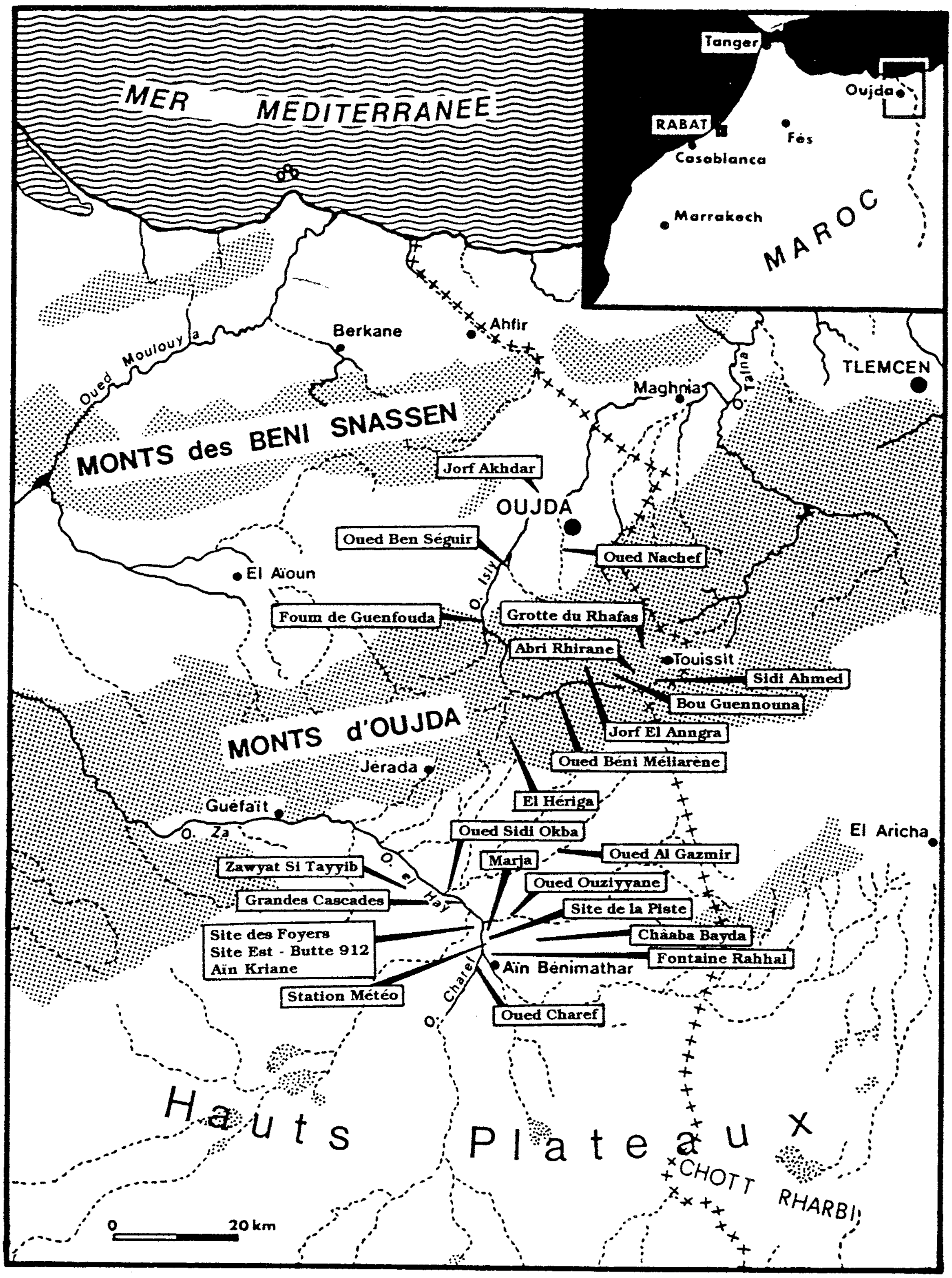

Fig. 1 : Localisation des sites du Maroc oriental datés par le radiocarbone.

1 - LA TRANSITION PALÉOLITHIQUE MOYEN - PALÉOLITHIQUE SUPÉRIEUR

Les datations les plus anciennes proviennent de la terrasse alluviale la plus récente attribuée à la dernière phase humide du Pléistocène supérieur grâce à des critères géopédologiques, à sa position dans le paysage par rapport aux formations similaires (Wengler et Vernet, 1992) et à la présence d'industries préhistoriques en place. Dans le bassin de l'Oued El Haÿ, près de la Zawyat Si Tayyib, la partie basale de la série sédimentaire débute par une nappe de galets contenant des passées travertineuses constituées par des manchons carbonatés dus à l'activité de cyanobactéries autour de roseaux (fig. 2). Leur datation a donné un âge de 24300±500 ans B.P. (Ly-4209). Bien que l'âge obtenu sur ce type de matériau soit sujet à caution, dans ce cas, il est en accord avec la présence dans la partie moyenne de la même série d'un niveau atérien évolué et d'un niveau ibéromaurusien vers le sommet (Wengler *et al.*, 1992) ; en effet, les datations de divers sites maghrébins montrent que l'Atérien est remplacé par l'Ibéromaurusien vers 22000 ans B.P. (Delibrias et Roche, 1976 ; Saxon *et al.*, 1974).

L'Atérien est une industrie du Paléolithique moyen caractérisée par un débitage Levallois important, des outils sur éclat et par des pièces pédonculées et de rares pièces foliacées bifaciales (fig. 3), tandis que l'Ibéromaurusien se singularise par un débitage lamellaire et de nombreuses lamelles à bord abattu. Considéré au départ comme une industrie épipaléolithique, il s'avère que son ancienneté, ses caractéristiques et sa place dans les cultures préhistoriques maghrébines en font le Paléolithique supérieur de cette région.

Une autre date a été fournie par une terrasse alluviale semblable décrite dans le bassin plus septentrional de l'Oued Isly. Cette fois, la datation a porté sur la matière organique d'une paléovasière (GIF-8005 : 21200±500 ans B.P.) située dans la partie supérieure de la coupe, ainsi que sur les carbonates constituant la phase micritique de ce dépôt (GIF-8006 : ≥36000 ans B.P.). Si la datation des carbonates reflète un héritage géologique ancien, l'âge de la matière organique paraît contemporain de sa formation et précise donc celui de la partie supérieure de cette terrasse.

Ces datations permettent de situer la formation de cette terrasse alluviale contemporaine de la dernière phase humide du Pléistocène et la succession Paléolithique moyen-Paléolithique supérieur dans la région entre 25- et 20000 ans B.P. sans qu'il y ait de véritable coupure chronologique entre ces deux stades culturels comme on le supposait précédemment (Roche, 1976) d'autant que certains éléments sont communs à ces deux cultures.

2 - LE PALÉOLITHIQUE SUPÉRIEUR ET L'ÉPIPALÉOLITHIQUE

A l'exception des dates anciennement connues pour l'Ibéromaurusien de la grotte de Taforalt, actuellement aucune information nouvelle ne concerne la période entre 20- et 12000 ans B.P. Par contre, à partir de 12000 ans B.P. les données recueillies dans les formations géo-

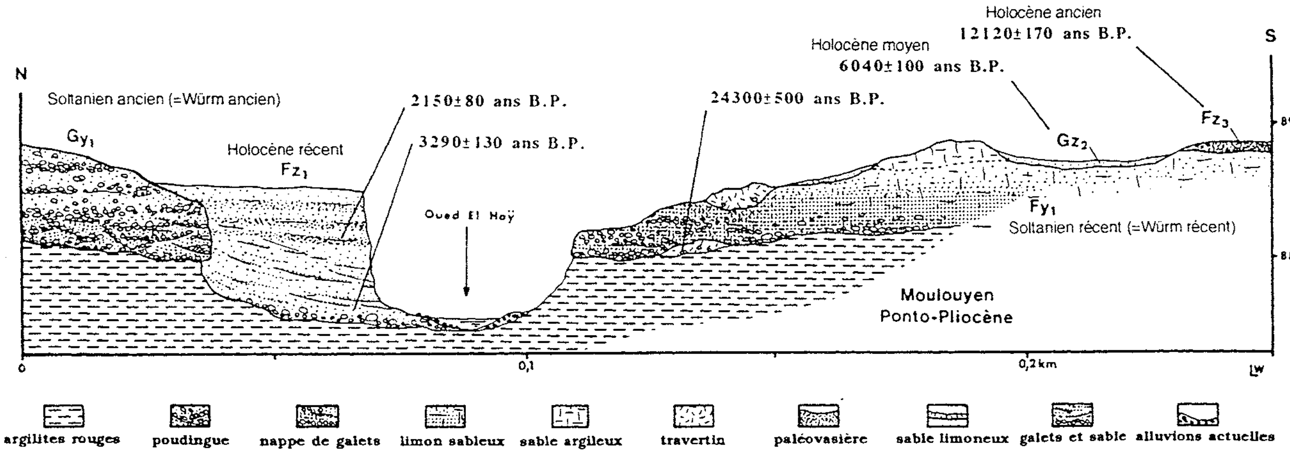

Fig. 2 : Coupe transversale des dépôts sédimentaires dans la partie centrale du bassin de l'Oued El Haÿ en aval des Grandes Cascades (G : glacis ; F : terrasse alluviale ; y : formation soltanienne (= Würm) ; z : formation rharbienne (= Holocène).

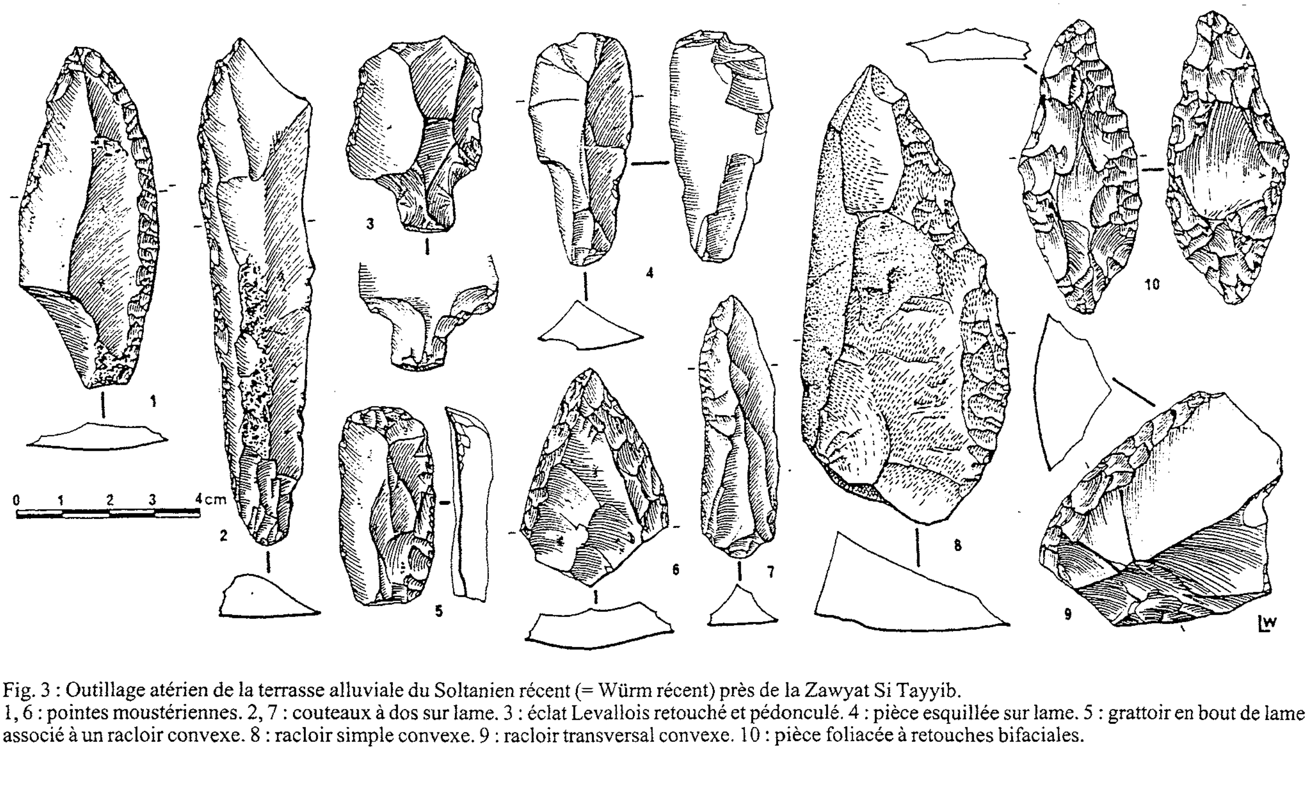

Fig. 3 : Outillage atérien de la terrasse alluviale du Soltanien récent (= Würm récent) près de la Zawyat Si Tayyib.
1, 6 : pointes moustériennes. 2, 7 : couteaux à dos sur lame. 3 : éclat Levallois retouché et pédonculé. 4 : pièce esquillée sur lame. 5 : grattoir en bout de lame associé à un racloir convexe. 8 : racloir simple convexe. 9 : racloir transversal convexe. 10 : pièce foliacée à retouches bifaciales.

logiques et les sites archéologiques de plein air ou sous abri sont assez abondantes. Elles permettent de situer dans le temps les cultures qui se sont succédé dans la région et couvrent certaines périodes de l'Holocène qu'elles ont contribué à délimiter.

Dans le bassin de l'Oued El Haÿ, plusieurs sites ibéromaurusiens de plein air ont été découverts et se caractérisent par la présence d'un abondant outillage lithique où le débitage lamellaire est important. Parmi les outils, les lamelles à bord abattu dominent ; cependant, les grattoirs, les coches et les denticulés sont représentés en quantité non négligeable avec les segments, qui sont les seuls microlithes géométriques présents. Sur les sites, la faune est rarement conservée, mais on retrouve des fragments de test d'œuf d'autruche sur lesquels les datations ont été effectuées. Les âges (tab. 1) s'échelonnent entre 11500 et 9500 ans B.P. et concernent des sites où des structures de campement ont été découvertes, comme à Marja près d'Aïn Béni Mathar.

Dans la même zone, et sans que l'on ait pu établir de rapport de superposition directe avec l'Ibéromaurusien, apparaît un épipaléolithique bien individualisé dans les sites de la Chaâba Bayda (fig. 4) et de la Piste où il a été reconnu lors de fouilles. Le matériel lithique présente un type de débitage semblable à celui de l'Ibéromaurusien et l'outillage s'enrichit en grattoirs et en microlithes géométriques au détriment des lamelles à bord abattu. De nouveaux types d'outils apparaissent comme les triangles et les trapèzes tandis que le microlithisme d'une partie de l'industrie s'accentue (fig. 5). Aucun objet décoré n'a jusqu'à présent été découvert et l'industrie osseuse paraît extrêmement réduite. Dans cette culture, l'emploi d'ocre paraît habituel et les structures domestiques rencontrées correspondent à des habitats temporaires de nomades qui ne pratiquaient probablement pas l'élevage. Les restes de faune étudiés par P. Ducos sont attribués à des animaux chassés comme *Bos primigenius*, *Alcelaphus buselaphus*, *Gazella sp.* et *Ammotragus lervia.*

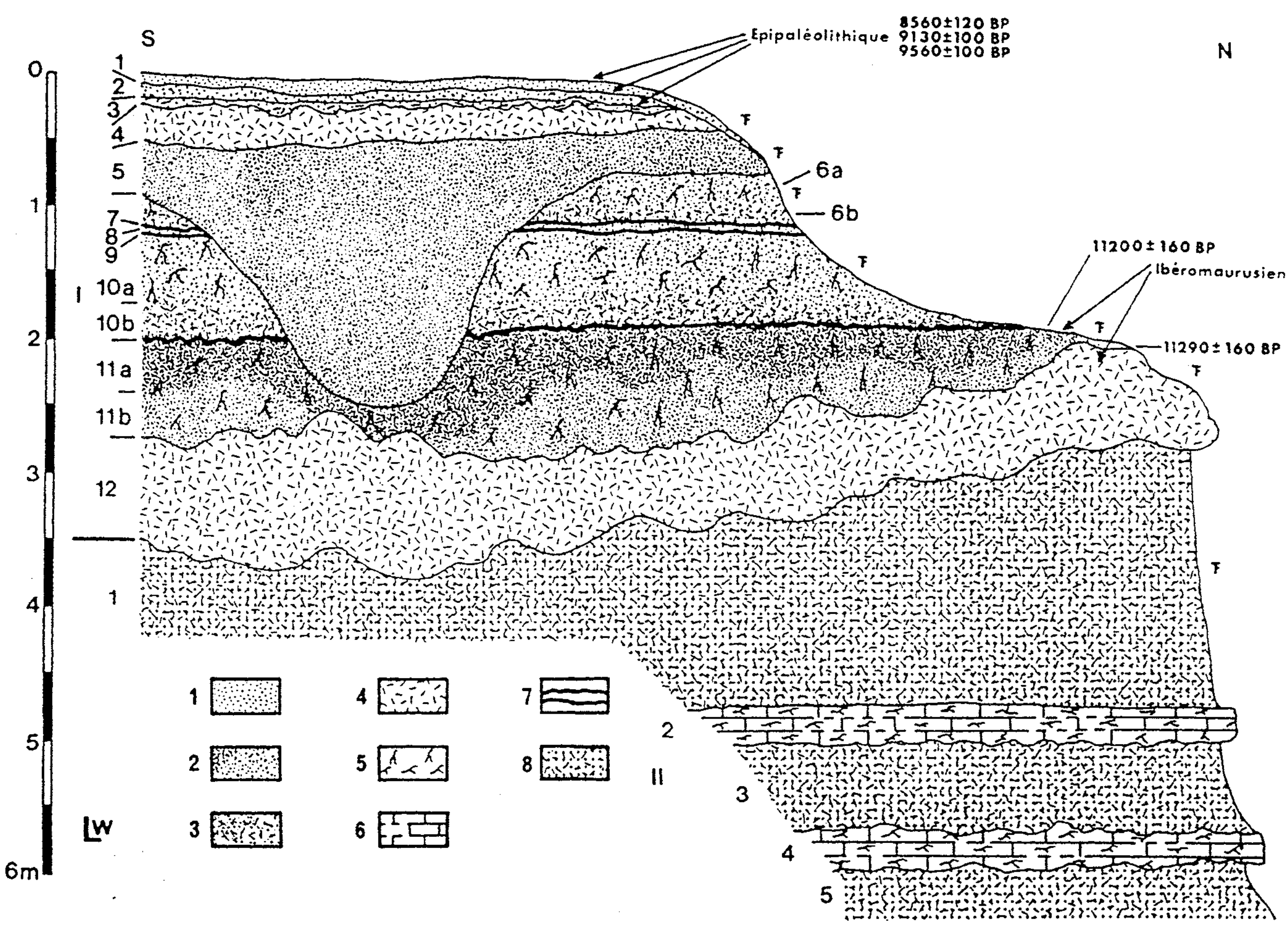

Fig. 4 : Stratigraphie des dépôts alluviaux du Rharbien ancien de la Chaâba Bayda et position des sites préhistoriques. Ensemble I : dépôts du Rharbien ancien. Ensemble II : sédiments fluvio-palustres du Soltanien récent.
1 : sable fin argileux. 2 : sable fin grisâtre plus ou moins riche en matière organique. 3 : sable riche en matière organique et concrétions algaires, calcaires, remaniées. 4 : travertin. 5 : niveau noir, très riche en matière organique. 6 : traces de racines. 7 : sable fin limoneux, carbonaté, riche en fragments de travertin remaniés.

Site	Référence	Age B.P.
Châaba Bayda, site 1 - surface	GIF-6497	11290±160
Châaba Bayda, site 2 - surface	GIF-6187	11200±160
Site Est de la Butte 912 - surface	GIF-7066	10400±110
Marja, zone D5 - surface	GIF-6188	9930±90
Site des Foyers - surface	GIF-6936	9500±100

Tab. 1 : Datations des sites ibéromaurusiens récents dans le bassin de l'Oued El Haÿ obtenues à partir de fragment d'œuf d'autruche.

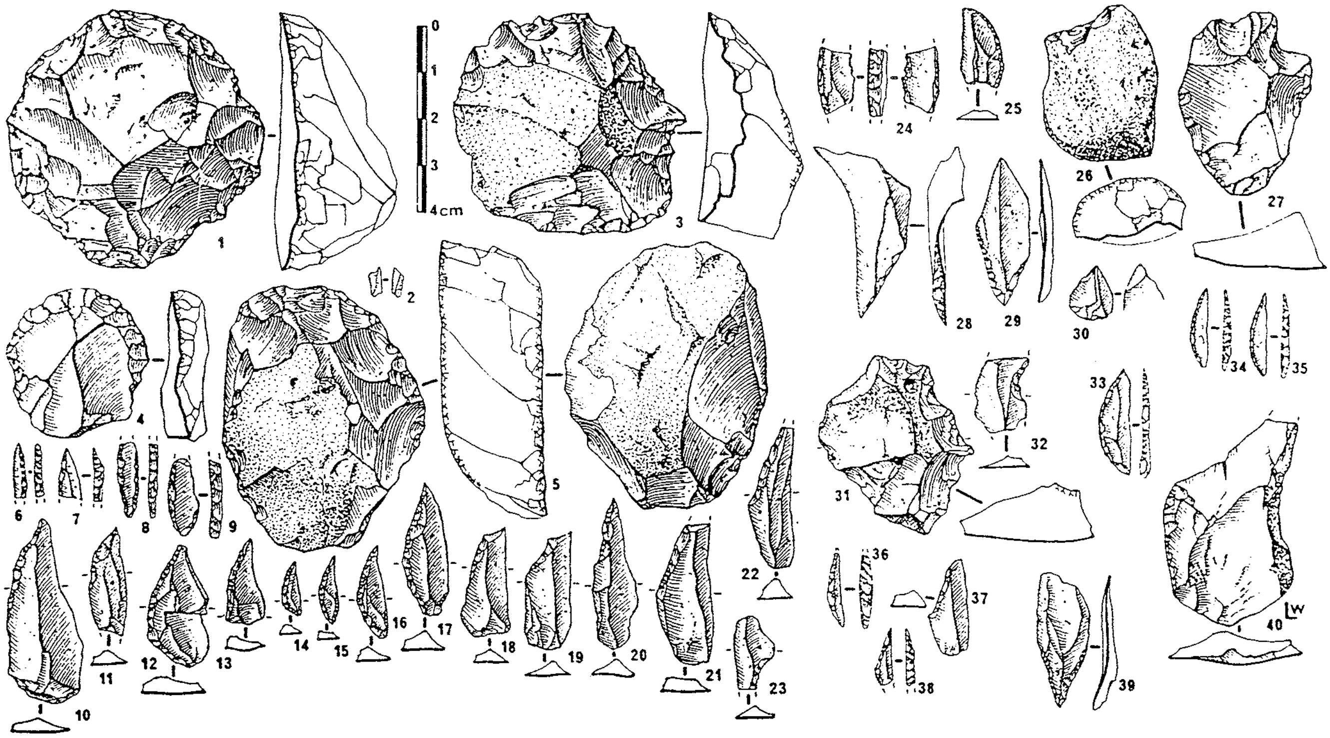

Fig. 5 : Outillage épipaléolithique «Kérémien» du site de la Piste dans le bassin de l'Oued El Haÿ.
1, 3 à 5 : grattoirs. 2, 30 : microburins. 6 à 25 : lamelles à bord abattu. 26 : éclat tronqué. 27, 31 : éclats denticulés. 28, 37 : lamelles tronquées. 29, 39 : lamelles à base bitronquée. 32 : lamelle à coche. 33 à 36 : segments. 38 triangle. 40 : éclat à retouche continue.

L'ensemble de ces données et notamment celles sur la typologie montrent que cette culture présente de fortes affinités avec le Kérémien (Cadenat et Vuillemot, 1944 ; Camps, 1974) connu en Algérie dans la région de Tiaret à 300 km plus à l'Est et plus particulièrement avec celle de Bou Aïchem, gisement littoral à l'Est d'Oran (Goetz, 1967) qui semble un peu plus vieux : 9700±400 ans B.P. Alg.-26 sur charbon de bois et 10215±400 ans B.P. Alg.-25 sur mollusque marin (Camps *et al.*, 1973).

Dans l'Oriental, les datations effectuées sur des sites de plein air présentant des stratigraphies et sur des sites de surface à partir de fragments d'œuf d'autruche donnent des âges qui varient entre 9500 et 8500 ans B.P. (tab. 2) dont un seul (couche 3b du site de la Piste), obtenu à partir du collagène des os, paraît aberrant. Toutefois, comme aucune superposition directe avec une culture plus récente n'est connue dans la région étudiée, il serait hasardeux de considérer la date de 8500 ans B.P. comme étant celle à laquelle cette culture disparaît.

Plus au Nord, dans les Monts d'Oujda, le site de plein air de Sidi Ahmed, associé à une terrasse alluviale, a livré une industrie riche en microlithes géométriques qui représente une autre culture épipaléolithique dont la datation (tab. 3) nécessite quelques commentaires. La couche archéologique, épaisse d'environ 40 cm, est riche en matière organique, en charbons de bois et en traces de racines dont certaines sont récentes. Elle est recouverte par plus d'un mètre de sables limoneux plus récents d'origine alluviale. Si les fragments d'œuf d'autruche sont bien contemporains de l'activité humaine et fournissent un âge parfaitement acceptable, celui obtenu à partir de la matière organique semble avoir été rajeuni par la présence de racines récentes, mais on est surpris par celui des charbons de bois qui semblent indépendants de l'activité humaine et peuvent dater la mise en place des sédiments.

Tous ces sites sont associés à des formations alluviales constituant une terrasse de l'Holocène ancien que différentes données paléobotaniques permettent de situer dans une phase plus humide que l'actuel. Cette formation a pu être datée entre 12000 et 8200 ans B.P. le long de plusieurs cours d'eau (Wengler *et al.*, 1994), mais les âges obtenus (tab. 4) sont très hétérogènes suivant

Site	Niveau	Référence	Age B.P.
Aïn Kriane, site 1	surface	GIF-6937	9450±100
Marja, zone J5	surface	GIF-6500	9070±130
Site de la Piste	couche 1	GIF-6495	8960±130
Site de la Piste	couche 3b	GIF-6496	4900±280
Site de la Piste	couche 3c	GIF-6826	9340±100
Site de la Piste	couche 4	GIF-6827	9350±100
Châaba Bayda, site 3	surface	GIF-6498	8560±120
Châaba Bayda, site 3	couche 2	GIF-6828	9560±100
Châaba Bayda, site 3	couche 3	GIF-6829	9130±100

Tab. 2 : Ages des niveaux épipaléolithiques dans le bassin de l'Oued El Haÿ obtenus à partir de fragments d'œuf d'autruche et de collagène extrait des os (site de la Piste, couche 3b).

Matériel daté	Référence	Age B.P.
charbon de bois	GIF-7571	11000±120
œuf d'autruche	GIF-7553	8680±80
matière organique	GIF-7699	8260±80

Tab. 3 : Age du site de plein air épipaléolithique de Sidi Ahmed dans les Monts d'Oujda.

Site	Matériel daté	Référence	Age B.P.
Oued Charef (formation putride)	Matière organique	Ly-3881	12120±170
Oued Charef (radier)	Mollusque d'eau douce	GrN-5570	11360±75
Oued Al Gazmir (vasière sup. 1)	Carbonates	GIF-7630	16980±220
Oued Al Gazmir (vasière sup. 2)	Matière organique	GIF-7630 bis	6760±120
Oued Al Gazmir (vasière inf.)	Matière organique	Ly-4211	8130±150
Oued Al Gazmir (base 1)	Carbonates	GIF-7629	11700±130
Oued Al Gazmir (base 2)	Matière organique	GIF-7629 bis	5920±80

Tab. 4 : Age des formations alluviales de l'Holocène ancien dans le bassin de l'Oued El Haÿ.

Site	Niveau	Matériel daté	Référence	Age B.P.
Oued Ouziyyane (foyer)	couche 2	Charbon de bois	GIF-7399	5700±110
Jorf Akhdar (foyer)	couche 3d	Charbon de bois	GIF-6493	5080±70
Jorf Akhdar (foyer)	couche 6b1	Charbon de bois	GIF-6494	5930±80
Jorf Akhdar (foyer)	couche 8a	Charbon de bois	GIF-6879	5700±70
Jorf Akhdar	couche 9 bas	Charbon de bois	GIF-6923	5870±100
Jorf Akhdar	couche 11c	Charbon de bois	GIF-7684	5760±80
Oued Béni Méliarène (foyer)	couche 1d	Charbon de bois	GIF-7002	4420±270
Oued Ben Séguir	couche 1-2	Charbon de bois	GIF-7685	4410±90
Oued Ben Séguir	couche 4	Charbon de bois	GIF-7552	4610±70
Oued Ben Séguir	couche 5	Charbon de bois	GIF-7686	4810±70
Oued Nachef	couche I 2	Matière organique	GIF-7803	4790±100

Tab. 5 : Datations de différentes couches des terrasses alluviales de l'Holocène moyen bordant les oueds.

les lieux, même sur une même couche, et parfois ne datent qu'un héritage ancien (Oued Al Gazmir [vasière sup. 1]) ou un rajeunissement (Oued Al Gazmir [vasière sup. 2], [base 2]) dû probablement à des apports d'acides humiques.

3 - LE NÉOLITHIQUE

A l'Holocène ancien humide succède une brève recrudescence de l'aridité pendant laquelle une forte reprise de l'érosion a entamé les formations antérieures et détruit une partie importante des dépôts sous abri, et pour laquelle peu de renseignements sont disponibles. Entre 6500 et 4400 ans B.P. un nouvel épisode plus humide permet l'installation d'une tendance biostasique et la reprise d'un alluvionnement important qui a pu être daté dans les deux bassins hydrographiques régionaux : Oued Isly et Oued El Haÿ (tab. 5).

Dans les terrasses alluviales et les glacis associés de cette période, les témoins anthropiques sont nombreux, mais les vestiges permettant de caractériser les cultures sont rares, la céramique ayant la plupart du temps disparu. On sait seulement qu'il s'agit d'un Néolithique dont les représentants taillaient abondamment les roches dures. La structure de l'industrie lithique se rapproche de l'Epipaléolithique avec toutefois quelques rares pointes de flèches foliacées (Wengler, 1987-88) et des pièces foliacées bifaciales ovalaires comme au Site Nord de la Zawyat Si Tayyib dans le bassin de l'Oued El Haÿ daté de 6040±100 ans B.P. (GIF-7400) sur œuf d'autruche. Cette culture est différente du Cardial connu sur une partie de la frange littorale et correspond peut-être dès 6000 B.P. à un Néolithique moyen.

Entre 5200 et 3400 ans B.P. (tab. 6), les abris sous roche et les porches de grotte des Monts d'Oujda ont livré des dépôts témoignant de la fréquentation des lieux par les Néolithiques dont la culture est semblable à celle connue en Oranie (Wengler *et al.*, 1989). Les formes de poterie et les thèmes de décoration sont similaires. L'industrie lithique est abondante avec notamment un petit outillage, toujours très pauvre en pointes de flèche, où dominent les lamelles à bord abattu. Différents types de haches polies et du matériel de broyage font également partie des vestiges recueillis en fouille. L'analyse de la faune montre qu'il s'agit de populations pastorales pratiquant la chasse au gros et petit gibier. Leur cheptel est constitué d'Ovicaprinés, puis vers 4600 ans B.P. il paraît s'enrichir de bovidés de petite taille.

Au cours de cette période, on a pu déceler un épisode plus aride entre 4400 et 3500 ans B.P., pendant lequel se produit une forte incision linéaire des cours d'eau. Peu après, un nouveau système de glacis-terrasse bien représenté et daté à partir de charbons de bois dans le bassin de l'Oued El Haÿ (fig. 2) se met en place à l'Holocène récent entre 3300 et 2000 ans B.P. (tab. 7) à l'occasion d'un retour à des conditions plus humides. Aucun vestige de métaux n'a été trouvé en place dans les sites archéologiques de la région, si bien qu'il est difficile, en l'état des recherches, de parler d'un véritable âge des métaux, d'autant que sur le petit site de la Fontaine Rahhal, près

Site	Niveau	Matériel daté	Attribution	Référence	Age B.P.
Grotte du Rhafas	couche 1	Charb. de bois	Néolithique	GIF-6185	5190±100
Grotte d'El Hériga	couche 2	œuf d'autruche	Berbère	GIF-6830	1220±50
Grotte d'El Hériga	couche 2	œuf d'autruche	Berbère	GIF-6831	1430±50
Grotte d'El Hériga	couche 3a	œuf d'autruche	Remaniement	GIF-6832	1450±50
Grotte d'El Hériga	couche 3c	œuf d'autruche	Néolithique	GIF-6186	4600±60
Jorf El Anngra	couche 3	œuf d'autruche	Néolithique	GIF-6492	4110±90
Abri Rhirane	couche 3	œuf d'autruche	Néolithique	GIF-6490	3900 ±90
Abri Rhirane	couche 3	œuf d'autruche	Remaniement	GIF-6183	1800±80
Abri Rhirane	couche 4	œuf d'autruche	Remaniement	GIF-6184	3490±90
Abri Rhirane	couche 4	Charb. de bois	Remaniement	GIF-6878	720±50
Abri de Bou Guennoua	couche 2	œuf d'autruche	Néolithique	GIF-6491	3820±90
Abri de Bou Guennoua	couche 2	Charb. de bois	Néolithique	GIF-6880	3400±80

Tab. 6 : Age de différentes couches des sites néolithiques des Monts d'Oujda.

Site	Formation	Niveau	Matériel daté	Référence	Age B.P.
Grandes Cascades	Terrasse Fz1	couche 3	Charbon de bois	GIF-6499	2150±80
Grandes Cascades	Terrasse Fz1	couche 3	Charbon de bois	Ly-3619	1480±120
Grandes Cascades foy.	Terrasse Fz1	couche 16	Charbon de bois	Ly-3620	3290±130

Tab. 7 : Datation d'un foyer et de niveau charbonneux dans la basse terrasse alluviale de l'Oued El Haÿ.

d'Aïn Béni Mathar, daté de 2460±60 ans B.P. (GIF-6825) à partir de fragments d'œuf d'autruche, la tradition lithique paraît extrêmement vivace. La population berbère d'alors fréquentait les mêmes sites que les Néolithiques et utilisait les œufs d'autruche dont les fragments ont contribué à dater des couches en place ou remaniées à cette époque, notamment dans la grotte d'El Hériga et à l'Abri Rhirane.

4 - AUTRES ESSAIS DE DATATION

D'autres essais de datation (tab. 8) ont été effectués sans succès sur des croûtes carbonatées (Station Météo, site 2) couronnant une formation alluviale antérieure à la terrasse datée de 25- à 20000 ans B.P. et correspondant à l'inter Soltanien ancien-Soltanien récent (= inter Würm ancien-Würm récent) ; les âges obtenus paraissent trop jeunes par rapport aux données géologiques et culturelles disponibles. Il en a été de même pour un essai de datation d'un niveau Atérien ancien dans la grotte du Rhafas effectué à partir du collagène des os (couche 2, GIF-6489 : 14060±150 ans B.P.). A ce propos, il faut remarquer que les deux datations effectuées sur ce type de matériel dans la région (Site de la Piste, couche 3b) se sont révélées incompatibles avec le contexte dans lequel ces vestiges ont été trouvés et cela sans que l'on puisse proposer une explication satisfaisante.

5 - CONCLUSIONS

L'ensemble de ces datations permet de constituer une première trame chronologique des événements constituant l'histoire géologique, paléoenvironnementale et culturelle de la région nord du Maroc oriental (fig. 6) depuis la fin du Paléolithique moyen, tout en mettant en évidence un certain nombre de zones d'ombre.

Sur le plan géologique, les datations ont été un élément déterminant pour situer précisément sur une échelle chronologique les différentes phases d'alluvionnement qui se sont succédé depuis la fin du Pléistocène. Elles montrent la durée de plus en plus courte de celles-ci et leur succession de plus en plus rapprochée. La dernière de ces phases au cours du Pléistocène dure relativement peu de temps par rapport à celle durant laquelle l'incision linéaire domine. On remarque l'inversion de ces phénomènes durant l'Holocène pendant lequel se produit une accélération des cycles érosion-sédimentation. Ces différentes phases ont pu être mises en parallèle avec des tendances climatiques grâce aux données paléobotaniques et ont servi au découpage des 25 derniers millénaires, mais leurs limites manquent parfois de précision et nous n'avons que très peu de données sur les phases arides, sauf dans quelques dépôts d'abris sous roche où la fréquentation de l'Homme a favorisé la constitution de dépôts sédimentaires confirmant cette tendance climatique. La fin du Soltanien (= Würm) et l'ensemble de cette période apparaissent globalement arides tandis que le Rharbien (= Holocène) est nettement plus humide avec de nombreuses oscillations dont l'actuelle, qui se manifeste par une forte incision linéaire dans la région et une tendance rhéxistasique marquée.

Au niveau des cultures préhistoriques, les datations obtenues réduisent considérablement le hiatus entre le Paléolithique moyen et le Paléolithique supérieur, puisque l'Atérien le plus récent de cette région est postérieur à 24000 ans B.P. tandis que l'Ibéromaurusien est connu dès 22000 ans B.P. ; toutefois, les relations entre ces deux cultures ne sont pas encore claires, bien que certaines traditions atériennes se retrouvent dans l'Ibéromaurusien ancien. Seule la phase terminale de cette culture est bien représentée dans la région étudiée et son évolution progressive vers un Epipaléolithique de type

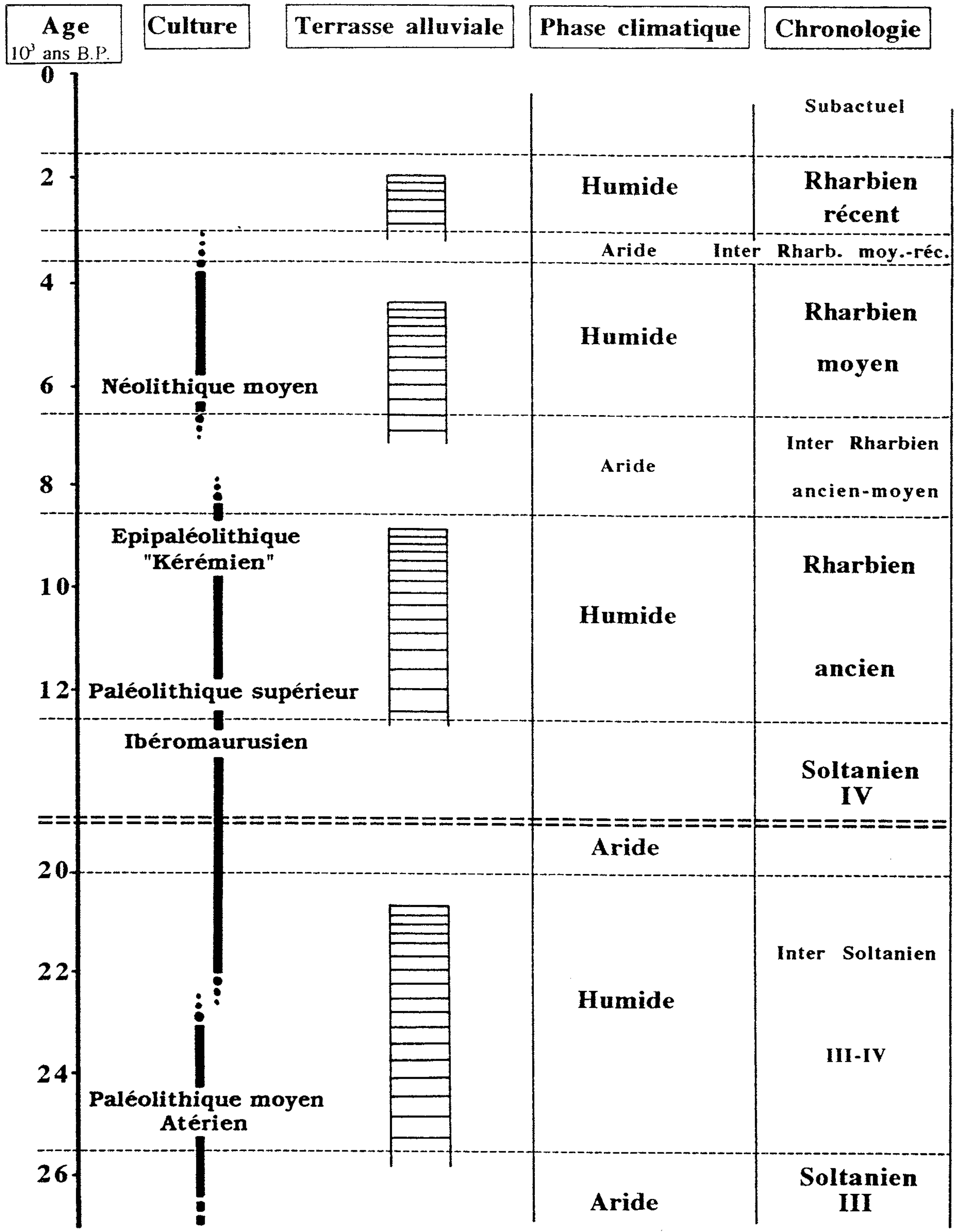

Fig. 6 : Rapports chronologiques entre les cultures préhistoriques et certains aspects paléoenvironnementaux au Maroc oriental.

Site	Niveau	Matériel daté	Référence	Age B.P.
Station Météo, site 2	couche 1a	Carbonates	GIF-7627	15100±180
Station Météo, site 2	couche 1a	Matière organique	GIF-7627 bis	8800±500
Station Météo, site 2	couche 2b	Carbonates	GIF-7626	20200±310
Station Météo, site 2	couche 2b	Matière organique	GIF-7626 bis	insuffisant

Tab. 8 : Résultats des essais de datation sur des croûtes carbonatées terminant une séquence alluviale de l'inter Soltanien ancien-Soltanien récent.

Kérémien est un fait nouveau qui a pu être daté vers 9500 ans B.P. Par contre, on ne sait rien sur la fin de cette culture et ce jusque vers 6000 ans B.P. où l'on constate la présence d'un Néolithique moyen qui va perdurer longtemps et sur lequel les informations s'accumulent. On remarquera que les différents changements culturels qui ont pu être datés se produisent lors de phases de modification des paléoenvironnements ; cependant, les limites proposées pour les événements et les cultures demandent encore à être précisées dans l'avenir en tenant compte d'un nombre de données plus important.

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UN FOUR DE MÉTALLURGIE DU FER EN STRATIGRAPHIE A KOUSSANÉ (MALI) : FOUILLE, ANTHRACOLOGIE ET DATATIONS SUR CHARBONS

Christian DUPUY et Christiane ROLANDO***

Résumé : Un fragment de charbon de *Prosopis africana* inclus dans une scorie donne comme âge 1715 BP pour un four de métallurgie du fer découvert en stratigraphie à Koussané. Jusqu'à l'obtention de cette date AMS, les données de la fouille, l'analyse anthracologique des charbons retrouvés à proximité du four, tous identifiés à du *Prosopis africana*, alliés à quatre datations sur charbons, suggéraient un fonctionnement plus ancien. L'écart entre l'âge réel et l'âge présumé s'explique par une fréquentation épisodique du site durant plus d'un millénaire que ni la nature du mobilier mis au jour ni même sa répartition ne mettent en évidence.

Abstract : A charcoal *Prosopis africana* fragment included in a slag gives an age 1715 bp for an iron smelting furnace discovered in stratigraphy at Koussane. Up until this AMS dating was made, excavation data and anthracological analysis of charcoals in the vicinity, all identified as *Prosopis africana*, together with four charcoals datings, had suggested earlier functioning. The difference between the actual and presumed ages may be explained by episodic settlements at the site over more than a millenarium, and which hitherto had not been revealed by either the types and the spatial distribution of artifacts.

Mots-clés : Age ancien du Fer, région tropicale, mélanges d'industries.

Key-words : Early Iron Age, Tropical Region, mixing of artifacts.

Lors d'une mission de prospection menée en 1993 dans la vallée de la Kolimbiné, nous découvrons à l'ouest du village de Koussané, le long d'un front d'érosion sur un substrat en pente douce, des scories de fer sous 40 à 50 cm de puissance d'un sol à dominance sablo-silteuse (Vienne, 1997) avec quelques tessons sous-jacents. Un sondage de 2 mètres carrés permet la mise au jour d'un charbon situé au même niveau et à proximité immédiate des scories. Ce charbon fournit l'âge de 2520 ± 70 BP (Gif-9585), soit après correction dendrochrononologique un âge compris entre -800 et -420 av. J.-C. (95 % de confiance).

Koussané est situé dans une région soumise au régime des pluies de mousson où la pluviométrie moyenne est actuellement de 700 mm par an (fig. 1). A cette latitude comme aux latitudes voisines, la répartition originelle des vestiges peut se trouver modifiée par déflation et érosion des sols sous les effets conjugués des sécheresses, des défrichements, des déboisements, de la violence des vents et de certaines pluies et (ou) par les passages répétés des hommes et des animaux sur les sites à l'abandon. De plus, les charbons présents sur les sols nus de fin de saison sèche, quelle que soit leur taille, peuvent être transportés par l'eau et le vent. Afin de savoir si le charbon daté de 2520 BP se rapporte ou non à une activité de métallurgie, une fouille sur 70 mètres carrés est réalisée en 1995.

UNE OPÉRATION DE RÉDUCTION ANTÉRIEURE A 1840 ± 95 BP

Le premier niveau de vestiges apparaît sous 40 à 50 cm du sol actuel, pratiquement à l'horizontale (fig. 2). Le matériel le plus volumineux consiste en trois grosses scories situées à proximité immédiate d'une structure complexe d'épaisseur centimétrique attenante à l'une des scories de taille importante. Le démontage de cette structure lors de la fouille a montré qu'elle était constituée pour l'essentiel de plaques d'argile cuite, de restes de boudins réalisés dans la même argile et de fragments

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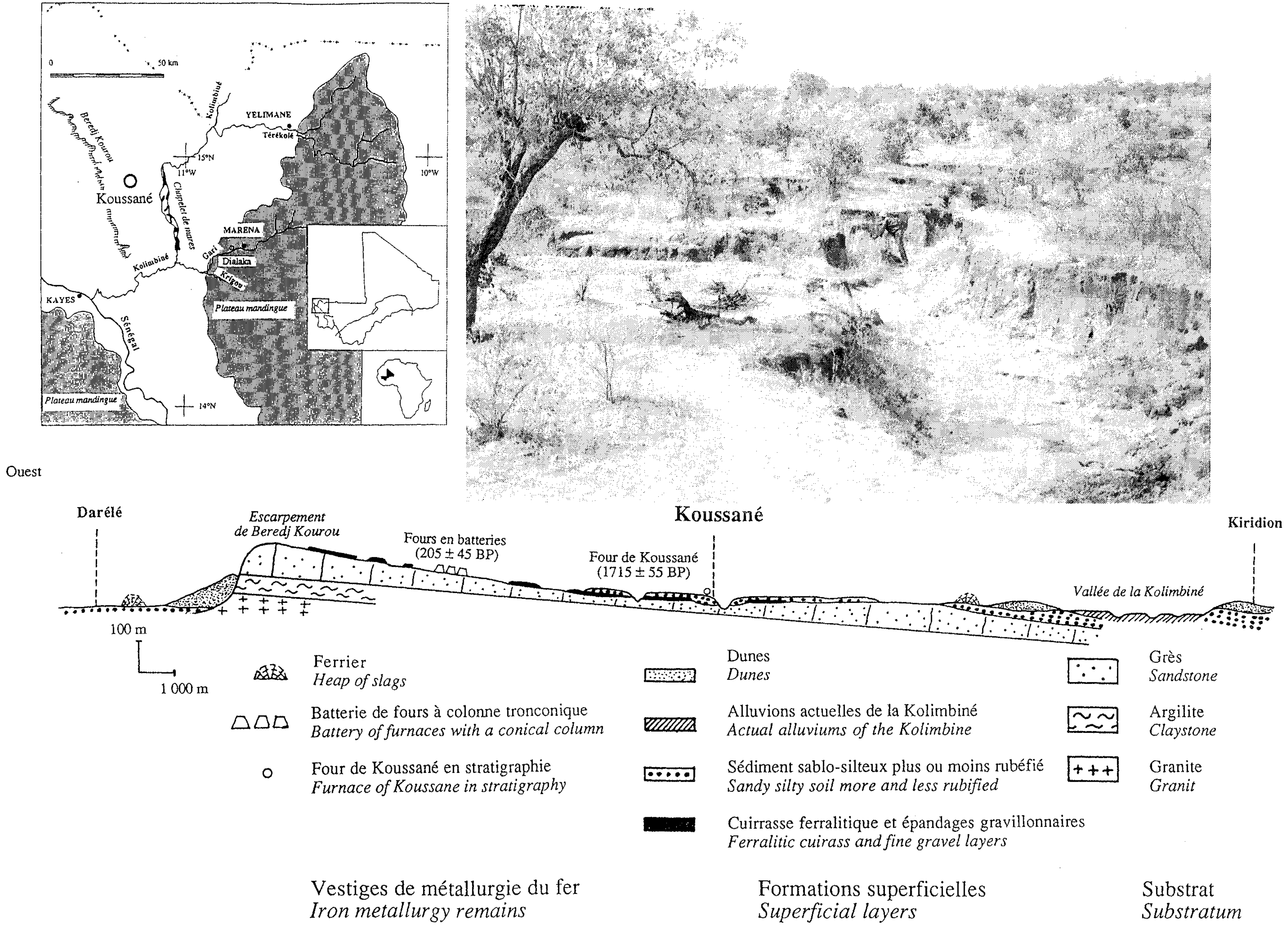


Fig. 1 : Situation géographique et position topographique de Koussané.
Fig. 1 : Geographical location and topographical location of Koussane.

de tuyères en partie vitrifiées. Un boudin, partiellement remonté en laboratoire, s'est trouvé épouser une courbure identique au contour en arc de cercle de l'une des trois scories volumineuses. La présence sous cette dernière de cendres, d'empreintes de végétaux sur sa face inférieure, l'aspect moulé de son contour et son profil en cuvette, nous font l'identifier au culot d'un fond de four en place aux deux tiers brisés. Le matériel de petite taille se répartit alentour sans organisation apparente. Il comprend des fragments de tuyères, des morceaux concassés et bien calibrés d'un minerai ferromagnétique, des petites scories coulées, une vingtaine de tessons de faible épaisseur portant quatre types de décors imprimés, quelques éclats de quartz, d'argilite, de grès et un tranchant non émoussé en argilite. Les piétinements et le ruissellement ont probablement causé la fragmentation et la dispersion des tuyères et des tessons.

Sans entrer dans les détails ici, les vestiges en relation avec la métallurgie se rapportent selon toute vraisemblance à une seule et même opération de réduction. Celle-ci s'est effectuée dans un four qui était constitué d'une fosse en cuvette sans dispositif d'évacuation des scories et d'une structure en élévation («cellule» ou «colonne» pour suivre la terminologie établie par B. Martinelli, en 1993, sur les fonderies ouest-africaines), laquelle recevait au moins quatre tuyères d'après le nombre d'embouts scorifiés retrouvés en fouille et remontés en laboratoire. Une fois l'opération terminée, la structure en élévation a été déplacée vers l'amont et le culot brisé, peut-être lors du prélèvement de l'éponge en fer. Des esquilles charbonneuses apparues au dessus du culot en cours de décapage ont été prélevées et datées de 1840 ± 95 BP (Ly-7124), soit de -10 av. J.-C. à 400 ap. J.-C. De ces observations, il ressort que la dernière activité à s'être exercée sur le site de Koussané antérieurement à 1840 ± 95 BP a été une opération de réduction.

UNE OPÉRATION DE RÉDUCTION SUSCEPTIBLE DE DATER DE 2910 ± 45 BP

Le matériel sous-jacent ne comporte aucun vestige de métallurgie. Il se répartit sur 20 à 40 cm d'épaisseur sans division stratigraphique ni organisation spatiale apparentes. Plus de 400 tessons très petits, parfois usés et érodés, une cinquantaine d'éclats de quartz et d'argilite, une quinzaine de fragments de grès présentant des surfaces polies et des angles émoussés, quatre fragments d'une meule en granite incomplète, deux tranchants et un talon de hache ou herminette en roche dure étaient intégrés, épars, dans ces 20 à 40 cm. Aucun remontage entre tessons n'a été possible. Les quatres types de décors imprimés observés sur les tessons du niveau supérieur se retrouvent sur les tessons sous-jacents, ces derniers offrant une gamme de décors plus étendue. De plus, associés à ces tessons, des charbons, dont certains de plus d'un centimètre de côté, sont apparus groupés une dizaine de mètres en aval du four. L'analyse anthracologique révèle qu'il s'agit de *Prosopis africana*, une espèce à fort pouvoir calorifique prisée des métallurgistes de l'Afrique de l'Ouest (Echard, 1983 ; Levy-Luxereau, 1983 ; Seignobos, 1991). Deux gros charbons situés à un mètre de distance ont fourni les âges de 2920 ± 45 BP (Ly-6990) et 2895 ± 45 BP (Ly-8057), c'est-à-dire un âge moyen de 2910 ± 45 BP, soit -1230 à -950 av. J.-C.

L'apparentement des vestiges sous-jacents avec le mobilier du premier niveau et leur état de conservation identique nous font envisager deux hypothèses :

- Ou bien, tout le matériel recueilli appartient aux métallurgistes et les charbons de *Prosopis africana* comptent parmi ceux sélectionnés par les métallugistes mais non utilisés par eux lors la réduction. La position de ces charbons en aval du four pourrait résulter d'un charriage par le ruissellement ou correspondre à une aire de production de charbons de bois par calcination des troncs à l'air libre suivie d'une extinction par étouffement au sable ou par aspersion d'eau. Auquel cas le four aurait fonctionné en 2910 BP.
- Ou bien ces charbons de *Prosopis africana* et le matériel lithique et céramique associé étaient déjà intégrés dans le sol sur lequel se sont installés les métallurgistes ; auquel cas le four aurait fonctionné entre 2910 BP et 1840 BP, peut-être en 2520 BP, âge du charbon prélevé au voisinage immédiat et au même niveau que les scories volumineuses découvertes en 1993 sur le front d'érosion.

UNE OPÉRATION DE RÉDUCTION DATÉE DE 1715 ± 55 BP

Afin de trancher en faveur de l'une ou l'autre de ces possibilités, une partie du fond du four et des scories associées ont été broyées avec l'espoir de trouver d'éventuels charbons prisonniers. Par chance une scorie renfermait deux petits charbons. Un seul a pu être identifié : il s'agit de *Prosopis africana*.

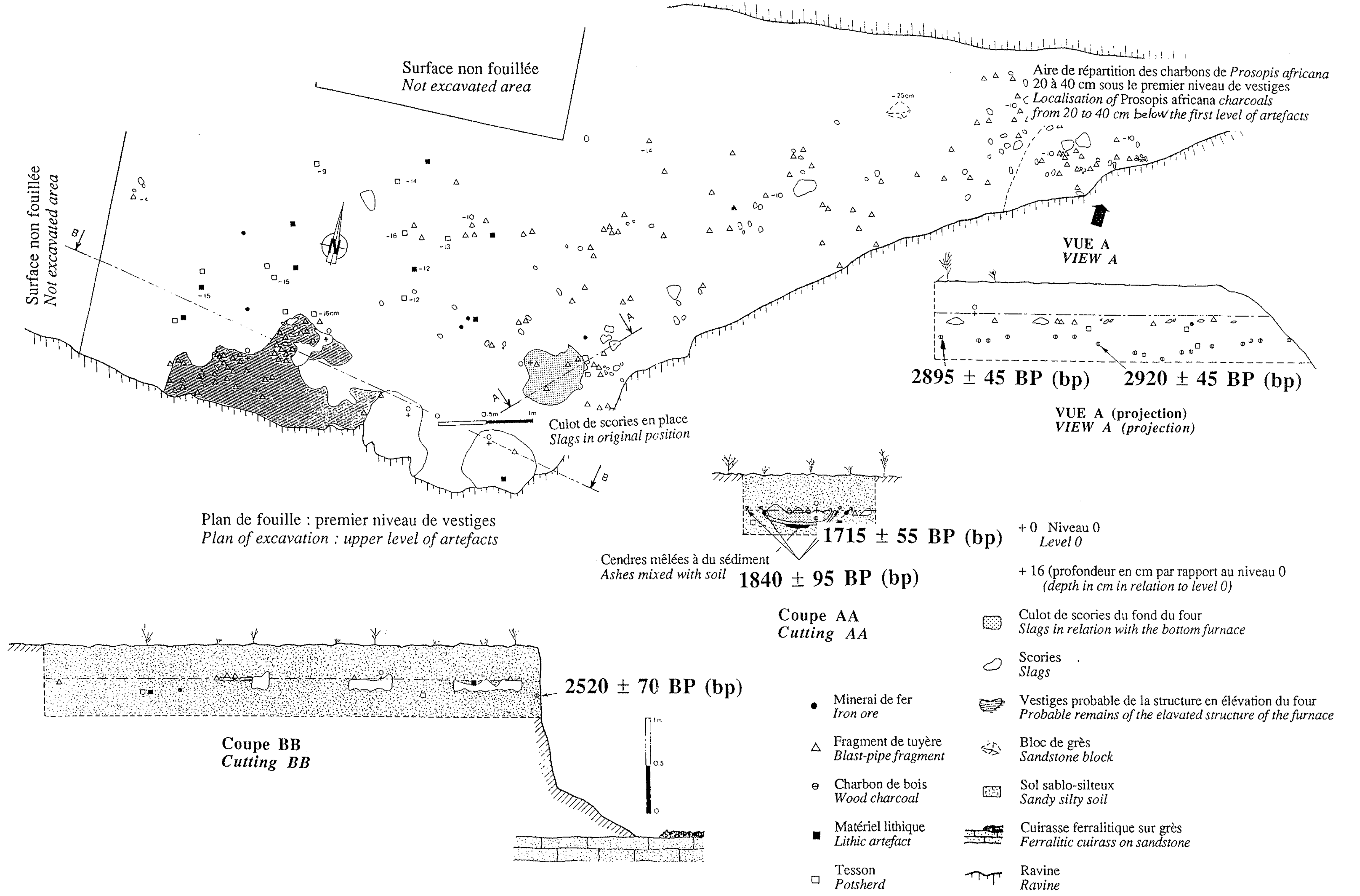
Cette identification nous apparaissait comme un indice sérieux en faveur d'une réduction vers 2910 BP. Nous avons fait soumettre ces petits charbons à une datation par accélérateur. Cette datation a fourni l'âge de 1715 ± 55 BP (Lyon-329 / AA-21696), soit 210 à 460 ap. J.-C.

Parallèlement, des fragments de tuyères, du sédiment en partie vitrifié au contact du culot en cuvette et des plaques d'argile cuite liées à la structure en élévation ont été soumis à une étude de databilité par thermoluminescence. Les résultats préliminaires obtenus laissent penser que ce matériel serait datable avec une précision convenable à condition de pouvoir mesurer *in situ*, aux points précis de prélèvement des objets à dater, la radioactivité du milieu d'enfouissement. En attendant, les résultats préliminaires, du fait de leur dispersion (le sédiment vitrifié a donné 1700 ± 200 BP, les autres éléments des âges compris entre 900 ± 200 BP et 1100 ± 200 BP) ne permettent pas d'avancer une date qui confirmerait les données du radiocarbone.

CONCLUSIONS

De la série des dates radiocarbones obtenues (tab. 1), on peut déduire que des métallurgistes sont venus fondre leur minerai à Koussané aux alentours de 1715 BP, en un lieu qui était fréquenté épisodiquement depuis au moins un millénaire. Leur four, à l'issue de la réduction, sera rapidement recouvert par des poussières éoliennes et des colluvions à une époque où le bassin du Sénégal dans son ensemble était soumis à une aridité marquée (Dupuy et *al.*, 1995, p. 60-61).

Si l'érosion linéaire et la déflation actuelles se poursuivent, les vestiges de métallurgie du fer, aujourd'hui en stratigraphie, se présenteront demain en surface. Les résultats radiométriques montrent que la meilleure manière de confirmer l'âge d'une opération de réduction en région tropicale passe par l'extraction des charbons susceptibles d'être inclus dans des scories.


Surface non fouillée
Not excavated area
Surface non fouillée
Not excavated area
Aire de répartition des charbons de Prosopis africana
20 à 40 cm sous le premier niveau de vestiges
Localisation of Prosopis africana charcoals
from 20 to 40 cm below the first level of artefacts
VUE A
VIEW A
2895 ± 45 BP (bp)
2920 ± 45 BP (bp)
VUE A (projection)
VIEW A (projection)
Culot de scories en place
Slags in original position
Plan de fouille : premier niveau de vestiges
Plan of excavation : upper level of artefacts
1715 ± 55 BP (bp)
Cendres mêlées à du sédiment
Ashes mixed with soil
1840 ± 95 BP (bp)
Coupe AA
Cutting AA
2520 ± 70 BP (bp)
Coupe BB
Cutting BB
+0 Niveau 0
Level 0
+16 (profondeur en cm par rapport au niveau 0
(depth in cm in relation to level 0)
Culot de scories du fond du four
Slags in relation with the bottom furnace
Scories
Slags
Minerai de fer
Iron ore
Vestiges probable de la structure en élévation du four
Probable remains of the elavated structure of the furnace
Fragment de tuyère
Blast-pipe fragment
Bloc de grès
Sandstone block
Charbon de bois
Wood charcoal
Sol sablo-silteux
Sandy silty soil
Matériel lithique
Lithic artefact
Cuirasse ferralitique sur grès
Ferralitic cuirass on sandstone
Tesson
Potsherd
Ravine
Ravine

Référence *Reference*	Identification des charbons *Identification of charcoals*	∂ 13C‰ *∂ 13C‰*	Ages 14C normalisés (± 1 sigma) *Conventional Ages (± 1 sigma)*	Ages corrigés (95% de confiance) *Calibrated Ages (95% confidence)*
Ly-329/AA-21696	*Prosopis africana*	-25,00	1715 ± 55	210 à 460 ap. J.-C.
Ly-7124	Non effectuée - Not done	-25,00	1840 ± 95	-10 av. J.-C. à 400 ap. J.-C.
Gif-9585	Non effectuée - Not done	-27,63	2520 ± 70	-800 à -420 av. J.-C.
Ly-8057	*Prosopis africana*	-25,98	2895 ± 45	-1210 à -940 av. J.-C.
Ly-6990	*Prosopis africana*	-26,32	2920 ± 45	-1250 à -960 av. J.-C.

Tab. 1 : Résultats des datations sur charbons de bois. Les datations Ly-6990 et Ly-7124 sont exprimées en années réelles par l'utilisation des courbes de corrections dendrochronologiques publiées en 1986 dans la revue Radiocarbon (Vol 28, N°2B) ; les datations Gif-9585, Ly-8057, Lyon-329/AA-21696 le sont par l'utilisation de celles publiées en 1993 dans la revue Radiocarbon (Vol 35, N°1).
Tab. 1 : Results of the datings on wood charcoals. The datings Ly-6990 et Ly-7124 are expressed in real years by using the dendrochronological adjustment curves published in 1986 in the review Radiocarbon (Vol 28, N°2B), the datings Gif-9585, Ly-8057, Lyon-329/AA-21696 by using the dendrochronological adjustment curves published in 1993 in the review Radiocarbon (Vol 35, N°1).

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DATATION DU PREMIER PEUPLEMENT DE LA RÉGION SAHULIENNE PAR LE RADIOCARBONE ET LA LUMINESCENCE

*Esmée WEBB**

Résumé : La récente application de la luminescence aux gisements sahuliens suggère la présence de l'homme sur la Terre d'Arnhem vers 60 000 BP, alors que les dates sahuliennes par le ^{14}C ne dépassent jamais 40 000 BP. La divergence entre les âges obtenus a provoqué des discussions animées parmi les archéologues australiens qui ont examiné à la loupe la validité des deux méthodes de datation. Les débats révèlent que la plupart des participants ne comprennent pas la luminescence et restent attachés aux dates indiquées par le ^{14}C. Il serait toutefois mal fondé de refuser l'âge donné par la luminescence simplement parce qu'il diffère de celui obtenu par le ^{14}C. Cet article examine la divergence entre les deux méthodes en comparant les dates sahuliennes avec celles des gisements du Paléolithique moyen européen. Il semble que chaque méthode chronométrique mesure le temps d'une façon autonome et que chaque résultat ne soit pas strictement comparable.

Abstract : Until recently, the only radiometric technique applied to Sahulian archaeological sites was ^{14}C. The ages obtained rarely exceeded 40,000 BP. Belief that the region was first colonised then has now been shaken by luminescence dates from several sites in Arnhem Land that suggest people arrived about 60,000 BP. The ensuing debate over their validity revealed that some participants are confused about the temporal limitations of ^{14}C dating and why it can yield very different ages from luminescence on samples from the same deposit. The temporal discrepancies between these techniques are re-examined here based on assays from Middle Palaeolithic and Sahulian sites. It is concluded that it would be premature to reject the luminescence assays from Arnhem Land on grounds of age alone.

Mots-clés : La chronométrie, le premier peuplement sahulien, les processus culturels.

Key-words : Chronometry, initial human colonisation of Sahul, cultural process.

Pour expliquer le passé, les préhistoriens doivent avant tout établir un cadre chronologique obtenu par des méthodes radiométriques, surtout si, comme c'est le cas au Sahul, la région à laquelle ils s'intéressent manque d'un cadre autonome fondé sur des données paléoclimatiques, faunistiques ou typologiques. Dans ce cas, les archéologues doivent s'efforcer de comprendre la chronométrie, sans quoi ils risquent de mal interpréter les résultats obtenus. Des problèmes peuvent survenir s'ils ne tiennent aucun compte des limites (temporelles, de confiance, de précision, d'exactitude) des méthodes radiométriques dont ils se servent. L'auteur étudie ici ces problèmes en passant en revue l'ancien débat sur le *tempo* et le *mode* du premier peuplement du Sahul.

LA PRÉHISTOIRE SAHULIENNE

Le *Sahul* comprend la Nouvelle-Guinée, l'Australie et la Tasmanie (fig. 1). Ce continent s'est formé lors de l'abaissement du niveau de la mer pendant les périodes glaciaires ; de la même façon, les îles du sud-est asiatique formaient un continent maintenant disparu, le *Sunda*. Ces deux continents ont toujours été séparés par la ligne biogéographique de Wallace (1860), qui sépare les faunes de marsupiaux d'Australie des faunes de placentaires d'Asie. Même pendant les maximaux glaciaires, les mammifères sans ailes émigrant de Sunda en Sahul ont dû traverser de grandes distances aquatiques. Seuls les rongeurs et l'homme y sont parvenus, ces derniers sur des radeaux. Par conséquent, l'arrivée de l'homme en Australie a une signification culturelle considérable car elle montre probablement le début du comportement moderne (Davidson et Noble, 1992 ; Bednarik, 1997). Peut-être les anthropologues pourront-ils établir le fait que l'Afrique est la source de l'homme moderne, ou si celui-ci a évolué simultanément dans plusieurs régions (Kramer, 1991).

On croit depuis longtemps que le Sahul a été colonisé vers 40,000 BP (White et O'Connell, 1982), car les dates ^{14}C obtenues ne remontent guère au-delà de cette limite. Plus récemment, des séries de dates par la luminescence ont été obtenues de Malakunanja II et Nauwalibila I au nord de l'Australie (fig. 1), indiquant que le plateau d'Arnhem fut occupé à partir de 60 000 BP (Roberts *et al.*, 1994b). L'ancienneté de ces dates ranime

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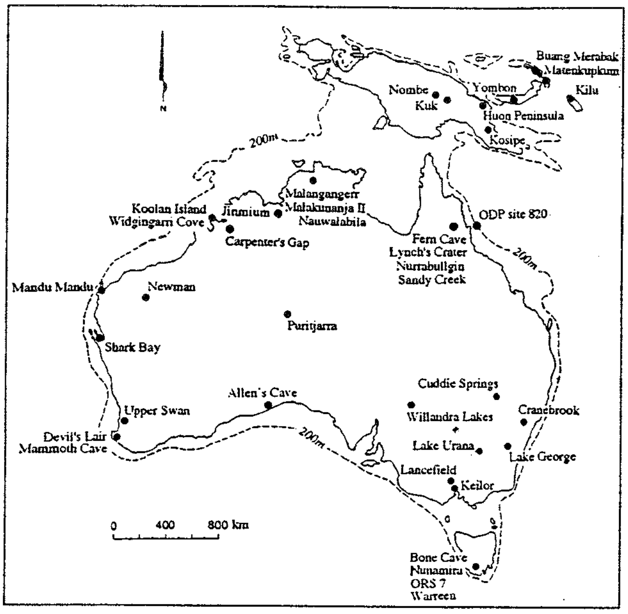

Fig. 1 : Les gisements les plus anciens de la région sahulienne d'après leur âge radiométrique.
Fig. 1 : Location of the Sahulian sites with the oldest radiometric dates.

le débat sur la date d'arrivée de l'homme (Allen, 1994 ; Roberts *et al.*, 1994a ; Allen et Holdaway, 1995 ; Chappell *et al.*, 1996). Elle a troublé plusieurs chercheurs car le ^{14}C donne pour des niveaux équivalents des âges nettement plus récents que ceux obtenus par la luminescence. A l'évidence, les archéologues ne saisissent pas la différence entre les deux méthodes. En comparant les dates sahuliennes avec celles du Paléolithique moyen européen, j'essaie ci-dessous de démontrer que ces différences de dates sont inhérentes aux méthodes utilisées et ne servent à réfuter aucune d'elles.

LA CHRONOMÉTRIE : THÉORIE ET PROBLÈMES

Quoique la théorie de la datation par le ^{14}C soit bien connue (Aitken, 1990, 56-119), il semble que quelques chercheurs australiens aient mal compris la divergence entre les années réelles, les dates ^{14}C et celles données par la luminescence, et la difficulté d'obtenir des dates ^{14}C au-delà de 40 000 BP. Ainsi, Allen (1994) suggère que les dates australiennes par la luminescence sont incorrectes parce qu'elles divergent des dates ^{14}C obtenues pour les mêmes niveaux, et qu'elles remontent au-delà de celles indiquées par la calibration du ^{14}C. Il confond deux aspects distincts : la divergence entre une date ^{14}C et une année réelle, et celle entre le ^{14}C et les âges donnés par l'analyse d'autres isotopes. Il est bien connu que la longueur des "années" ^{14}C varie et que chaque radio-isotope mesure le temps de sa propre façon. Par conséquent, ces divergences sont normales (Aitken, 1990). Les dates européennes, discutées ci-dessous, suggèrent que vers 35 000 BP la divergence entre une date ^{14}C et d'autres âges radiométriques est d'environ 7000 à 8000 ans, valeurs qui s'accordent bien avec les données sahuliennes.

Parce que la courbe de désintégration du ^{14}C devient asymptotique vers 35 000 BP, les échantillons de cet âge donnent des résultats qui ne concordent que par hasard avec leurs propres âges (Chappell *et al.*, 1996). Les dates proportionnelles au-delà de 30 000 BP ne sont donc que des calculs approximatifs, même si elles peuvent paraître exactes. Mais ceux qui critiquent les dates par luminescence ignorent celà (Bowdler, 1993 ; Allen, 1994 ; Allen et Holdaway, 1995). Ils supposent que les vieux échantillons sahuliens sont tous contaminés par le charbon allochtone qui rajeunit sensiblement leur âge. J'essaie de montrer ci-dessous qu'ils ont tort. Les gisements sahuliens ne donnent guère de dates ^{14}C au-delà de 40 000 BP en raison de l'effet asymptotique et de la difficulté d'analyser de vieux échantillons de faible qualité.

Il est vrai que la datation par la luminescence présente aussi des problèmes, surtout si on doit dater des sédiments qui, comme en Australie, ne se sont pas forcément déposés en même temps que les outils. Il y a aussi le problème de la luminescence héritée qui n'est pas toujours annulée pendant le transport du sédiment. D'autre part, la luminescence donne des dates "absolues", mais elles sont moins précises que celles données par le ^{14}C. Malheureusement, la plupart des archéologues pensent, à tort, que les dates imprécises sont inexactes.

COMPARAISON DE LA CHRONOMÉTRIE SAHULIENNE ET DE CELLE DU PALÉOLITHIQUE MOYEN

Allen et Holdaway (1995) essayent de nier l'effet asymptotique, car au Sahul les échantillons géologiques fournissent des dates bien au-delà de 40 000 BP. Ils concluent que la méthode ^{14}C n'a pas de limite temporelle et que le premier peuplement sahulien a eu lieu après 40 000 BP. Mais leur hypothèse est mal fondée. Les vieilles dates géologiques dont ils se servent viennent de deux tourbières tasmaniennes. Elles sont calculées sur des souches de bois par le laboratoire de Groningen utilisant parfois la technique d'enrichissement isotopique. En revanche, les échantillons archéologiques sont datés sans enrichissement par d'autres laboratoires, et ils comprennent des morceaux minuscules de charbon ou des fragments d'os ou de coquilles. Il n'y a donc pas de comparaison possible entre ces séries de dates car elles se distinguent nettement du point de vue de la qualité des échantillons, des milieux dont ils proviennent et de la méthode des décomptes.

Allen (1994) regrette qu'il n'y ait pas de série de dates obtenues par le ^{14}C ni par d'autres méthodes radiométriques pour la période 40 000 à 20 000 BP avec laquelle on pourrait comparer les dates sahuliennes ; mais il ignore la grande série de dates européennes disponibles pour cette période importante. J'essaie maintenant de réexaminer les questions de contamination et de divergence en comparant les dates sahuliennes avec celles du Paléolithique moyen obtenues par le ^{14}C et par d'autres analyses isotopiques. Si l'explication de la jeunesse des plus anciennes dates ^{14}C sahuliennes réside dans la contamination des échantillons, plutôt que dans les limites inhérentes à la méthode, les dates européennes devraient remonter bien au-delà de 40 000 BP. En revanche, si la divergence entre les résultats des analyses isotopiques est inhérente à la chronométrie, elle doit également se montrer en Europe.

La figure 2 montre les dates sahuliennes au-delà de 25 000 BP, comparées avec celles du Paléolithique moyen à ma disposition. Ces dernières comprennent les dates châtelperroniennes, szelétiennes et uluzziennes. Cette planche semble démontrer qu'Allen et Holdaway (1995) n'ont pas tort : le problème au Sahul est la contamination, car les dates du Paléolithique moyen remontent bien au-delà des dates sahuliennes. Mais cette conclusion n'est pas fondée : les vieilles dates européennes ont été données par Groningen, en utilisant parfois l'enrichissement. La figure 2 montre en fait que des métho-

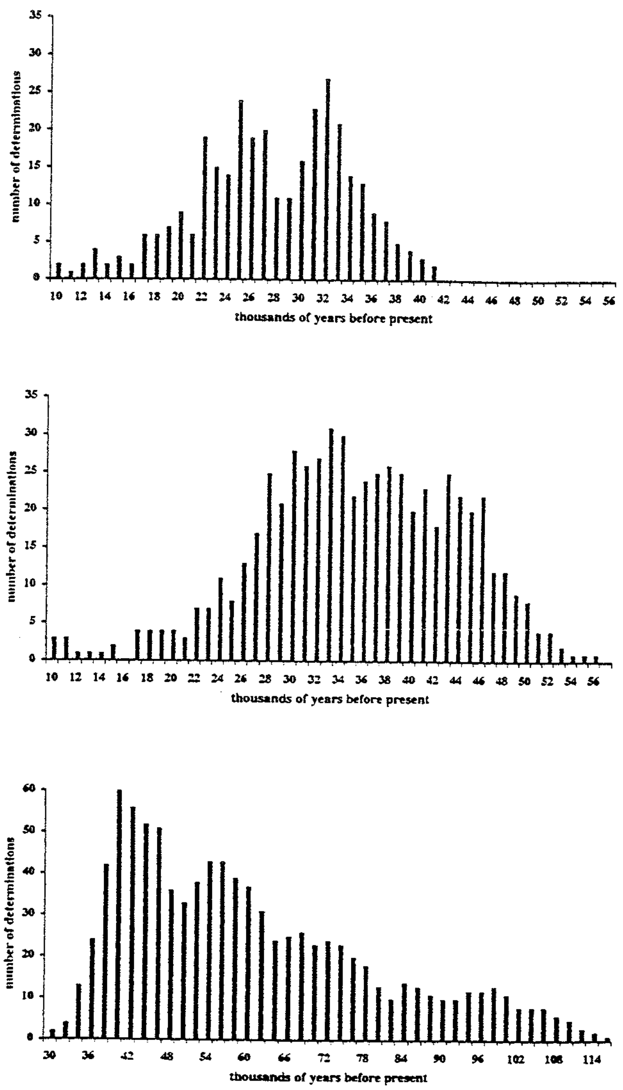

Fig. 2 : Calculs mobiles millénaires des dates ^{14}C sahuliennes (haut) et du Paléolithique moyen (milieu) comparés avec des calculs bimillénaires d'autres dates radiométriques pour le Paléolithique moyen (bas). Pour les dates par la résonance des électrons tournants : la valeur par l'absorption primaire mais aussi celle par l'absorption linéaire a été calculée ; elles n'ont été comptées qu'une fois quand elles se recouvraient.
Fig. 2 : Moving sums of the ^{14}C dates from the oldest Sahulian sites (top) and from European Middle Palaeolithic sites (middle) compared with bimillennial moving sums of Middle Palaeolithic dates based on other radioisotopes (bottom). For ESR dates, both the EUP and LUP values have been scored, but their age ranges were only counted once if the values overlapped.

des différentes produisent des résultats différents. Elle ne confirme pas que le Sahul a été colonisé pour la première fois après 40 000 BP car les deux séries ne sont pas strictement comparables. De plus, on sait que les dates européennes sont inexactes ; d'après son cadre géologique, le Paléolithique moyen commença avant le dernier interglaciaire et continua jusqu'à la fin du Würm II. La planche 2 montre l'effet asymptotique car les dates provenant des autres isotopes remontent vers 120 000 BP. Elle souligne donc l'inexactitude du ^{14}C, malgré sa précision car, même avec enrichissement, le ^{14}C ne donne pas des âges au-delà de 60 000 BP. Bien entendu, quelques-unes de ces dates indiquent des âges corrects, car le Paléolithique moyen s'étend jusqu'à 30 000 BP, mais il est indiscutable que la plupart des dates ^{14}C pour cette période sont trop jeunes.

Pour le Sahul, le problème est de distinguer les vraies dates ^{14}C des fausses. Jusqu'à présent il n'a pas été possible de les vérifier indépendamment, car la validité des dates appariées est contestée. Même en Europe, il y a très peu de dates appariées, soit en raison d'un manque d'échantillons appropriés, soit parce qu'on évite d'appliquer le ^{14}C à des niveaux que l'on sait très anciens.

Par conséquent, le fait que les dates par la luminescence soient plus vieilles que celles par le ^{14}C ne signifie pas qu'elles soient fausses. En revanche, l'inexactitude des dates ^{14}C européennes suggère que l'estimation de l'activité des petits échantillons de pauvre qualité dont l'âge approche l'asymptote reste problématique (Chappell *et al.*, 1996). Pour obtenir des âges anciens, il faut des échantillons bien purifiés, un compteur de haute précision et une longue série de comptages. Peu d'échantillons archéologiques reçoivent, ou méritent de recevoir, ce type d'attention. L'accélérateur ne permet pas de résoudre ce problème.

LE PREMIER PEUPLEMENT DE SAHUL

L'esquisse comparative discutée ci-dessus montre bien que les dates ^{14}C sont souvent inexactes. Mais il faut aussi confronter le manque de précision de toutes les méthodes radiométriques qui alimente les débats interminables sur le *mode* et le *tempo* du premier peuplement du Sahul.

Deux hypothèses principales ont été proposées. Pour Birdsell (1977), les hommes préhistoriques se sont répandus rapidement dès leur arrivée car ils n'ont pas rencontré de concurrence. Il pense qu'ils ont pu occuper toutes les niches possibles en 2000 à 5000 ans. Par contre, selon Bowdler (1977, 1990), le peuplement fut lent car dans leur patrie subtropicale, les hommes préhistoriques avaient probablement un mode de vie littoral. Selon elle, ils occupèrent d'abord des environnements sahuliens semblables : la côte et les bords des grands fleuves. Ils ne pénétrèrent guère au centre avant que toutes les autres niches ne soient remplies. Cette hypothèse a été controversée parce qu'aucun des gisements-clefs ne se situait au bord de la mer au temps des premières migrations (Hallam, 1987), et le "coeur mort" du continent paraît avoir été occupé à partir de 35 000 BP (Smith *et al.*, 1997).

Rindos et Webb (1992) évitent l'impasse issue de ces deux hypothèses en montrant que le taux de diffusion peut être dissocié du taux d'adaptation culturelle. Nous proposons en effet l'hypothèse selon laquelle les hommes préhistoriques se répandirent rapidement à travers des environnements inconnus parce qu'ils ne savaient pas comment exploiter efficacement leurs ressources naturelles. Par conséquent, ces milieux ne supportaient que des populations réduites, même s'ils avaient pu en accueillir de plus nombreuses. Les hommes préhistoriques se diffusaient donc à mesure que leur population augmentait. Par contre, s'ils se trouvaient dans un environnement connu, leur population pouvait devenir nombreuse avant qu'ils n'aient eu besoin de se déplacer. Dans ce cas, ils se diffusaient lentement.

Les dates ^{14}C disponibles soutiennent-elles ou nient-elles l'une de ces trois hypothèses ? Pour être sûr que deux dates appartiennent à des événements différents, il faut que leurs valeurs, quand les écarts-types sont multiplié par trois, soient nettement séparées ; en effet, on ne peut pas savoir si les événements datés ont prit place simultanément ou séparément si les écarts-types se recouvrent. Webb et Rindos (1997) ont appelé cette période d'incertitude l'*Intervalle Instantané Radiométrique*

(I.I.R.). Théoriquement, même à une précision de ± 1%, les vieilles dates ^{14}C donnent une incertitude d'au moins 2500 ans. Les autres méthodes chronométriques ont des incertitudes dix fois plus grandes. En fait, les dates des premiers gisements sahuliens revêtent des incertitudes tellement grandes qu'on ne peut jamais faire de distinction entre les hypothèses de colonisation proposées ci-dessus. La route périphérique du nord de l'Australie à la Tasmanie est d'environ 7000 km ; en ligne droite, la route n'est que de 4000 km, mais on dispose d'un IIR d'au moins 2500 ans. Par conséquent, si les hommes préhistoriques ont pû se répandre pendant cette période, leur diffusion paraît "instantanée", puisqu'on ne peut pas savoir si les gisements du nord du continent ont été occupés avant les gisements tasmaniens, comme le montre la planche 3 (Webb, 1997). Cependant, la diffusion a pu être lente : 2-3 km par an. Par conséquent, Rindos et Webb (1992) concluent qu'il n'est pas possible de discuter, ni le *tempo* ni le *mode* du premier peuplement de Sahul. A cause des incertitudes chronométriques, la colonisation paraît "instantanée", mais en fait, le taux de diffusion a pu être lent. Il faut donc que les archéologues australiens débattent d'autres problèmes.

Un projet de redatation par d'autres méthodes chronométriques, surtout la luminescence, du plus grand nombre possible de gisements sahuliens ayant fourni les plus anciennes dates ^{14}C est actuellement en cours. On revient donc à la question de la fiabilité de la luminescence posée par Allen et Holdaway (1995). Comme je l'ai montré ci-dessus, les problèmes qu'ils ont soulevés sont mal fondés. La divergence observée entre les dates ^{14}C et celle par la luminescence se retrouve dans les dates du Paléolithique moyen européen. Il faudra bien d'autres dates par la luminescence avant qu'on puisse accepter ou rejeter certaines d'entre elles. Pour l'instant, il semble qu'on anticipe un peu si le refus de l'âge donné par la luminescence reste simplement fonction de sa divergence avec les dates ^{14}C.

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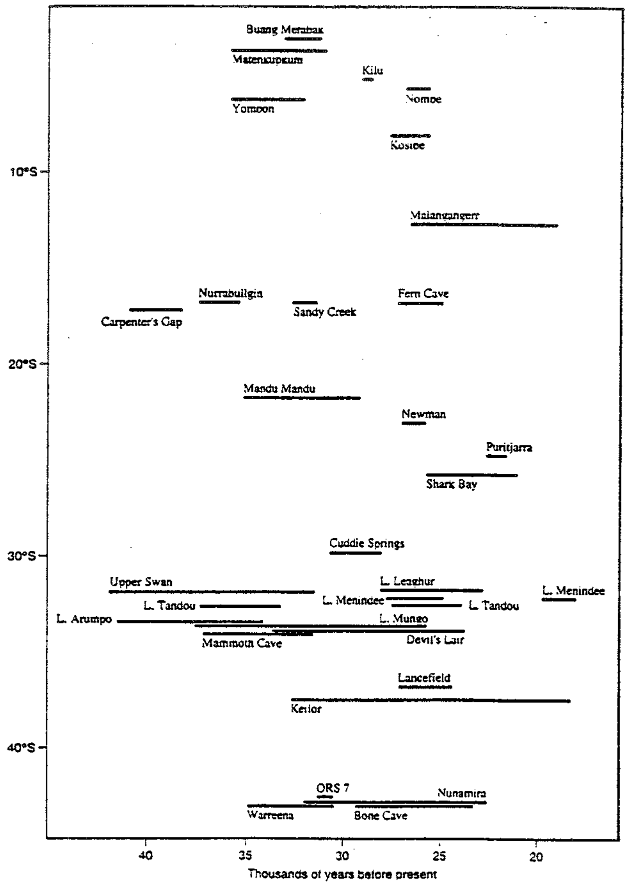

Fig. 3 : Ecarts-types d'âges des gisements sahuliens donnant des dates ^{14}C au-delà de 25 000 BP, présentés selon leur latitude.
Fig. 3 : Age ranges of Sahulian sites with ^{14}C dates >25,000 BP, graphed latitudinally.

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LA CHRONOLOGIE PRECISE
DE CERTAINES PHASES CULTURELLES

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HISTOIRE DES VARIATIONS DU TRAIT DE CÔTE DU GOLFE DE FOS : COHÉRENCE CHRONOLOGIQUE FONDÉE SUR LES DATATIONS RADIOCARBONE ET LES DATATIONS HISTORIQUES ET ARCHÉOLOGIQUES

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Résumé : Un canal maritime donnant accès au Rhône (le canal de Marius) et une agglomération côtière (*Fossae*) sont attestés par les sources écrites antiques dans le golfe de Fos. Mais, la localisation du canal demeure inconnue, l'interprétation et la datation de plusieurs vestiges archéologiques submergés posent des problèmes. Ces difficultés sont liées à l'histoire du littoral depuis l'époque romaine. Pour comprendre l'évolution du trait de côte, une étude paléoenvironnementale a été réalisée sur des dépôts littoraux (Vella *et al.*, 1998a) dans lesquels 35 échantillons ont été prélevés pour des datations radiocarbones. La chronologie ^{14}C obtenue est cohérente avec la stratigraphie et s'accorde aussi avec les dates proposées par les archéologues pour certains vestiges.

Abstract : A maritime canal (Marius canal) and a sea-side settlement (Fossae) are attested by Antique written sources in the Fos gulf. But the actual position of the canal is still unknown. Moreover many submerged archaeological remains are difficult to explain and to date as they are connected with shoreline history since the Roman period. In order to understand the evolution of the shoreline, a paleoenvironmental study (Vella *et al.*, 1998a) of the littoral deposits was performed. 35 samples were collected for radiocarbon dating. The obtained ^{14}C chronology is consistant with stratigraphy and also fits with archaeological dates of some remains.

Mots-clés : Delta du Rhône, trait de côte, archéologie, radiocarbone.

Key-words : Rhône delta, shoreline, archeology, radiocarbon.

INTRODUCTION

Le golfe de Fos constitue la terminaison orientale du delta du Rhône (fig. 1). Sa configuration a beaucoup changé au long des siècles. Il acquiert sa forme actuelle durant la période moderne avec l'édification du promontoire deltaïque du Grand Rhône et de ses bras précédents (Grand Passon, Bras de fer). Au début du XXème siècle la constitution de la flèche de la Gracieuse, issue des apports du fleuve par le grau principal de Roustan complète la morphologie du golfe.

L'histoire de l'évolution du trait de côte est étroitement dépendante des apports sédimentaires à la mer et de la variation du niveau relatif à l'échelle pluri-millénaire. Nous ne l'étudierons ici qu'entre le siècle avant J.-C. et le VIème siècle après J.-C., mais des données paléonvironnementales pour la période précédente ont été obtenues et sont déjà publiées ou en cours de parution (Vella *et al,*. 1998a, 1998b et Vella *et al., s.p.*).

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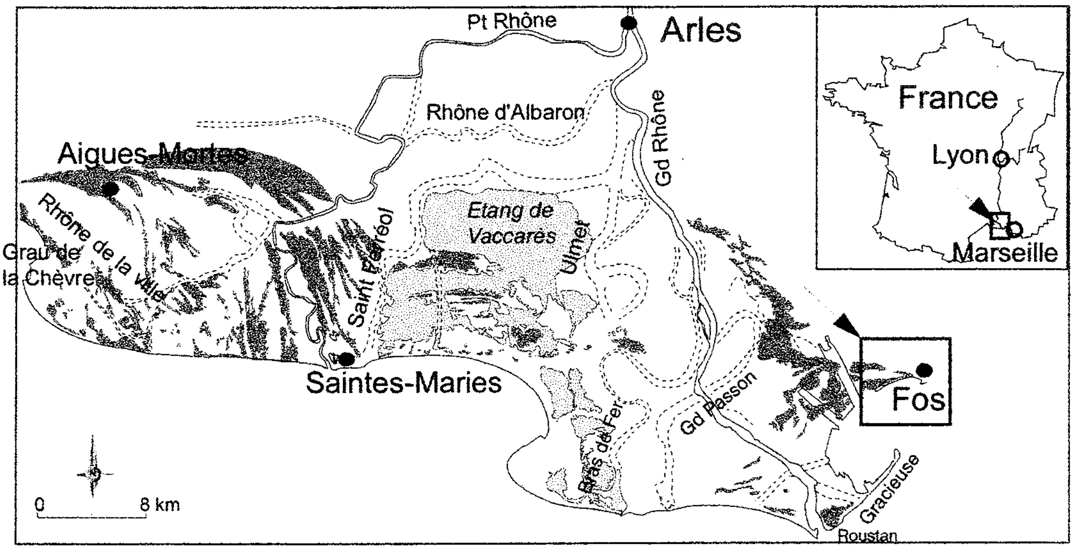

Fig. 1 : Localisation.

1 - LES APPORTS DES SOURCES ÉCRITES ET ARCHÉOLOGIQUES

Les sources écrites

Le canal de Marius a été construit en 102 av. J.-C. pour éviter le grau des massaliottes, embouchure naturelle probable du bras d'Ulmet, alors ensablé. Trois auteurs signalent le canal (Pomponius Mela (*De situ orbis*, 2, 5, 77) ; Strabon (IV, 1, 8) ; Plutarque Vie de Marius, XV) alors que Fos n'est probablement à l'époque pas même un port. Outre la mention du canal, ces textes permettent de déduire plusieurs faits qui concernent la dynamique sédimentaire et la morphologie côtière :

- l'embouchure du fleuve est peu navigable au Ier s. av. J.-C. du fait de son ensablement ;
- le canal présente des dimensions importantes et connaît les mêmes problèmes d'ensablement ;
- le canal débouche dans une zone protégée (un golfe ?).

A partir du Ier s. ap. J.-C., les textes ne parlent plus du canal. Par contre, la table de Peutinger (document daté du IVe s. ap. J.-C. qui reprend probablement des documents de la fin du Ier s. ap. J.-C.) signale Fos par un bâtiment presque identique à celui du port d'Ostie mais ne figure pas le canal.

Ces sources ne permettent pas de positionner le canal de Marius ni le port antique de Fos. L'absence de mention du port au Ier s. avant J.-C. semblerait indiquer que le secteur de Fos ne fût que la zone d'embouchure du canal. Par contre à partir du Ier s. ap. J.-C., le port existe alors qu'il n'est plus fait mention du canal. Le canal a-t-il été abandonné suite aux problèmes d'ensablement ou tout simplement du fait de la navigabilité à nouveau permise dans le grau naturel du Rhône ?

Les données archéologiques

Les vestiges archéologiques sont nombreux dans le golfe de Fos mais souvent mal datés. Ce sont essentiellement des structures bâties et des épaves.

Les structures bâties

Elles sont au nombre de six : 5 sont localisées dans l'anse de Saint-Gervais (fig. 2), la 6ème dans le prolongement de l'étang de l'Estomac, devant les salins de la Marronède.

La position bathymétrique de ces structures est comprise entre environ -3 m NGF et le niveau marin actuel. Une chronologie basée sur la céramique ou sur des éléments stylistiques attribue la plupart des structures au Ier et IIe s. ap. J.-C.

La structure n°1 est un mur en module maçonné qui aurait été relié par des parties de bois aujourd'hui disparues (Gassend & Maillet, 1989).

La structure n°2 est une palissade de bois non datée à 300 m du rivage.

A 75 m du rivage actuel, deux alignements réguliers de pierre, signalés par L. Monguillan (1977) et fouillés par J. M. Gassend et B. Maillet, constituent la structure n°3, la plus originale. Il s'agit de dés de pierre sur base maçonnée, espacés régulièrement et présentant une cavité sommitale probablement prévue pour recevoir un poteau. Le caractère indépendant de chaque base de poteau et le parfait alignement des dés montrent que la structure est en place. Les bases des dés se situent entre -2,50 m et -1,50 m sous le niveau marin et l'altitude homogène de leur sommet permet d'évaluer la submersion depuis l'abandon des structures.

La structure n°4, fouillée par M. Sciallano, est construite selon le même principe mais de bien moins grande ampleur. Elle occupe, à -1,20 m NGF, le fond de l'anse de Saint-Gervais à 35 m du rivage actuel. Les blocs, tous posés à 15 cm près à la même altitude, sont posés sur un radier de petits blocs, associés à de la céramique qui ne peut être antérieure à la deuxième moitié du Ier s. de notre ère.

La structure n°5 est constituée d'un alignement de stèles funéraires non associées à des sépultures. Elles reposent sur un fond de galets par -3,5 m de fond, au large de la structure n°3 entre 350 m et 400 m du rivage actuel. La stylistique de la taille permet d'attribuer ces stèles au IIe s. après J.-C.

La structure n°6 est un alignement de blocs empilés entre -1,85 m et -3,60 m NGF formant un enrochement de plus de 180 m interrompu sur 150 m et reprenant sur 40 m. Cette structure est interprétée comme une digue.

Les épaves

Quatre épaves ont été repérées et étudiées dans le secteur. Deux sont d'époque romaine et situées devant l'anse de Saint-Gervais entre 500 m et 600 m du rivage actuel. L'une (SGV 1) est datée entre 139 et 140 après J.-C. (Liou & Gassend, 1990), l'autre (SGV 3) est datée du milieu du IIe s. ap. J.-C. La troisième (SGV2), localisée immédiatement à l'est de la pointe de Saint-Gervais à 100 m du rivage, est beaucoup plus récente puisque que l'on estime son naufrage au début du VIIe s. après J.-C. (Jézégou, 1983). La quatrième (SGV 4), datée du Ier s. ap. J.-C. (Pomey, 1987), présente un moins grand intérêt pour la localisation du trait de côte du fait de sa position plus éloignée à environ 1,2 km de la côte et à -6 m de fond.

La concentration d'épaves dans ce secteur, malgré la mauvaise protection du site face aux vents dominants, permettait d'envisager la présence d'un port dans l'anse de Saint-Gervais.

La position en mer de structures initialement émergées à des distances et des profondeurs importantes et la proximité des épaves, nécessitaient donc une étude des dynamiques géomorphologiques et de l'évolution des milieux, afin de préciser le schéma de mise en place.

2 - LES DONNÉES PALÉOENVIRONNEMENTALES ET LA CHRONOLOGIE RADIOCARBONE

Les données paléoenvironnementales

La submersion importante, jusqu'à -3 m, des structures du Ier et IIe s. ap. J.-C., laissait soupçonner des phénomènes de mouvements du sol, ou de soutirage des sédiments meubles sous les structures (Paskoff & Trousset, *in* Liou 1987). Les niveaux marins relatifs à Fos paraissent tous décalés vers le bas par rapport aux différentes courbes obtenues sur les littoraux rocheux provençaux (Vella *et al.*, 1998b). En effet les données archéologiques obtenues à Marseille (sites de la Bourse, Jules Verne, Charles de Gaulle et César), géomorphologiques (Pirazzoli & Thommeret, 1973, Guéry *et al*, 1981 ; Morhange, 1994) et biologiques recueillies sur les littoraux corse et provençal (Laborel *et al*, 1994) établissent le niveau marin pour les deux premiers siècles après J.-C. entre -0,60 m et -0,5 m.

La chronologie radiocarbone

Afin de mettre en évidence les spécificités du site de Fos, nous avons réalisé une série de datations ^{14}C afin de tenter de reconstituer l'histoire de l'évolution du trait de côte depuis l'infralittoral (-3 m) jusqu'au supralittoral.

Les datations ont été réalisées sur des matériaux très variés (tourbe, coquilles marines, phanérogames marines...) d'origine marine ou continentale (tab. I). Aucune

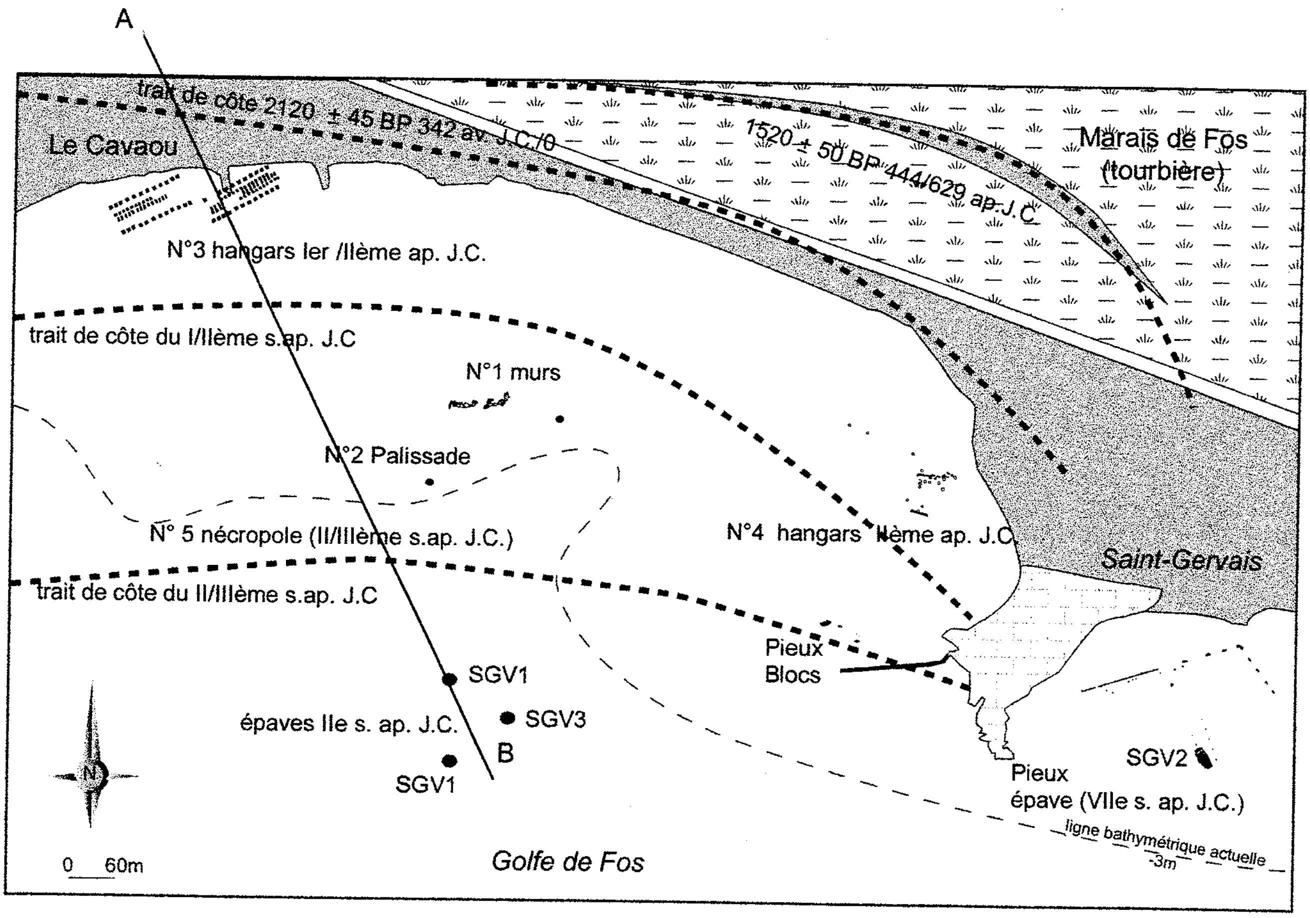

Fig. 2 : Position des structures archéologiques et des traits de côte depuis le début de notre ère à la fin de l'Antiquité.

Laboratoire	Fractionnement isotopique $\delta^{13}C$ ‰ P.D.B.	Date radiocarbone BP	Intervalle après correction av./ap. J.C	Nature de l'échantillon	Milieu de vie
Ly-7021	-25.04	6560 ± 85	[-5594 ; -5311]	limons organiques	lagune
Ly-7159	-24.89	6120 ± 55	[-4728 ; -4458]	posidonies	infralittoral marin
LGQ-744	estimé à -25	2110 ± 140	[-405 ; + 233]	bois	infralittoral marin
Ly-7860	-28.36	2120 ± 55	[-342 ; 0]	tourbe	continental dulçaquicole
Ly-7591	-27.30	2100 ± 45	[-305 ; -2]	tourbe	continental dulçaquicole
Ly-7686	-17.81	2315 ± 55	[-86 ; + 156]	posidonies	infralittoral marin
Ly-7861	-22.36	1520 ± 40	[+793 ; +995]	posidonies	infralittoral marin
Ly-7590	-24.04	1530 ± 45	[+780 ; + 995]	posidonies	infralittoral marin
Ly-8447	-28.44	1200 ± 55	[-700 ; + 965]	tourbe	continental dulçaquicole

Tab. 1 : Chronologie radiocarbone.

date n'a été écartée car elles sont stratigraphiquement cohérentes qu'elles soient réalisées sur des complexes (formations superposées) ou des ensembles (formations juxtaposées) de corps sédimentaires. La chronologie obtenue s'accorde avec les quelques vestiges datés par la céramique.

Reconstitution chronologique de l'évolution du littoral du golfe de Fos

Les structures antiques autour de l'anse de Saint-Gervais sont toutes bâties sur un cordon sableux qui surmonte des dépôts datés 2110 ± 140 BP (LGQ-744). Ces dépôts contiennent à la base des faunes infralittorales marines qui témoignent d'une position du littoral entre le trait de côte actuel et la tourbière située en arrière. Lors des tempêtes, la tourbière est occasionnellement envahie par des épandages sableux, datés entre 2120 ±55 BP (Ly-7860) et 2100 ±45 BP (Ly-7591), provenant d'un premier cordon situé en aval. Sa mise en place peut être située entre le IVe s. av. J.-C. et le début de notre ère. Le second cordon, supportant les structures antiques, résulte donc d'une progradation littorale à partir de ce précédent trait de côte (fig. 3).

La structure n°4 occupe un espace proche d'une lagune eurytherme et euryhaline confinée, où les concentrations de matières organiques naturelles ou anthropiques sont fortes (présence de *Pavicardium exiguum*). La datation 2315 ± 55 BP (Ly-7686) (-86/+156) indique un âge cohérent avec la céramique (identification L. Long : Drag. 24/25b bord de coupelle de sigillée, *oenochoée* à pâte grise augustéenne et amphore de Tarraconaise à pâte grise). Un cordon littoral situé plus au large isole donc une lagune en cours de comblement qui sert de dépotoir (Michon, 1965).

La progradation persiste jusqu'au IIe s. ap. J.-C. date de l'édification de la nécropole (structure n°5) sur un cordon à 400 m au large du trait de côte actuel. Les stratigraphies établies à partir de carottages montrent que les stèles funéraires reposent sur un cordon de galets qui surmontent tantôt un dépôt lagunaire tantôt le substrat pléistocène. Le cordon est daté entre 6560 ± 85 BP (Ly-7021) et 6120 ± 55 BP (Ly-7159). Ces stèles (vers -3,5 m) n'ont pas pu être mises en place sur un cordon néolithique s'étant tassé car certaines reposent sur le substrat, ni être dressées à un niveau marin particulièrement bas car l'étage infralittoral à Fos pour le IIe s. ap. J.-C. a été identifié jusqu'à au moins -2 m. Ces stèles bien que groupées ont donc subit un enfoncement sur place par soutirage des sédiments meubles. En effet, la montée du niveau marin relatif à Fos, dans un contexte particulier de déficit sédimentaire récurrent, lié à l'éloignement des embouchures du Rhône, induit un remaniement du matériel sédimentaire (Vella & Bourcier, 1998b).

A partir de 1520 ±40 BP (Ly-7861), un brusque recul du littoral sur sa limite sud est mis en évidence par les carottages dans la tourbière située en arrière du trait de côte actuel. Le caractère soudain du dépôt est confirmé par une seconde date très proche de la première 1530 ±45 BP (Ly-7590) située à 40 cm au-dessus. Ce recul du littoral permet de caler l'ensemble des structures archéologiques immergées entre le Ie/IIe s. après J.-C. et le VIIIe/Xe s. après J.-C., date du recul. L'établissement de ce nouveau trait de côte en arrière du précédent permet aux bateaux de s'approcher à au moins 100 m du trait de côte actuel comme en témoigne l'épave SGV 2.

C'est probablement une hausse rapide du niveau marin relatif qui induit le recul littoral, car il s'accompagne d'une modification importante de l'écoulement des nappes et contribue à la création d'un étang doux dans la tourbière où la sédimentation change brusquement, pour produire des boues carbonatées. Ce dépôt se met en place immédiatement après le recul, la base est datée 1200 ±55 BP (Ly-8447), soit entre le VIIe et Xe s. ap. J.-C.

3 - INTERPRÉTATION

D'après les textes antiques le nombre d'embouchures du Rhône varie de deux à sept. Les nombreuses études sur l'évolution du delta montrent qu'au moins trois bras sont plus ou moins actifs pour cette époque (fig. 1) : le plus occidental appelé plus tard Rhône de la ville prolonge vers le sud le bras d'Albaron et débouche par le grau de la Chèvre (L'Homer, 1986), le bras de Saint-Ferréol au centre et le bras d'Ulmet le plus oriental. Chaque bras peut aboutir à la mer par une ou plusieurs embouchures appelés graus.

La carte des épaves (Long, 1997) et les connaissances paléohydrologiques acquises sur le bras de Saint-Ferréol et le bras d'Ulmet (Arnaud-Fassetta, 1998) permettent d'envisager la navigabilité des graus. Entre le Ier av. J.-C. et le Ier ap. J.-C. le bras de Saint-Ferréol est emprunté, au vu des nombreuses épaves localisées à son embouchure.

Au débouché d'Ulmet, le grau des massaliotes est difficilement navigable d'après les textes à partir du Ier s. av. J.-C., d'où la nécessité de creuser le canal de Marius. Ce fait historique est confirmé par les travaux de G. Arnaud-Fassetta qui constate l'exhaussement du plancher alluvial et l'instabilité du Rhône d'Ulmet (Arnaud-Fassetta, 1998) dans la plaine deltaïque à cette période. A partir du IIe s. ap. J.-C. la station portuaire de Fos se développe indépendamment du canal de Marius dont on ne fait plus mention et qui, d'après Strabon, aurait au Ier s. ap. J.-C. déjà connu les mêmes difficultés d'ensablement. On peut émettre l'hypothèse que le grau naturel d'Ulmet redeviendrait navigable.

A Fos, le phénomène d'accrétion littorale mis en évidence entre le début de notre ère et le IIe s. ap. J.-C. serait non pas due à la présence d'un bras plus à l'est mais à un meilleur transit sédimentaire lié à l'effet combiné d'une régularisation du trait de côte depuis l'embouchure d'Ulmet, qui induit un accroissement de la compétence de la dérive littorale (Vella *et al*, soumis). L'augmentation de la charge alluviale du fleuve entre le Ier s. av. et Ier s.ap. J.-C. a contribué à la progradation littorale, qui établit le trait de côte du Ier s. ap. J.-C. à l'avant des structures n°3 et 4 à 100 m du trait de côte actuel, puis à au moins 400 m du littoral actuel à l'avant de la nécropole. La position présumée des barres littorales de cette époque correspond à l'emplacement des épaves entre 500 m et 600 m de la côte actuelle (fig. 3). Comme cela se produit à la période moderne, les navires lors des tempêtes soit par erreur de navigation soit sous avarie, viennent heurter la première barre littorale (Long, 1997). Les avaries occasionnées par le choc sont souvent très graves ; le bateau continue sa course au niveau du sillon littoral plus profond et vient soit s'emplager soit s'échouer sur la seconde barre. Aujourd'hui encore à Fos on peut observer une barre littorale située entre 50 et 80 m de la plage aérienne qui se situe entre -1 m et -0,7 m sous la surface. Les épaves SGV 1 et SGV 3 se situent non pas à l'entrée d'un port mais sur un littoral sableux particulièrement propice aux échouements accidentels. L'hypothèse d'un échouement sur ces barres semble confirmée par deux faits archéologiques : l'épave SGV 1 échouée sur la première barre est coupée en deux soit suite au choc, soit sous le déferlement des vagues comme c'est très souvent le cas à la période moderne (Illouze, 1988) et la cargaison de l'épave SGV 3 ainsi que la pompe de cale (Liou & Gassend, 1990) une fois échouée sur le littoral ont probablement pu être récupérées.

Suite au recul brutal de trait de côte du VIIIe/Xe s. ap. J.-C. la zone navigable s'étend vers le nord, ce qui explique la position plus en terre de l'épave SGV 2 qui semble échouée de la même manière (Jézégou, 1983).

La position du port de Fos dans l'anse de Saint-Gervais est donc remise en cause, et la présence d'une digue aujourd'hui submergée à la sortie de l'étang de l'Estomac, permet de poser l'hypothèse de la création du port en son sein. D'autant plus qu'à la période antique les ports internes sont très courants (Fréjus, Carthage, Ostie, Empuries...). Cette hypothèse a déjà été formulée par de nombreux archéologues travaillant dans la région (Gassend, Illouze, Sciallano).

Quant à la localisation du canal de Marius, la direction du trait de côte établie jusque vers le bras d'Ulmet, permet d'orienter les recherches vers le nord ouest des zones jusqu'alors prospectées car le recul du littoral du VIIIe /Xe s. ap. J.-C. a pu remanier les traces de l'exutoire.

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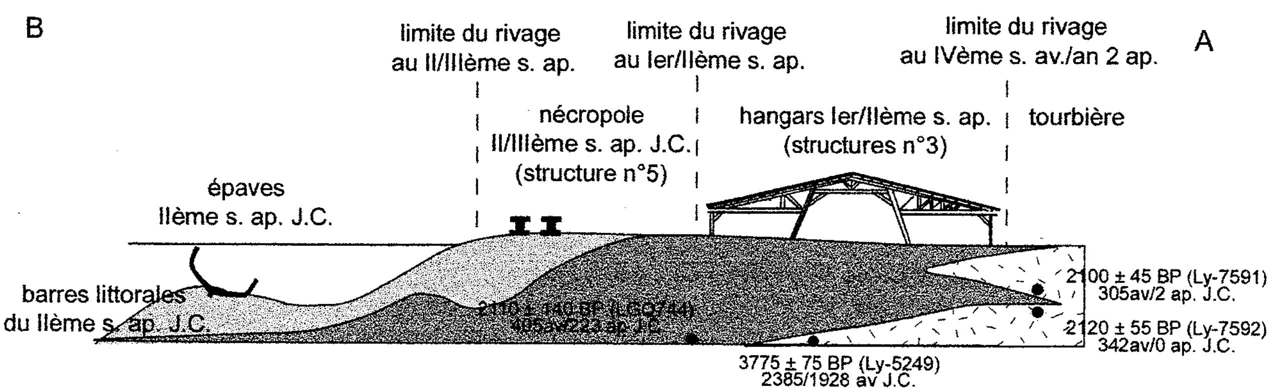

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ÉCHELLE DE TEMPS ET MISE EN ÉVIDENCE D'UNE OPÉRATION DE DRAINAGE : LE CAS DE LA VALLÉE DES BAUX A L'ÉPOQUE ROMAINE

Hélène BRUNETON, Philippe LEVEAU**, Valérie ANDRIEU*** et Christine OBERLIN*****

Résumé : L'analyse de sédimentologique de carottes prélevées dans le Marais des Baux près d'Arles (Bouches du Rhône) permet de mettre en évidence les mutations de faciès attestant un assèchement du milieu brutal et continu. Les dates radiocarbone obtenues sur ce site et sur un site proche permettent de démontrer que l'assèchement s'étend sur une longue partie de la période romaine et qu'il est contraire à la tendance contemporaine à l'élévation des nappes phréatiques. L'analyse pollinique permet de le mettre en relation avec une phase de culture et d'élevage. Les données archéologiques obtenues en fouille (moulin romain de Barbegal, implantation domaniale) et historiques (implantation de la colonie romaine d'Arles à partir de 46 av. J.-C.) permettent d'établir une relation entre cet événement hydraulique brutal et un drainage à des fins agricoles.

Abstract : Sedimentological cores analysis from the Baux marsh near Arles (Bouches du Rhône, France) show rapid features changes related to a sudden drying. Radiocarbon datings that were obtained on this site and on a near one allow to prove that this drying lasts for a long part of the roman period and that it is opposed to the natural aquifers elevation. The pollen analysis relates it to a cultivation and breeding phase. Archeological data (roman Barbegal mill, domanial setting) and historical ones (roman Arles colony from 46 B.C.) help us to make out a relation between this sudden hydraulic event and a drainage towards agricultural use.

Mots-clés : Marais, assèchement, drainage agricole, archéologie, sédimentologie, paléoécologie, échelles de temps.

Key-words : Marsh, drying, agricultural drainage, archeology, sedimentology, palaeoecology, time scales.

La question que pose l'identification d'opérations de drainage dans la Vallée des Baux (fig. 1) durant la période antique est celle de la différenciation possible entre assèchement d'origine naturelle et assèchement d'origine anthropique. Pour choisir entre causalité climatique et causalité anthropique, qui relèvent de deux sphères temporelles (temporalité historique et temporalité environnementale), la question chronologique occupe une place essentielle. S'agissant d'une région de plaine comme le Bas Rhône, un assèchement naturel sera caractérisé, une fois écartés les phénomènes de type catastrophique, par une progressivité n'excluant pas des retours qui exprimeront les oscillations d'un phénomène climatique. Il pourra être corrélé à d'autres tendances semblables au bas niveau dans des espaces proches, et à des tendances paléoclimatiques régionales. Au contraire, une opération de drainage, –et l'on pense à celle qui a commencé au siècle dernier et a débouché sur la transformation en polder– est caractérisée par la rapidité et la permanence liées à un écoulement forcé. Cette caractérisation est évidente dans le cas de l'artificialisation des milieux qui caractérise l'époque industrielle. Les sociétés disposent alors de moyens qui permettent d'assécher totalement et brutalement une dépression.

Elle est en revanche moins évidente à observer pour les périodes anciennes. S'agissant de sociétés ne disposant pas des capacités techniques actuelles, l'arrêt d'entretien des ouvrages peut avoir des effets analogues à

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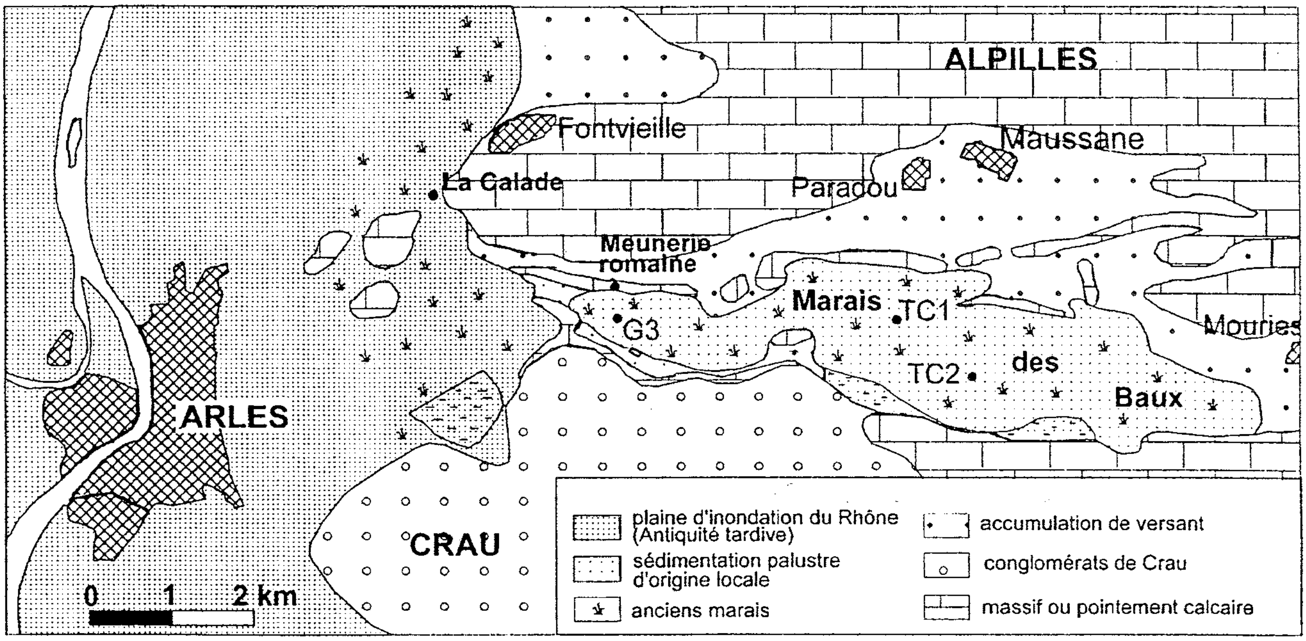

Fig. 1 : Situation du Marais des Baux.

ceux d'une évolution naturelle. Ainsi dans la vallée des Baux, on sait que le drainage réalisé au XVI[e] siècle par le hollandais Van Ens n'a pas été durable. Dès lors il convient de prendre en compte l'ensemble des données.

Ces précautions prises, il est possible de poser comme principe qu'une différenciation entre phénomène naturel et phénomène anthropique peut être opérée à partir de considérations chronologiques. La convergence d'observations stratigraphiques multiples portant sur les données sédimentologiques, faunistiques et palynologiques pourra faire pencher en faveur d'un assèchement d'origine anthropique si les données chronologiques en montrent la rapidité et la durabilité. Pour la vallée des Baux, à défaut de descriptions par des observateurs contemporains du phénomène, la prise en compte d'un contexte historique particulier justifiant à la fois les capacités techniques et la volonté de la société –ici l'installation d'une colonie romaine– peut intervenir dans l'argumentation.

DONNÉES HISTORIQUES ET HISTORIOGRAPHIQUES GÉNÉRALES RELATIVES A L'ÉVENTUALITÉ D'UN DRAINAGE DE LA VALLÉE DES BAUX A L'ÉPOQUE ROMAINE

Jusqu'à ces dernières années la Vallée des Baux était considérée par les archéologues et les historiens comme une cuvette inondée et rattachée à une vaste zone de marais développée en rive gauche du bas Rhône. Formulée au siècle dernier, cette théorie avait été admise par l'historien E. Desjardins dont par la suite les cartes ont été largement utilisées par les environnementalistes. La permanence du marais n'était pas mise en question. Elle s'appuyait sur les témoignages des travaux de drainage qui débutent aux Temps Modernes, confirmés par l'autorité de l'archéologue F. Benoit. Intégrant les données connues de l'environnement, les historiens de l'Antiquité considéraient en effet que la permanence de la nappe d'eau constituait une importante activité commerciale. La prospérité de l'Arles antique était largement due à une localisation à la tête du delta ; passage obligé pour la navigation fluviale vers l'intérieur de la Gaule, la ville assurait la redistribution des marchandises importées et la collecte des produits régionaux grâce à la navigation sur le système lagunaire. Le fouilleur des moulins, F. Benoit, proposait de les replacer dans le cadre de l'économie urbaine d'Arles et du système romain impérial de l'annone. Il établissait une relation entre l'usine et les cryptoportiques d'Arles. Ces derniers auraient été des *horrea* recevant les blés qui pouvaient provenir du Rhône moyen par l'axe fluvial. Ces blés auraient été acheminés par voie d'eau à Barbegal pour être moulus et distribués à la troupe et à la population de la région.

Les fouilles conduites au pied des moulins de Barbegal ont conduit à une remise en question de l'image que l'on avait de la plaine d'Arles dans l'Antiquité. La fondation de la colonie romaine d'Arles a été mise en relation avec les possibilités d'exploitation agricole des zones basses environnantes. Cette hypothèse présentait l'avantage de la conformité aux caractéristiques économiques habituelles d'une colonie romaine. Dans la continuité de la politique agraire des Gracches, les créations coloniales romaines du I[er] siècle avant J.-C. répondent aux revendications de terres par les légionnaires. Ceux qui sont installés à Arles avaient vocation à devenir propriétaires de domaines et non de navires, paysans plutôt que marins ou commerçants. On supposait l'existence d'étangs au périmètre variant en fonction de l'hydrologie de l'année, d'ailleurs conforme à un « modèle romain » de la mise en valeur des zones humides. Les historiens de cette période font des allusions précises aux plaintes des soldats protestant contre les lots qu'on leur attribue et les terrassements que leur imposaient leurs chefs. La construction de canaux est en effet bien attestée et, précisément, dans la zone deltaïque, la construction par Marius d'un canal de navigation assurant l'accès du fleuve constituait un précédent. Compte tenu de l'absence de structure artificielle connue par la documentation écrite ou attestée par l'archéologie, on pouvait imaginer des aménagements peu importants, non des travaux comparables à ceux qui ont été mise en oeuvre au siècle dernier mais des réseaux de canaux favorisant l'écoulement des eaux vers des plans d'eau résiduels.

Les travaux géomorphologiques récents sur le Marais des Baux montrent qu'il constitue un témoin de l'état des nappes phréatiques des Alpilles et de la Crau, enregistrant les fluctuations paléoclimatiques holocènes locale (Bruneton en cours). Les données paléotopographiques montrent de plus qu'un éventuel drainage à la période romaine était favorisée par des facteurs climatiques, fluviaux et hydrologiques. La plaine d'inondation rhodanienne était encore peu remblayée et plus basse que la zone étudiée : elle pouvait permettre une évacuation vers la Camargue. L'hypothèse d'une tendance climatique chaude et sèche a également été formulée pour cette période (Jorda et Provansal, 1996).

MÉTHODES DE RECONSTITUTION DES MILIEUX PALUSTRES

La mise en évidence de phases d'assèchement repose sur la reconstitution de la profondeur et la végétalisation des étangs. Trois types caractérisés par leur lithologie, leurs concrétions carbonatées et leurs faunes d'ostracodes sont distingués par l'adaptation des méthodes de Brochier (1982) et Magny (1992, 1995) à un marais méditerranéen.

La sédimentation des phases de haut niveau palustre est carbonatée (craies lacustres). Les concrétions qui en sont issues présentent des formes liées à l'absence de battage par les courants (formes en « chou-fleur ») et des morphotypes associés aux characées immergées (« tube »). Enfin, les ostracodes d'eau douce sont abondants avec de fortes proportions de *Metacypris*, *Paralimnocythère* et *Darwinula*, sauf dans la charaie permanente.

La sédimentation des milieux inondés très végétalisés, liée à la couronne de végétation littorale, est carbonatée à organico-crayeuse. Dans ces milieux, les morphotypes en « plaques » sont associés aux macrophytes littoraux et/ou aux plantes flottantes. Deux ostracodes d'eau douce vivent dans ces zones végétalisées : *Herpetocypris* et *Ilyocypris*.

La sédimentation des phases de bas niveau palustre est fréquemment organique. En effet, la nappe d'eau, source des carbonates, peut disparaître pendant des phases d'exondation saisonnières ou plus prolongées. Les concrétions cependant observées ont une forme en « boule » (oncolithes), liée au battage par les légers courants de surface. Les ostracodes sont rares du fait de phases d'émersion prolongées. Les espèces supportant les exondations saisonnières sont fréquemment surreprésentés en valeurs relatives. C'est le cas de *Candona*.

Les ostracodes permettent, de plus, de reconstituer des fluctuations dans la chimie des eaux : *Cyprideis* est ainsi associé aux eaux saumâtres.

UNE MUTATION DES MILIEUX PALUSTRES À LA CHARNIÈRE DES CHRONOZONES SUBBORÉAL-SUBATLANTIQUE ?

Trois carottes (TC1 et TC2 éloignées de 1 km dans la cuvette est, G3 à 5 km dans la cuvette ouest) permettent de reconstituer l'histoire du Marais entre l'Age du Fer et la fin de la Période romaine (fig. 2). Une chronologie appuyée sur les zones polliniques se décompose ainsi :

- A la fin du Subboréal ou au début du Subatlantique, une phase de haut niveau est décelée dans TC1 et TC2. Le site de TC2 constitue alors le coeur de la cuvette (charaie permanente). Les sites de TC1 et de G3 se prêtent au développement d'une association d'ostracodes caractérisant un plan d'eau de forte alcalinité (*Paralimnocythère*), proche de la nappe actuelle très chargée en nitrates et fréquentée par les troupeaux (*Limnocythère*, *Cypridopsis*), végétalisé malgré l'épaisseur de la tranche d'eau (*Ilyocypris*, *Herpetocypris*). Cette phase serait donc marquée par un premier impact important des sociétés humaines sur le marais, dans le contexte d'un climat humide. Une telle tendance climatique est connue en Provence pour le Premier Age du Fer (VI^{e}-V^{e} s. av. J.-C, Jorda et Provansal, 1996).
- L'assèchement qui suit n'en apparaît que plus net. Dans la carotte TC1 comme dans le sondage G3, il est total : les faunes d'ostracodes se résument à quelques individus et des fragments de travertins constituent plus de 40 % des concrétions observées. En parallèle, les pollens de Cypéracées disparaissent totalement, au profit des Poacées. Une nappe d'eau résiduelle subsiste sue le site de TC2 (couches organico-crayeuses de milieu végétalisé). Les ostracodes peuvent être abondants dans certains niveaux, mais témoignent d'une intense évapostranspiration (faune saumâtre). L'établissement du bas niveau est associé à une mise en valeur agricole des environs dont témoignent les assemblages polliniques : une phase de défrichements, accompagnée d'indices de mise en culture, est attestée dans trois diagrammes. Ce bas niveau, marqué par d'importantes traces de mise en valeur agricole, qui fait suite à un haut niveau attribué à l'Age du Fer, pouvait logiquement être attribué à la période romaine.

L'INTERPRÉTATION DES DATES RADIOCARBONE

Dans les Carottes TC1 et TC2, quatre datations sur racines ont été obtenues par AMS : trois dates entre 4500 et 3500 BP (Tucson, AA-22857, AA-22860 et AA-22861), correspondant au bas niveau maximal de la fin de l'Atlantique et du début du Subboréal, et une date de 2070±65 BP (calibré de 135 av. J.-C. à 35 ap. J.-C.) (Tu. AA-22856) correspondant au début de la période romaine. La concordance des tendances climatiques déterminées à partir de la sédimentologie, de la mise en valeur agricole de grande ampleur perçue à travers les pollens et des données régionales sur l'histoire géomorphologique des environnements conduit à accepter la date de 1980±50 BP, calibré de 41 av. J.-C. à 101 ap. J.-C. (Tu. AA-22589), réalisée à la base des sédiments de bas niveau dans la carotte TC2. L'altitude obtenue de -1 m NGF (190 cm de profondeur dans TC1) par la position de la racine datée de 2070±65 BP correspondait à celle de la nappe d'eau lors des phases les plus sèches de l'Antiquité. Dans la partie occidentale, les fouilles de l'aval des moulins romains ont démontré un abaissement du niveau par rapport à la Protohistoire, durant la période de fonctionnement de la structure (II^{e} et III^{e}s. ap. J.-C.), (Leveau, 1996). D'autre part, un espace exondé d'altitude -90 cm NGF, sans tassements possibles, est daté de 1765 ± 90 BP, calibré de 144 à 409 ap. J.-C. (Ly 8158) sur os.

Les trois dates permettent de déterminer durant la période romaine une phase où l'altitude de la nappe d'eau est inférieure à -1 m NGF et où une grande partie de la cuvette est exondée. L'intervalle minimal de cet événement est de 35 ap. J.-C. à 144 ap. J.-C. L'intervalle maximal court de la fin du II^{e}s. av. J.-C. à la fin du IV^{e}s. ap. J.-C (fig. 3).

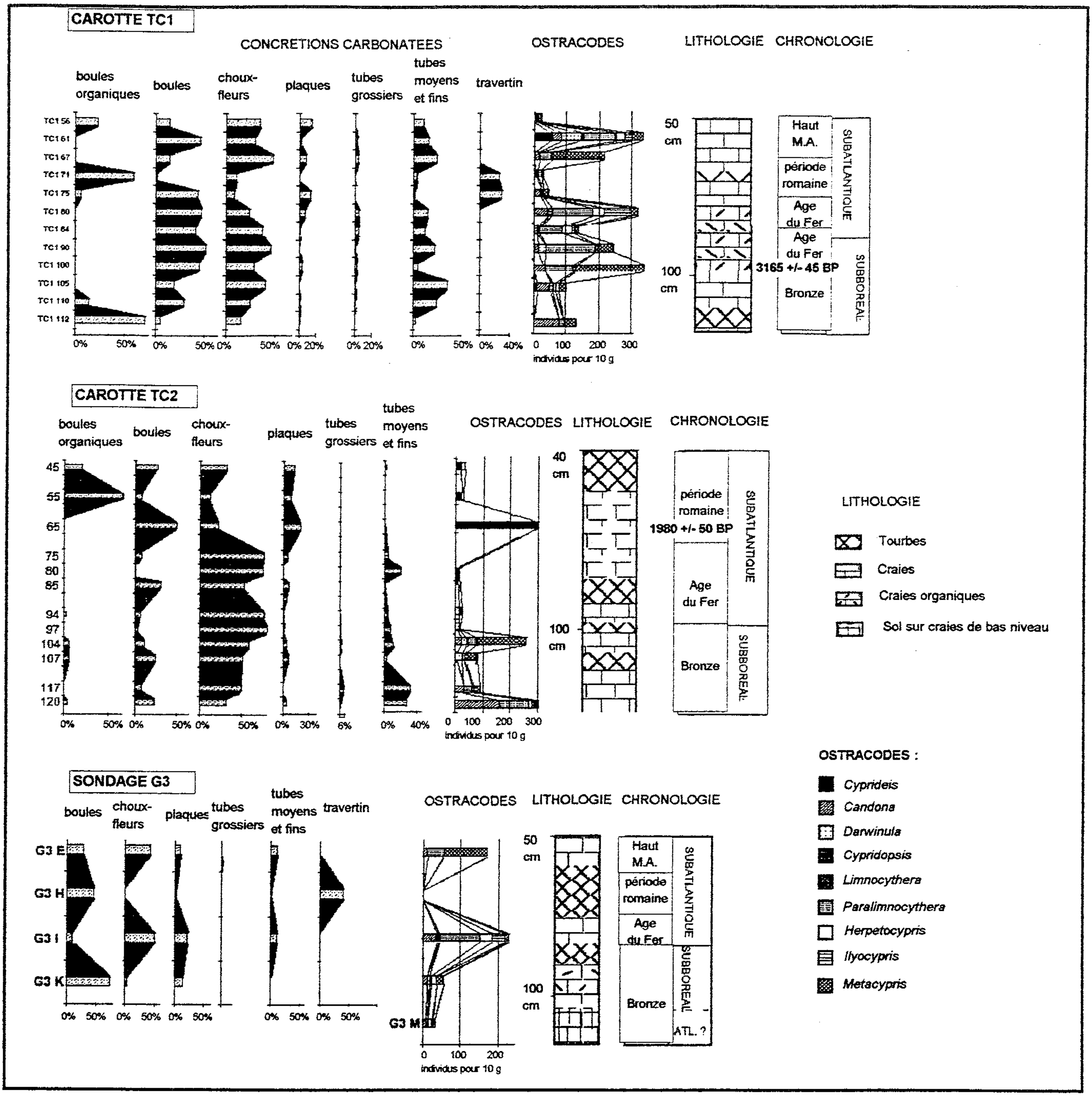

Fig. 2 : Analyses sédimentologiques et faunistiques sur TC1, TC2 et G3.

Le site de la Calade, localisé en bordure des marais du lit d'inondation du Rhône, à 4 km à l'ouest du Marais des Baux, fournit un point de comparaison. Plusieurs sondages y montrent la transgression des zones humides sur les versants depuis la fin de la Protohistoire. Trois dates réalisées sur matière organique totale, dans un milieu peu carbonaté, sont acceptées sur critères palynologiques (présence de *Juglans* attribué à la période romaine à la base de la coupe) et par comparaison avec les données régionales qui montrent un Rhône très débordant à l'antiquité tardive (Arnaud-Fassetta, 1998).

Les associations d'ostracodes mettent ici en évidence, après l'intrusion des marais durant la Protohistoire, une montée continue des niveaux entre 2145 ± 60 BP (calibré de 355 à 16 av. J.-C.), Ly 8152, et 1630 ± 50 BP (calibré de 287 à 545 ap. J.-C.), Ly 8151, datant le passage de crues en milieu palustre au-dessus d'un moulin de l'antiquité tardive, ou de 1580 ± 40 BP (calibré de 419 à 588 ap. J.-C.), Ly 8153, dans le sondage du marais. En effet les individus supportant l'exondation cèdent progressivement la place à des associations plus variées. Une salinisation passagère se marque par un niveau à nombreux *Cyprideis*.

Malgré ces traces de salinisation, peut-être liées à une tendance chaude du climat, le site de la Calade illustre une tendance générale à la remontée des nappes au cours de la période romaine, en liaison avec la tendance à l'exhaussement du lit du Rhône. Le brutal assèchement du marais des Baux est donc en contradiction avec l'hydrologie régionale, ce qui conduit à invoquer un drainage artificiel.

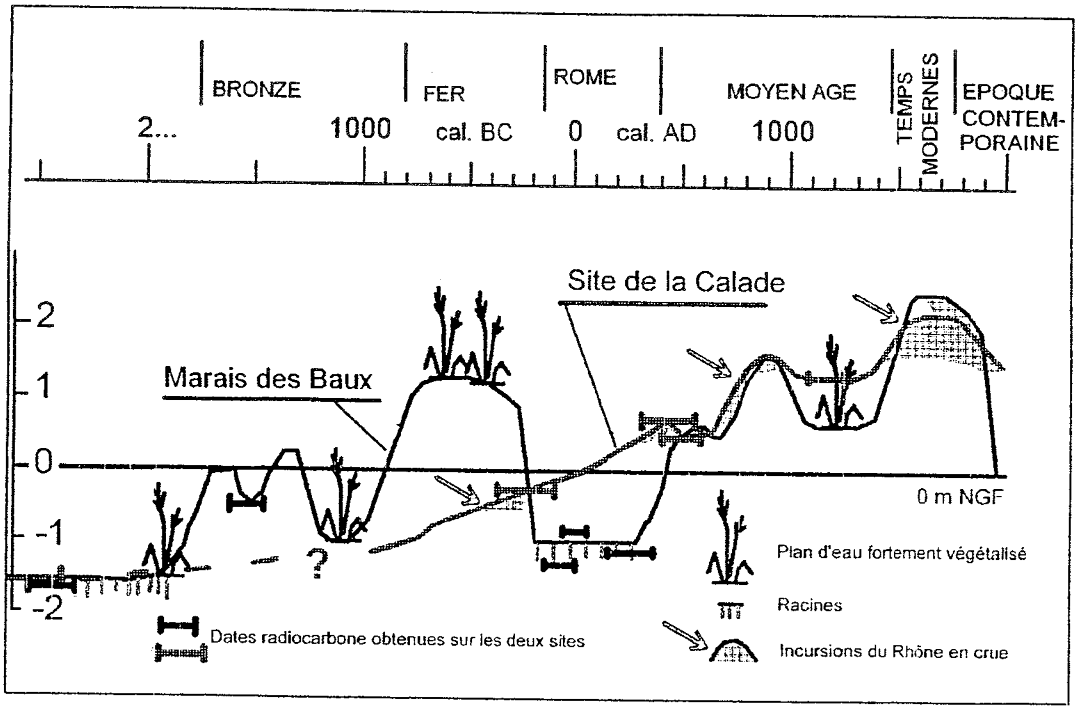

Fig. 3 : Image de l'altitude du plan d'eau depuis le Subboréal.

CARACTÉRISATION DU MODE D'OCCUPATION DE LA VALLÉE DES BAUX DURANT LE HAUT EMPIRE ROMAIN

La poursuite des recherches archéologiques dans la vallée a permis d'y reconnaître l'existence d'un établissement agricole de type *villa.* A quelques mètres d'un cimetière du haut Moyen Age, les travaux agricoles ont remonté en surface de nombreux fragments de *dolia* : à cet endroit, existait un grand bâtiment. De là provenait également une grande cuve de pierre ayant pu servir au foulage du raisin, qui invite à supposer la proximité d'un vignoble antique. Les fouilles de 1995 ont en outre amené la découverte d'un abri sur poteau dont la couverture de *tegulae* s'était écroulée. D'autres bâtiments complètent cette exploitation : un bâtiment paraît exister à l'emplacement de la ferme actuelle. Par ailleurs une inscription datée du début du I^er^ siècle atteste la présence d'un esclave probablement détaché de la *familia urbana* d'un aristocrate arlésien dont les propriétés familiales se trouvaient dans la région. D'autres réemplois provenant de mausolées confortent l'hypothèse d'un centre domanial. Il faut donc admettre que les moulins n'étaient pas un monument isolé mais constituent seulement une pièce importante, la seule conservée, d'un domaine qui présidait à la mise en culture de la dépression. Il n'existe encore aucune donnée archéologique sur les cultures pratiquées. Cependant les sols d'un marais drainé sont favorables aux cultures céréalières. Par ailleurs prenant en compte les travaux de O. Badan, J.-P. Brun et G. Congès qui ont identifié en Crau des bergeries montrant qu'à l'époque romaine, la plaine était l'objet d'une exploitation pastorale systématique, il est possible de suggérer que ces troupeaux trouvaient, l'été, de quoi subsister dans les zones humides de la plaine du Rhône, en Camargue, et... dans la vallée des Baux.

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NÉCROPOLE ET ^{14}C : L'EXEMPLE DE NOTRE DAME DU BOURG A DIGNE

Gabrielle DEMIANS d'ARCHIMBAUD, Jacques EVIN** et Christine OBERLIN***

Résumé : Au cours des dix années de fouille de la nécropole de Notre Dame du Bourg à Digne, 54 datations radiocarbone ont été effectuées sur les diverses parties du gisement. Après un examen des conditions particulières d'interprétation des dates dans ce site, on répertorie pour chaque époque quels résultats ont été obtenus et comment ils s'intègrent dans l'interprétation archéologique.

Abstract : During the ten years excavation programme of Notre Dame du Bourg necropolis in Digne, 54 radiocarbon datings were made on different parts of the site. After studying the special conditions in which the dates are to be interpreted there, we list the results obtained for each period and see how they can be integrated into the archaeological interpretation.

Mots-clés : Datation radiocarbone, nécropole, Moyen Age, Provence, France.

Key-words : Radiocarbon dating, necropolis, Middle Age, Provence, France.

INTRODUCTION : LE SITE DE NOTRE DAME DU BOURG A DIGNE

L'église Notre Dame du Bourg est une ancienne cathédrale située en périphérie du centre de la ville de Digne (Alpes de Haute-provence). C'est un édifice du XIIIe siècle mais on sait depuis longtemps qu'il fait suite à plusieurs édifices de construction plus ancienne qui se sont succédés depuis l'antiquité tardive car le siège épiscopal de Digne peut avoir été fondé à la fin du IVe siècle. Toutefois il y a très peu de textes pour renseigner sur son histoire jusqu'au XIe siècle.

L'extension de la ville moderne rendit nécessaire la remise en fonction de l'église médiévale et une restauration complète de l'édifice fut décidée. Dès l'ouverture du chantier en 1983, les sondages exploratoires réalisés à l'intérieur de la cathédrale, puis du clocher en 1984, confirmèrent l'intérêt archéologique du site. La mise en évidence de niveaux anciens, de l'Antiquité tardive et du haut Moyen Âge, protégés par l'exhaussement des sols de plusieurs mètres firent décider une étude exhaustive de toute l'église et de ses environs immédiats (Demians d'Archimbaud, 1989 et 1997). Ces fouilles qui ont duré plus de dix ans, ont eu lieu dans l'église elle-même, qui fut entièrement excavée, et dans ses abords au nord et à l'ouest.

La figure 1 montre l'ensemble des découvertes après dix années de travaux et la complexité des structures mises au jour. Il a été ainsi mis en évidence :

- des ensembles monumentaux antiques avec deux portiques à l'est et à l'ouest datant du Ier au IIe siècle.
- une zone funéraire au Nord autour de deux mausolées datant du IVe siècle.
- une basilique avec un vaste chevet plat à l'emplacement de la croisée du transept de l'église actuelle datant du Ve et VIe siècle.

A partir du IVe siècle, et surtout après de larges transformations au XIe siècle, l'ensemble des structures du site a été envahi par des séries considérables de tombes (on en a dénombré plus de 1400), les inhumations s'étant étalées sur un laps de temps de 13 siècles.

L'ÉTUDE DE LA NÉCROPOLE PAR LA STRATIGRAPHIE ET LE RECOURS AU RADIOCARBONE

Cette accumulation de tombes constitue la caractéristique principale de cette fouille et son grand intérêt tant par l'étude de leurs faciès que par celle de leur succession stratigraphique et de leurs relations avec les édifices construits. Toutefois l'enchevêtrement des sépultures et la rareté de leur matériel archéologique datant ont

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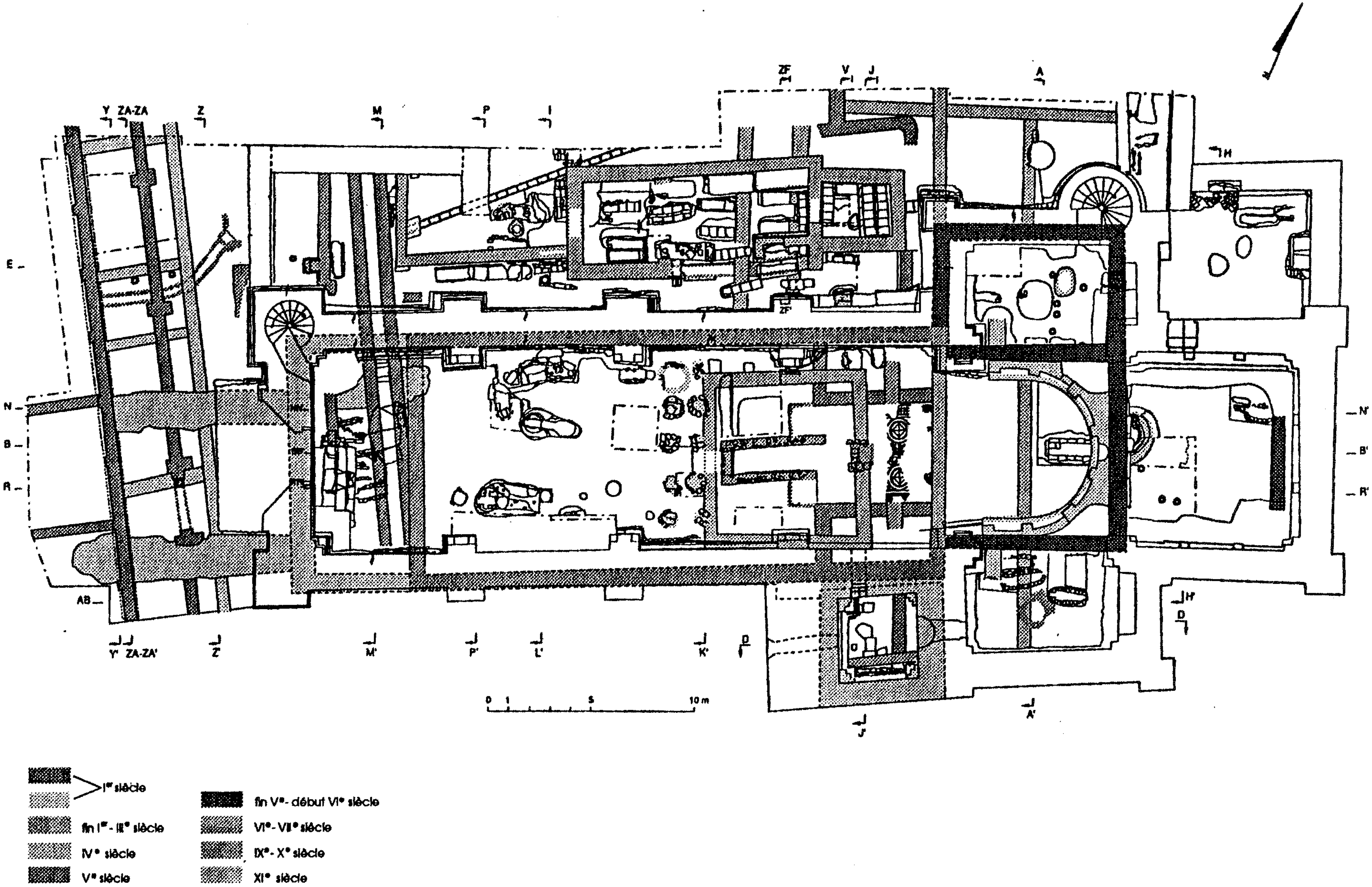


Fig. 1 : Le plan périodisé de l'ensemble des découvertes de dix années de fouille à la cathédrale Notre-dame du Bourg à Digne (Alpes de haute-Provence) (dessin F. Gillet).

toujours rendu l'étude très délicate. On avait, tout à la fois, à faire à des permanences typologiques d'inhumations et à des positions stratigraphiques difficilement corrélables d'un point à l'autre de la zone fouillée.

Dès le début de la fouille, il fut donc décidé d'avoir recours systématiquement aux datations radiocarbone et une série d'analyses fut effectuée chaque année, au fur et à mesure de la progression de l'excavation. Après 10 années de sélection d'échantillons sur le terrain et de mesures au laboratoire, l'ensemble de 54 datations obtenues constitue une des plus importantes séries de dates pour une nécropole médiévale et un exemple de longue coopération entre des études sur le terrain et en laboratoire (Oberlin et Evin, 1996).

PROCÉDURES DE PRÉLÈVEMENT SUR LE TERRAIN ET DE TRAITEMENT AU LABORATOIRE, CONDITIONS D'INTERPRÉTATION

Les échantillons furent choisis sur le terrain en fonction des types d'inhumation à dater, de leur position stratigraphique ou du matériel associé dont on voulait contrôler l'attribution chronologique. Ce choix n'a pas été limité par des considérations techniques car il s'est tout de suite avéré que, sur l'ensemble du site, le matériel osseux était parfaitement conservé (Evin, 1992).

Les ossements

Il est certain que la nature argileuse du terrain et l'absence de lessivage par des eaux météoriques en raison de la protection du site par les constructions postérieures ont permis cette excellente conservation du matériel. On a constaté au laboratoire de fortes teneurs en collagène, quel que soit l'âge des ossements, de telle sorte qu'on a pu extraire en moyenne, pour 400 grammes d'ossements, de 12 à 32 grammes de collagène. De ce fait il a été possible de mesurer toutes les teneurs en radiocarbone par la méthode des comptages de radioactivité et le système de mesure par accélérateur n'a été utilisé qu'une seule fois (OxA-5640/Lyon-169) où l'on ne disposait que de quelques esquilles. On peut aussi remarquer que pour les 27 prélèvements où la mesure du fractionnement isotopique était faite, la valeur moyenne obtenue est de -19,20 ‰ PDB avec une variance maximale de 1 ‰. Cela montre une population au régime alimentaire homogène en végétaux et animaux terrestres. Cette valeur moyenne est très proche de -20 ‰, valeur qui a été prise forfaitairement pour le calcul de l'âge lorsque la mesure du delta ^{13}C n'avait pas été faite (les mesures portant les codes de laboratoire Ly-4879 à Ly-6125). Il n'a pas été tenu compte du fait que, en raison d'un certain temps possible de résidence du carbone dans l'organisme, la date calculée peut correspondre à quelques années avant la mort de l'individu. Cependant cette hypothèse, qui pourrait entraîner un âge apparent des ossements d'une dizaine ou d'une vingtaine d'années n'a pas encore été ni prouvée, ni mesurée avec précision.

Il faut aussi noter que dans l'étude des nécropoles, particulièrement dans celles qui sont densément occupées, il existe toujours le danger de rajeunissement en raison de possibles réinhumations qui sont souvent difficiles à détecter. En effet l'étude du squelette en place après une réinhumation renvoie, le plus souvent, à une période plus tardive que celle de la construction de la tombe et pouvant atteindre un siècle, ou plus :

Ly-8497	*Tombe sous tuiles* *1430±40 de 562 à 667 après J.-C.*	*N°351A*
Ly-8498	*Réduction dans la même tombe sous tuiles* *1555±40 de 431 à 599 après J.-C.*	*N°351RHC*

Les charbons de bois et terres charbonneuses

Cinq échantillons de charbon de bois ont été analysés parmi lesquels trois n'ont pas montré de problème d'état de conservation tandis que deux autres (Ly-4882 et Ly-4883) n'ont pu donner qu'une très faible quantité de carbone pour la mesure car ils étaient peut-être constitués presque uniquement de cendres, en particulier celui provenant du four de bronzier.

Une certaine prudence est requise dans l'interprétation des résultats obtenus sur des charbons lorsqu'il s'agit de dater une couche d'incendie. En effet il est évident que la mesure de la teneur en radiocarbone donne l'âge de croissance des bois datés et non pas celui de leur carbonisation. L'exemple significatif à cet égard est celui de la couche 584, datée archéologiquement de la fin du XIIe siècle. Elle correspond à un incendie qui serait à l'origine de la reconstruction de la basilique ; or la date ^{14}C du matériel brûlé donne un intervalle de temps de deux à trois siècles antérieur : les charbons de bois mesurés proviendraient donc probablement de gros bois de charpente.

Ly-4885	*Charbons* *1160±40 de 700 à 967 après J.-C.*	*couche 484*

CALCUL, CORRECTION DES ÂGES RADIOCARBONE, REPRÉSENTATION GRAPHIQUE ET INTERPRÉTATION D'ENSEMBLE

Un seul résultat jugé aberrant a été obtenu à partir de la tombe 1117 : Ly-5730 : 2070 +/- 110 BP (de -360 à + 128 av./ap. J.-C.) alors qu'on attendait le VIIe ou le VIIIe siècle. Une nouvelle mesure sur d'autres ossements de la même tombe a donné un résultat plus plausible : Ly-5815 : 1570 +/- 50 (de 392 à 590 ap. J.-C.), sans qu'il ait été possible d'expliquer cette anomalie. Il ne peut s'agir d'une mauvaise élimination de produits organiques de consolidation car, ni sur le terrain ni au laboratoire d'anthropologie, ces produits n'ont été utilisés sur les ossements provenant de cette étude. La procédure habituelle de conversion des âges ^{14}C en intervalles de dates en années réelles a été pratiquée à partir des courbes de correction dendrochronologique classiques (Stuiver et Reimer, 1993). Comme les comptages de radioactivité ont été poursuivis jusqu'à l'obtention d'une précision de la date BP de +/- 40, les intervalles de dates en années réelles s'étendent sur un à deux siècles. Deux, voire trois, pics de probabilité maximale, ont à chaque fois été mis en évidence entre lesquels les données archéologiques ont permis de choisir une date plus probable (Evin et Oberlin, 1998).

Un graphique regroupant l'ensemble des résultats permet de mettre en évidence la durée globale d'occupation du site et les périodes les plus représentées parmi les tombes ayant fait l'objet d'analyses (fig. 2).

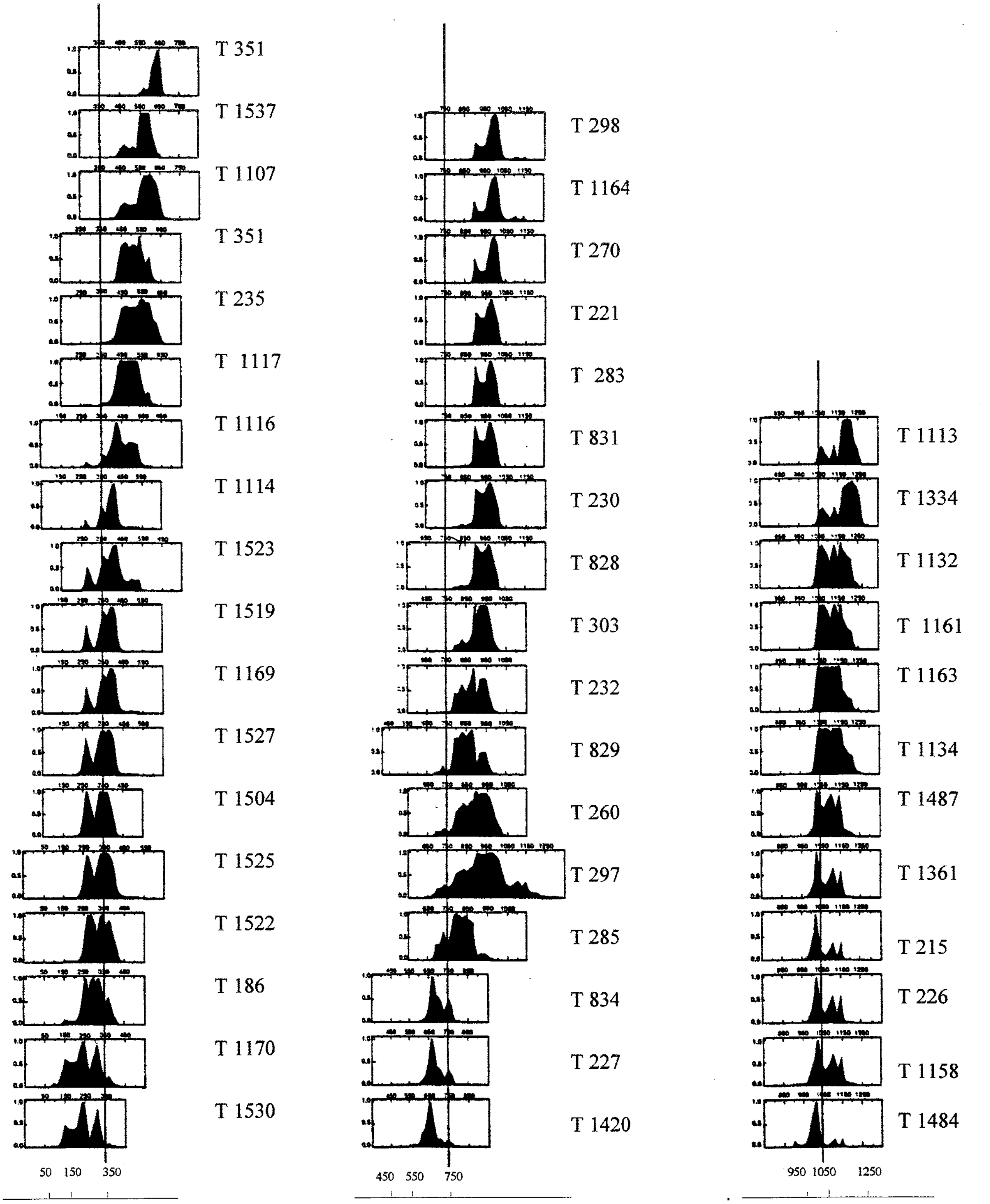


Fig. 2 : Graphique regroupant l'ensemble des résultats des datations radiocarbone effectuées sur des échantillons provenant de Notre Dame du Bourg à Digne.

HISTOIRE DU SITE DÉDUITE DE L'INTERPRÉTATION DES ENSEMBLES DE DATATIONS

A la lumière des données de la fouille, des arguments archéologiques et des 54 datations radiocarbone, il est possible de diviser l'histoire de la nécropole de Notre Dame du Bourg au cours du premier millénaire en trois phases :

- la première allant de la fin de l'antiquité jusqu'au début du haut moyen âge, avec une phase précédent de peu la christianisation, puis son apparition enfin avec son plein épanouissement correspondant à une importante basilique ;
- la seconde couvrant la fin des temps mérovingiens et la période carolingienne avec des aménagements de cette basilique ;

- enfin la troisième correspondant aux Xe et XIe siècles, immédiatement avant la construction de l'église actuelle. La figure 3 permet de situer l'emplacement de toutes les tombes datées suivant la reconstitution des structures construites de chaque époque.

A - PREMIÈRES INHUMATIONS ET MAUSOLÉES

Les plus anciennes datations correspondent à des sépultures isolées en fosse ou en cercueil. Elles se rapportent au IIIe ou IVe siècle. Elles confirment la désorganisation de l'habitat et des zones de circulation (portiques) observée simultanément dans les fouilles urbaines proches (fig. 3a) :

Ly-7333	*Tombe à coffre de bois* *1515±35 de 141 à 337 après J.-C.*	*N°1530*
Ly-7329	*Tombe à coffre de bois* *1795±35 de 130 à 371 après J.-C.*	*N°1170*
Ly-8489	*Tombe en fosse avec dépôt funéraire* *1005±40 de 175 à 391 après J.-C.*	*N°186*

Du début de cette époque correspondent les charbons de bois issus d'une fosse dépotoir :

Ly-4884	*Couches 266 et 266B* *1965±40 de -38 à + 128 av./ap. J.-C.*	

Au IVe siècle une mutation se produit avec la construction, dans la partie nord du site, de deux mausolées vite reliés entre eux par un enclos envahi de sépultures. Toutes celles qui purent être fouillées furent datées, ce qui a permis de déterminer trois temps de transformation :

- Dans une première période, alors que le mausolée occidental à mur-écrin abrite sans doute encore une sépulture, le mausolée oriental et l'enclos qui le précède servent d'abri à des tombes attribuables pour l'essentiel à la seconde moitié du IVe siècle, au cours duquel rien ne permet d'affirmer alors la christianisation (fig. 3a) :

Ly-7948	*Tombe sous tuiles en caveau construit* *1735±40 de 236 à 403 après J.-C.*	*N°1522*
OxA-5460 (Lyon-169)	*Tombe dans mausolée* *1710±50 de 238 à 441 après J.-C.*	*N°1525*
Ly-7994	*Tombe sous tuiles* *1755±40 de 249 à 410 après J.-C.*	*N°1504*
Ly-7332	*Tombes sous tuiles* *1700±45 de 253 à 446 après J.-C.*	*N°1527C*
Ly-7328	*Tombe construite sous tuiles et marbres dans enclos funéraires* *1685±40 de 262 à 479 après J.-C.*	*N°1169C*
Ly-7330	*Tombe dans mausolée* *1690±35 de 263 à 432 après J.-C.*	*N°1519*
Ly-7331	*Tombe sous tuiles* *1670±50 de 262 à 526 après J.-C.*	*N°1523*

- Dans une seconde période, au cours du Ve siècle, la christianisation se précise car apparaissent des objets à décor chrétien tandis que les bâtiments sont transformés en lieux de culte (fig. 3b). Ainsi s'expliquerait la suppression des sépultures dans le mausolée oriental et la multiplication des tombes contre la paroi et la porte Sud obturée :

Ly-7947	*Tombe à sarcophage* *1670±35 de 272 à 493 après J.-C.*	*N°1114*
Ly-5729	*Tombe sous tuiles* *1615±45 de 329 à 542 après J.-C.*	*N°1116*
Ly-5815	*Tombe sous arcosolium* *1570±50 de 392 à 590 après J.-C.*	*N°1117*

Enfin, dans la seconde moitié du VIe siècle, deux sépultures identiques, au faciès exceptionnel, sont mises en place dans l'angle sud-est du bâtiment et devant l'entrée (fig. 3c) dont une seule, stratigraphiquement la plus récente, a été datée :

Ly-5727	*Tombe sous tuiles* *1475±60 de 443 à 653 après J.-C.*	*N°1107*

B - LA BASILIQUE DU Ve AU Xe SIECLE

- La fouille de la cathédrale médiévale *stricto sensu* montra qu'elle succède à une basilique importante, amplifiée encore par la construction d'un vaste chevet plat (fig. 3c) avant le milieu ou la seconde moitié du VIe siècle, d'après la datation de trois tombes sous tuiles contre lui :

Ly-5347	*Tombe sous tuiles* *1520±65 de 409 à 632 après J.-C.*	*N°235*
Ly-8498	*Tombe sous tuiles* *1555±40 de 431 à 599 après J.-C.*	*N°351 RHC*
Ly-8492	*Tombe sous tuiles* *1365±45 de 617 à 771 après J.-C.*	*N°227*

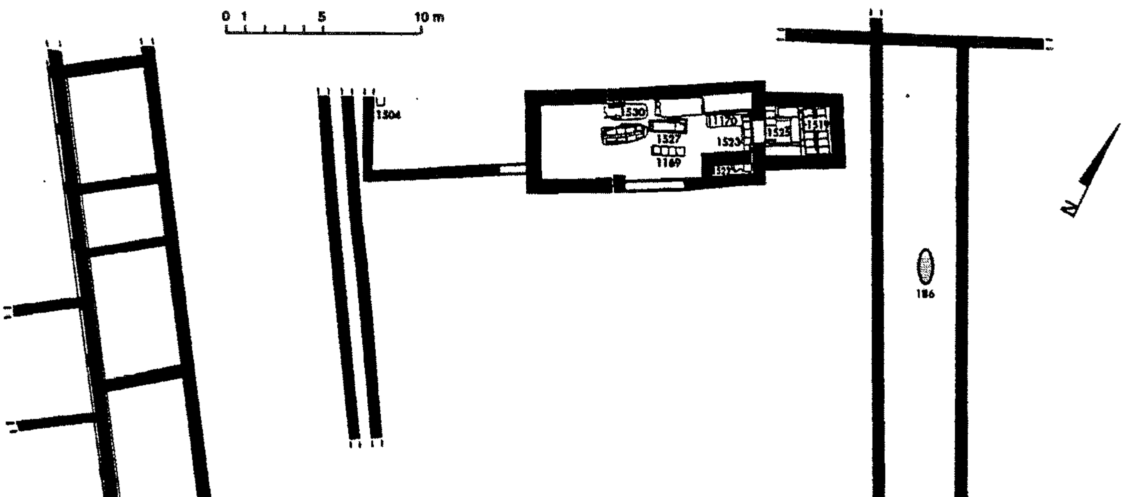
- La multiplication progressive des inhumations, sur plusieurs niveaux, à l'est, comme dans une moindre mesure à l'ouest de la basilique, posait un problème : il était évident, stratigraphiquement, que des types anciennes de tombes tels que les sépultures sous tuiles, pouvaient se maintenir, côtoyant des inhumations de faciès différents (fig. 3d). Une série d'analyses réalisées sur des tombes supposées tardives confirma ce fait. On constate la continuité de l'emploi des tombes sous tuiles au VIIe siècle, et en pleine période carolingienne, voire même au delà :

Ly-6123	*Tombe sous tuiles* *1370±50 de 592 à 759 après J.-C.*	*N°1420*
Ly-7327	*Tombe sous tuiles* *1345±45 de 637 à 777 après J.-C.*	*N°834*
Ly-5346	*Tombe sous tuiles* *1085±45 de 838 à 1014 après J.-C.*	*N°230*
Ly-8493	*Tombe sous tuiles* *1165±40 de 787 à 971 après J.-C.*	*N°232*
Ly-6125	*Tombe sous tuiles* *832±55 de 1049 à 1264 après J.-C.*	*N°1334*

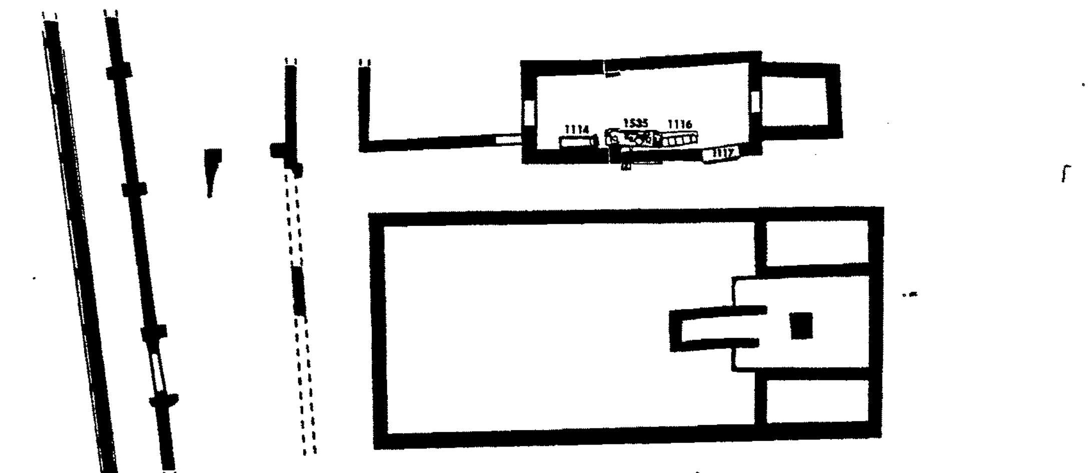
D'autres résultats précisent les périodes d'apparition des inhumations à coffre de pierre parfois maçonnées ou recouvertes d'une épaisse couche de plâtre :

Ly-4881	*Tombe maçonnée* *1210±45 de 695 à 917 après J.-C.*	*N°285*
Ly-4880	*Tombe maçonnée* *1140±60 de 728 à 999 après J.-C.*	*N°260*
Ly-7990	*Tombe maçonnée* *1190±45 de 729 à 961 après J.-C.*	*N°829*
Ly-7989	*Tombe maçonnée* *1110±45 de 829 à 1008 après J.-C.*	*N°828*
Ly-7991	*Tombe maçonnée* *1095±40 de 884 à 1012 après J.-C.*	*N°831*
Ly-8495	*Tombe maçonnée* *1095±40 de 889 à 1012 après J.-C.*	*N°283*
Ly-4879	*Tombe maçonnée* *1075±40 de 890 à 1013 après J.-C.*	*N°221*
Ly-8494	*Tombe maçonnée* *1065±45 de 895 à 1029 après J.-C.*	*N°270*
Ly-7992	*Tombe en coffrage de pierre* *1050±50 de 895 à 1126 après J.-C.*	*N°1164*

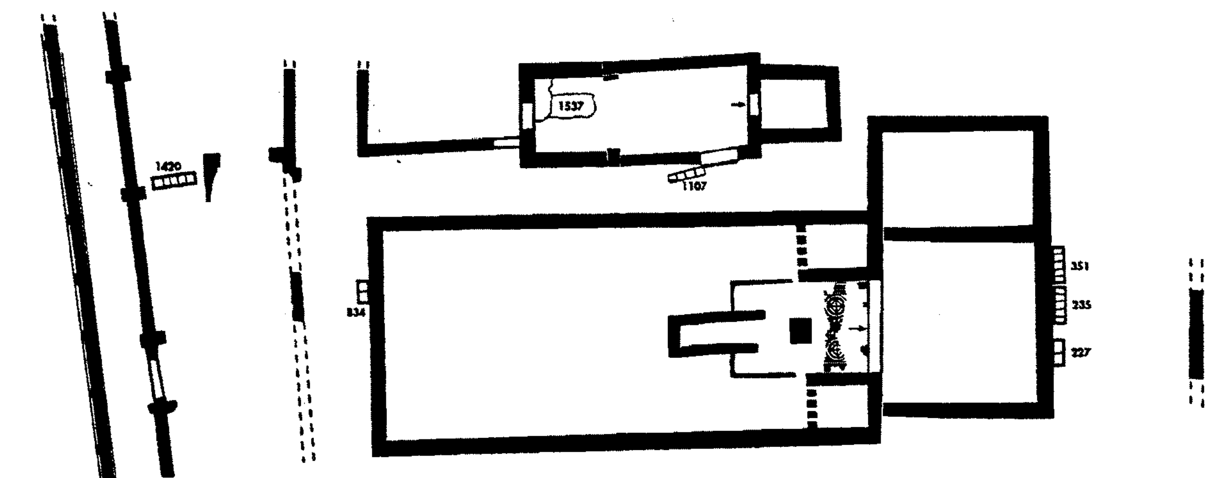
Enfin on trouve aussi des dates variées pour les tombes en fosse dont la chronologie indiquée par le radiocarbone est confirmée par celle proposée, en un cas, par le matériel associé (des céramiques du Latium datables du Xe siècle) :



Fg. 3a : IV^e siècle

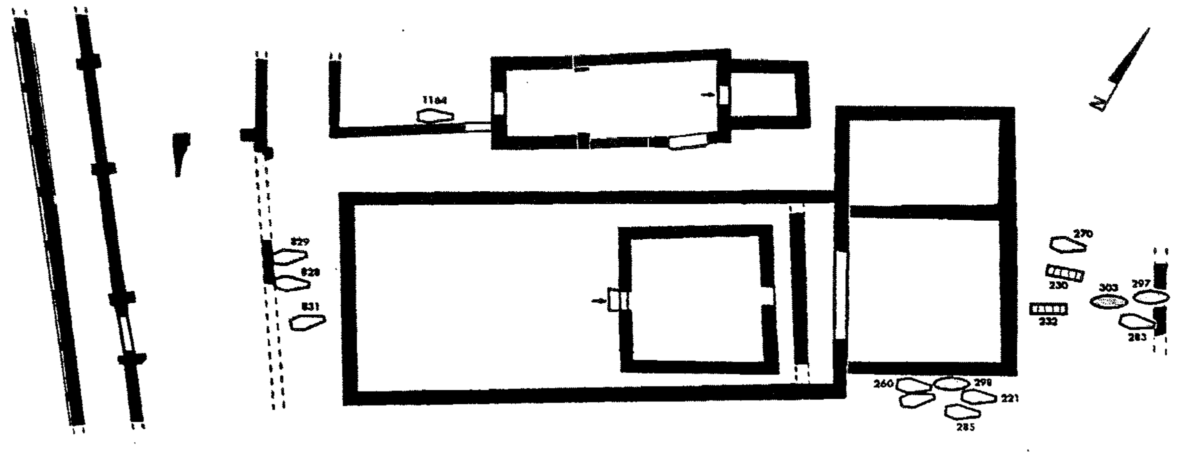


Fg. 3b : V^e siècle

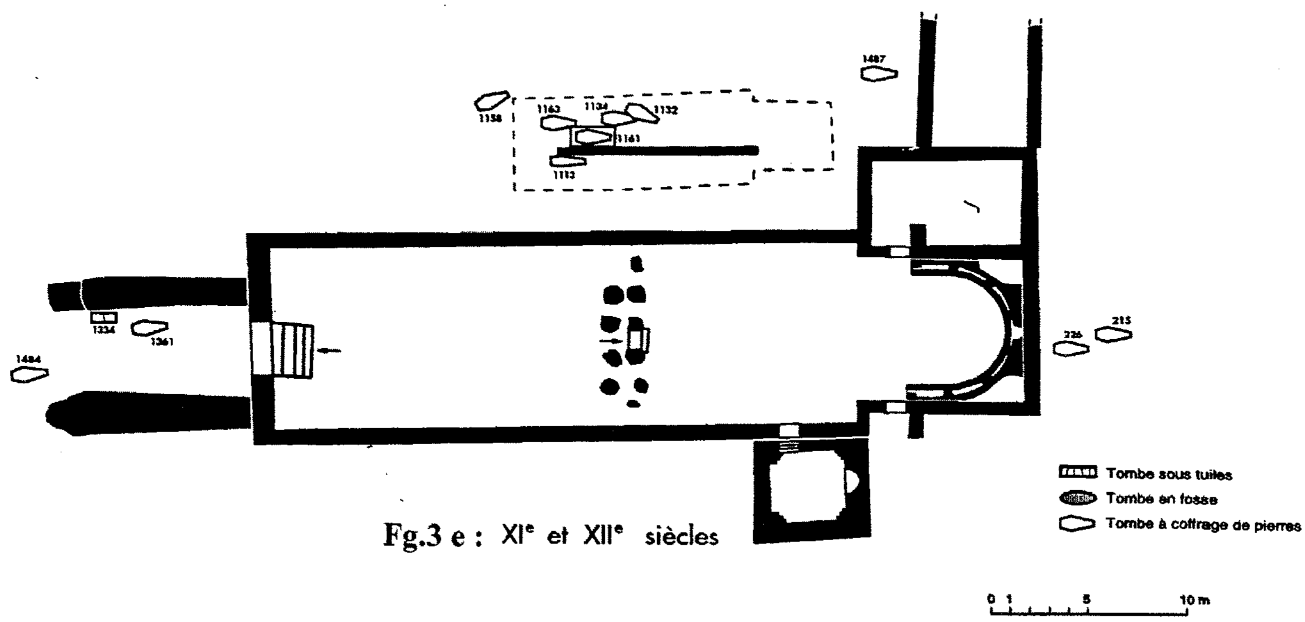


Fg. 3c : Fin V^e / VI^e / VII^e siècles

Fig. 3 : Schémas d'évolution du site de la cathédrale Notre Dame du Bourg à Digne, avec la localisation des tombes datées par le radiocarbone.



Fg.3 d : VIIIe / Xe siècles



Fg.3 e : XIe et XIIe siècles

Fig. 3 : Suite.

Ly-5349	*Tombe en fosse avec bois* *1045±45 de 897 à 1086 après J.-C.*	*N°298*
Ly-5348	*Tombe en fosse* *1085±108 de 703 à 1167 après J.-C.*	*N°297*
Ly-8496	*Tombe en fosse* *1140±40 de 804 à 988 après J.-C.*	*N°303*

- A ce niveau intermédiaire peuvent être rattachés trois prélèvements sur charbon de bois : les deux premiers sans grande signification étant donné la large marge statistique datent respectivement soit le premier niveau de tombes maçonnées, soit un terminus de la couche à tombes maçonnées.

Ly-4882	*Charbon en structure* *1815±155 de -170 à +538 av./ap. J.-C.*	*158, foyer bronzier*
Ly-4883	*Charbons* *1385±225 de 167 à 1094 après J.-C.*	*couche 240*

Le troisième est plus significatif car il est sensé dater une couche d'incendie, archéologiquement attribuée à la fin du XIIe siècle, incendie qui serait à l'origine de la reconstruction de la basilique ; or la datation donne un intervalle de temps correspondant à un ou deux siècles avant le XIIe, les charbon incendiés provenant peut-être de gros bois de charpente.

Ly-4885	*Charbons* *1160±40 de 700 à 967 après J.-C.*	*couche 484*

C - LES MUTATIONS DES Xe ET XIe SIÈCLES

Une troisième phase apparaît ensuite, marquée aussi bien par de profondes transformations architecturales que par l'évolution de rites d'inhumation. On abandonne alors l'ancienne dissociation des lieux de culte et de leurs annexes au profit du développement de l'église principale. Celle-ci est allongée vers l'ouest et précédée d'une puissante avant-nef ; un clocher latéral est bâti au sud, au dessus d'une petite salle à exèdre orientée. Le chevet lui-même est transformé par l'insertion d'une abside en hémicycle à l'intérieur de l'ancienne structure. Au nord, une galerie apparaît délimitée par un mur est-ouest construit en travers des anciens mausolées. Mais très vite tout l'espace environnant au Nord comme à l'Ouest de l'église est envahi par des tombes en lauzes, souvent avec des dépôts funéraires (céramiques ou verres) (fig. 3e). Les datations obtenues sur onze de ces tombes accumulées sur plusieurs niveaux montrent qu'elles se succèdent du début du XIe siècle jusqu'au milieu du XIIIe et pas au delà car aucune des limites chronologiques indiquées par les intervalles de dates ne dépassent les années 1250-1260 :

Ly-7993	*Tombe sous lauzes*	*N°1484*
	1030±45 de 907 à 1148 après J.-C.	
Ly-8490	*Tombe sous lauzes*	*N°215*
	1005±40 de 983 à 1154 après J.-C.	
Ly-8491	*Tombe à cordon de pierres*	*N°226*
	991±40 de 983 à 1154 après J.-C.	
Ly-5818	*Tombe sous lauzes*	*N°1158*
	977±50 de 978 à 1166 après J.-C.	
Ly-6124	*Tombe en coffre de pierre*	*N°1361*
	971±40 de 994 à 1159 après J.-C.	
Ly-6122	*Tombe en coffre de pierre*	*N°1487*
	950±45 de 1008 à 1185 après J.-C.	
Ly-5732	*Tombe en fosse dans sol de tuileau*	*N°1163*
	920±40 de 1028 à 1208 après J.-C.	
Ly-5816	*Tombe sous lauzes*	*N°1134*
	915±45 de 1027 à 1216 après J.-C.	
Ly-5731	*Tombe construite et maçonnée*	*N°1161*
	900±35 de 1036 à 1213 après J.-C.	
Ly-5817	*Tombe sous lauzes*	*N°1132*
	890±40 de 1038 à 1225 après J.-C.	
Ly-5728	*Tombe sous lauzes*	*N°1113*
	855±40 de 1052 à 1250 après J.-C.	

Correspondant à la même période, deux analyses ont été faites :

- sur les restes d'un foyer entaillé dans le béton de tuileau de la nef de la basilique :

Ly-7326	*Charbon foyer 704*	*couche : 705*
	970±45 de 1006 à 1181 après J.-C.	

- sur des charbons provenant du nettoyage d'un four à pain établi à l'intérieur des portiques, sous la nécropole médiévale :

Ly-6121	*Charbon*	*couche : 2010*
	1075±35 de 895 à 1012 après J.-C.	

CONCLUSION

Les datations radiocarbone ont été déterminantes pour la reconstitution de l'histoire du site de Notre Dame du Bourg en trois périodes. Elles ont permis aussi bien d'établir la chronotypologie des inhumations et de dater le mobilier que d'interpréter la succession architecturale du site. L'analyse de l'ensemble des résultats montre une très bonne cohérence et cela conduit à une bonne hypothèse de reconstitution de l'histoire du site sur près d'un millénaire, ce qui n'aurait pu être obtenu avec les seules indications de la stratigraphie, trop imprécise dans un site aussi complexe.

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ARCHÉOLOGIE PASTORALE ET HISTOIRE DE L'ENVIRONNEMENT EN HAUTE MONTAGNE : L'APPORT DES DATATIONS RADIOCARBONE

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Résumé : On présente une série de 27 datations effectuées sur des échantillons provenant de sites du versant montagnard de la commune d'Enveig, dans les Pyrénées-Orientales (France). Ces mesures radiocarbone, relatives à des sites pastoraux, à des charbonnières et à des tourbières, couvrent la longue durée des sociétés rurales, du Néolithique à nos jours. Ainsi permettent-elles d'appréhender, tout au long de son histoire, l'exploitation de ce territoire d'altitude sous ses aspects écologiques, techniques et sociaux. La confrontation des résultats de ces datations à différents niveaux - site, puis ensemble de sites, enfin grandes séquences archéologiques et environnementales - conduit à l'élaboration de modèles d'évolution du versant qui s'efforcent de prendre en compte non seulement les données cohérentes et synchrones, mais aussi les décalages ou les divergences.

Summary : This article presents a series of 27 datations effected on the mountain slopes around Enveig in the Eastern Pyrenees (Pyrénées-Orientales, France). These radiocarbon estimations, concerning pastoral sites, charcoal and peat concentrations, cover an important time span, from the Neolithic to the present day. They therefore allow an apprehension throughout its history of the highland territorial exploitation with its ecological, technical and social aspects. By confronting the datation results at different levels - by site, group of sites, then wide archeological and environmental sequencies - an elaboration of evolutive models of the slopes can be reached, trying to take into account not only coherent and synchronic data, but also time-shiftings and divergencies.

Mots-clés : Pyrénées, pastoralisme, longue durée.

Key-words : Pyrenees, pastoralism, long run evolution.

INTRODUCTION

La montagne d'Enveig fait depuis plus de dix ans l'objet d'une étude monographique interdisciplinaire portant sur les rythmes et les formes d'exploitation d'un territoire pyrénéen d'altitude au cours du temps. Entreprise à l'échelle du versant (environ 2000 ha), cette recherche associe archéologie, histoire, ethnologie, écologie historique. En ce qui concerne la longue durée, les données de terrain proviennent essentiellement de la prospection et de la fouille archéologique des sites pastoraux, de l'analyse palynologique de carottes prélevées dans les tourbières, enfin de l'analyse anthracologique des charbons de bois issus des sols d'habitat ou, plus rarement, des charbonnières et des carottes tourbeuses. La confrontation des résultats de ces trois approches conduit à corréler deux dynamiques, celle des transformations de l'environnement et celle des activités humaines. On peut suivre ainsi sur un peu plus de six millénaires les variations de l'intensité de l'impact anthropique.

Comme les prélèvements de tourbe, les sites archéologiques sont ici datés presque exclusivement par le radiocarbone. A quelques rares exceptions près en effet, ils ne peuvent faire l'objet d'une attribution chronologique au vu de leur seul mobilier, toujours très pauvre, souvent totalement absent.

Nous disposons actuellement, pour saisir l'évolution de ce versant, de deux séries de datations ^{14}C (fig. 1) : 19 relatives aux niveaux archéologiques de 11 sites, 7 effectuées sur 2 carottes de tourbe, 1 sur une structure de type charbonnière. Comment évaluer la représentativité de ces mesures, sachant que même si les échantillons

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Code labo	Matériel	Lieu-dit	Site	Niveau	Date ¹⁴C BP	Intervalle (- = av. J.C.) (+ = ap. J.C.) (95% de probabilités)	Dates de probabilités maximales			
SITES ARCHEOLOGIQUES										
Ly- 7542	charbons	Orri d'en Corbill	Cab 79	C2 foy 1	190 ± 45 BP	[+1648, +1955]				
Ly- 7537	charbons	Maurà	Cab 13	C3 Foy 2	200 ± 50 BP	[+1641, +1955]				
Ly- 5530	charbons	La Padrilla	Cab 42	C6	480 ± 40 BP	[+1341, +1470]	1430			
Ly- 7495	charbons	La Padrilla	Cab 42	ST1 C6 F6	520 ± 45 BP	[+1321, +1460]	1422			
Ly- 7540	charbons	La Padrilla	Cab 42	Zone3 foy 4	610 ±50 BP	[+1298, +1417]	1321	1340	1393	
Ly- 7538	*charbons*	*La Padrilla*	*Cab 42*	*St1 Foy 3*	*770 ± 45 BP*	*[+1184, +1300]*	*1278*	*non recevable*		
Ly- 7539	charbons	La Padrilla	Cab 42	St2 C4	800 ± 50 BP	[+1094, +1286]	1252			
Ly- 7063	charbons	La Padrilla	Cab 42	St3 foy 5 n3	815 ± 45 BP	[+1078, +1282]	1130	1239		
Ly- 5337	charbons	Maurà	Cab 22	C2 Foy 1	1015 ± 50 BP	[+903, +1151]	1013			
Ly- 7519	charbons	Orri d'en Corbill	Cab 81	C2c inc n°2	1225 ± 50 BP	[+693, +943]	730	788	810	850
Ly- 7060	charbons	Orri d'en Corbill	Cab 82	C2 foy 1	1375 ± 50 BP	[+601, +766]	660			
Ly- 7062	charbons	Orri d'en Corbill	Abri 83	C4	2020 ± 50 BP	[-145, +91]	0	50		
Ly- 7061	charbons	Orri d'en Corbill	Cab 82	82015 n 6	2215 ± 50 BP	[-376, -126]	-349	-312	-229	-205
Ly- 8222	charbons	Orri d'en Corbill	St. 85-1	C2	3107 ± 45 BP	[-1454, -1242]	-1394	-1329		
Ly- 8223	charbons	La Padrilla	Cab 49	C2A	3810 ± 55 BP	[-2435, -2057]	-2272	-2253	-2203	-2149
Ly- 6242	charbons	La Padrilla	Enclos 2	sond. 5	4370± 68 BP	[-3302, -2880]	-3023	-2994	-2928	-3070
Ly- 7064	charbons	La Padrilla	Cab 75	C2 foy O13	4550 ± 60 BP	[-3473, -3051]	-3339	-3269	-3209	-3149
Ly- 7496	charbons	La Padrilla	Cab 75	C2 -foy N14	4950 ± 50 BP	[-3903, -3651]	-3749	-3707		
Ly- 7541	charbons	La Padrilla	Cab 49	C2 foy L12	5290 ± 60 BP	[-4287, -3985]	-4204	-4125	-4053	-4047
TYPE CHARBONNIERE										
Gif-10920	charbons	Pla de l'Orri	charbon. 1	base	1930 ±80 BP	[-103, +320]	80			
TOURBIERES										
Gif-9578	tourbe	Pla de l'Orri		25-28	760 ± 50 BP	[+1177,+1307]	1280			
Gif-9570	tourbe	Pla de l'Orri		87-90	4310 ± 60 BP	[-3049, -2863]	-2911			
Gif-9427	tourbe	Pla de l'Orri		107-113	6230 ±100 BP	[-5339, -4922]	5219	5156	5146	
Gif-9574	tourbe	Maurà		11-16	230 ± 70 BP	[+1615, +1890]	1663			
Gif-9575	tourbe	Maurà		28-31	700 ± 70 BP	[+1219, +1407]	1293			
Gif-9576	tourbe	Maurà		35-40	930 ± 80 BP	[+989, +1267]	1085	1121	1139	1156
Gif-8362	tourbe	Maurà		71-75	4590 ± 90 BP	[-3537, -3031]	-3353			

Fig. 1 : Datations radiocarbone (sites archéologiques et tourbières).

que l'on soumet sont ceux que l'on juge *a priori* les plus fiables, les résultats des comptages ^{14}C ne peuvent être confrontés à aucun contexte culturel précis ?

Les critères de discrimination résident dans la cohérence propre à chaque séquence, archéologique ou tourbeuse, puis dans les corrélations qui peuvent s'établir entre différentes séquences de même nature : il existe ici, pour plusieurs époques, des parallélismes nets tant en matière d'évolution typologique des sites qu'entre les courbes de plusieurs diagrammes palynologiques.

Lorsqu'on croise les résultats obtenus par les différentes disciplines, il arrive qu'ils se confortent mutuellement, confirmant ainsi les tendances aperçues par l'une ou l'autre approche, ou bien qu'ils montrent des divergences, voire des contradictions. Comme celles-ci ne peuvent remettre en cause la validité de datations radiocarbone déjà jugées cohérentes, elles restent à interpréter. Le recours à une analyse plus fine, qui relativise dans l'espace ou dans le temps le poids de ces datations, permet dans certains cas de moduler localement les dynamiques générales, dans d'autres de mieux évaluer la durée des phénomènes enregistrés. On aboutit ainsi, à titre d'hypothèse, à des modèles plus complexes où l'impact anthropique peut être mieux qualifié.

1 - DE LA FIN DU Ve AU DEBUT DU IIIe MILLÉNAIRE AV. J.-C. : DES TÉMOIGNAGES CONCOMITANTS, A L'ÉCHELLE DES TEMPS NÉOLITHIQUES (fig. 2)

a) Les sites et leurs datations

Sur les grands plas sommitaux, à 2300 m d'altitude et à 250 m de distance, deux sites archéologiques, 49 et 75, ont fait l'objet de quatre datations dont les résultats sont compris entre la fin du Ve et le début du IIIe millénaire en années calendaires.

Il s'agit dans les deux cas de petits habitats du Moyen-Age ou du bas Moyen-Age en surface, établis contre la paroi verticale d'un rocher et révélés à la prospection par un ovale de pierres correspondant aux assises de superstructures en matériaux périssables.

* La cabane 49 présente une stratification de trois niveaux d'occupation : sous l'habitat médiéval (C1), la couche 2 possède 2 foyers dont l'un est daté du Bronze ancien (Ly-8223). Le niveau sous-jacent a livré une datation du Néolithique moyen (Ly-7541).

* La cabane 75 est une cabane d'époque moderne. Sous-jacente à cet habitat récent, une couche plus étendue en surface a livré plusieurs lentilles cendreuses et charbonneuses et deux véritables structures de combustion, l'une de la première (Ly-7496), l'autre de la seconde moitié du IVe millénaire av. J.-C. (Ly-7064). La durée de sédimentation de cette couche peut correspondre à plusieurs occupations successives.

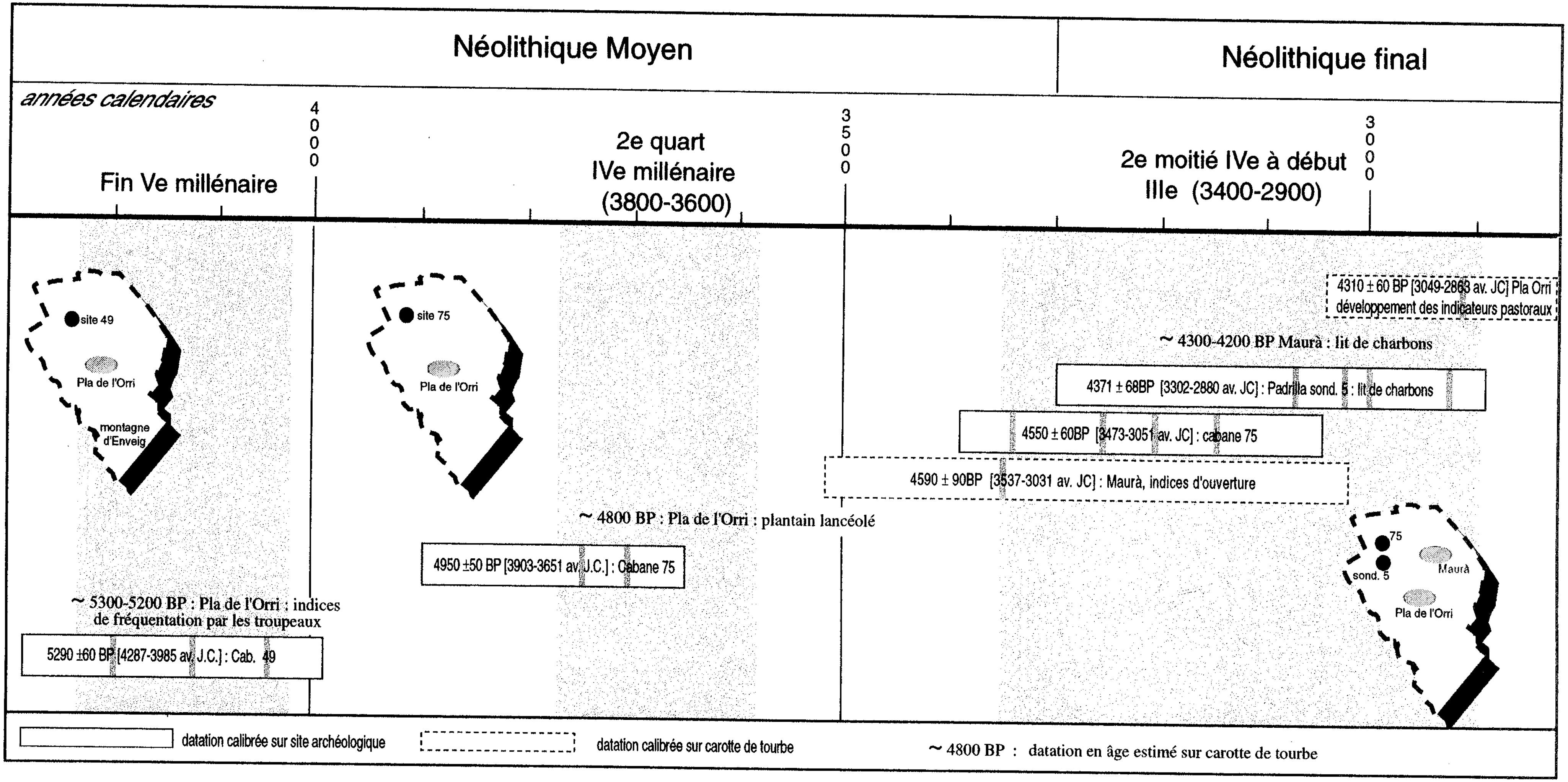

Fig. 2 : Rythmes et dynamiques d'exploitation de la montagne d'Enveig : le Néolithique.

Dans leur état néolithique, ces deux sites n'ont pas fourni d'éléments pouvant donner lieu à des comparaisons typologiques fines. Seule leur implantation est comparable, mais utiliser la face verticale d'un rocher pour y appuyer une cabane est une pratique courante encore au Moyen Age.

La datation Ly-6242 concerne un lit de charbons mis en évidence à 50 m environ en amont de la cabane 75, hors habitat, sous le mur d'un enclos du bas Moyen-Age.

b) La cohérence avec les données écologiques

- *Sur les plas sommitaux*

* Dans la tourbière de Maurà, située à 2200 m d'altitude et environ 2 km de la Padrilla, autour de la date de 4590 ±90 BP (Gif-8362), des indices d'une ouverture du milieu sont lisibles : faible diminution du pin, augmentation des poacées et de certains taxons héliophiles.

* Cette séquence tourbeuse enregistre ensuite, à un âge estimé en fonction du rythme de tourbification à 4300-4200 BP, un lit de charbons qui peut être interprété comme le résultat d'une déforestation par brûlage d'une pinède à crochets, d'après l'analyse anthracologique (pin à crochets et bouleau). Le caractère anthropique de cet événement est suggéré par l'apparition du plantain lancéolé. La coïncidence est remarquable avec la datation du niveau de charbons de bois repéré à quelques dizaines de mètres du site 75, dans le sondage 5 (Ly-6242).

- *A l'échelle du versant*, d'autres indications sont fournies par le sondage de la tourbière du Pla de l'Orri, située sur un replat intermédiaire, à 2100 m d'altitude : vers 5300-5200 BP (âge estimé), le développement des oseilles, la présence des chénopodiacées et la diminution du pin pourraient attester la fréquentation par les troupeaux et d'éventuels déboisements à proximité. On note ensuite l'occurrence de *Plantago lanceolata* vers 4800 BP (âge estimé) puis le développement, vers 4310 ± 60 BP (Gif-9570), des Cichorioidées et des Armoises qui constituent des traces d'activités pastorales.

Ainsi, malgré l'apparente dispersion chronologique et spatiale des traces, des concordances entre données archéologiques, palynologiques et anthracologiques apparaissent à plusieurs reprises (fig. 2) qui conduisent à interpréter le tournant des IVe-IIIe millénaires non comme un démarrage soudain mais comme le prolongement d'une dynamique antérieure dont les pulsations sont faibles mais perceptibles. Le haut du versant est fréquenté par les troupeaux probablement dès la fin du Ve millénaire. L'activité pastorale progresse durant toute la période et l'utilisation régulière de ces zones situées à la limite supérieure de la forêt aboutit à une pérennisation et à une extension des pâturages dont témoignent les premières déforestations par le feu.

2 - DE L'AGE DU BRONZE AU HAUT MOYEN AGE : DES DYNAMIQUES DIVERGENTES A MODULER DANS L'ESPACE (fig. 3)

a) Les sites et leurs datations

Six datations seulement, réparties sur 5 cabanes, jalonnent les trois millénaires qui s'étendent du début des Ages des Métaux au haut Moyen Age. Celle de la cabane 49 mise à part, toutes sont relatives à une série d'habitats très proches dans l'espace puisque situés sur un même petit replat pastoral du bas de la montagne, vers 1900 m d'altitude : l'Orri d'en Corbill.

Archéologiquement, toutes ces datations sont recevables. Elles indiquent une occupation du replat à la charnière Bronze moyen / Bronze final (site 85), puis au deuxième Age du Fer et aux alentours du changement d'ère (cabane 82 et abri 83), enfin aux VIIe-IXe s. de notre ère (cabanes 81 et 82).

* La fouille du site 85 en est à ses débuts. Le caractère tout à fait inédit des vestiges (3 enclos de pierre sèche accolés) par rapport à la typologie reconnue pour les autres périodes et les autres secteurs de la montagne accrédite cette datation (Ly-8222).

* Sur la cabane 82, les 2 mesures ^{14}C effectuées sont en bonne cohérence avec la stratigraphie. Celle-ci présente en effet une succession de trois sols d'habitat : le plus ancien, daté des IVe-IIIe s. av. J.-C. (Ly-7061), est recouvert par un épais remblai formant la butte sur laquelle se sont installées les occupations postérieures : C3 niveau d'habitat probable mais pas certain, daté par un fragment de sigillée attribuable à la première moitié du Ier siècle ap. J.-C ; C2, cabane datée du VIIe s (Ly-7060).

L'abri sous roche 83, qu'il faut considérer comme l'annexe d'un habitat voisin, fut utilisé au Ier siècle de notre ère, ce qui paraît compatible avec les autres traces d'occupation contemporaines (Ly-7062).

* La cabane 81 (Ly-7519) est typologiquement très proche de la cabane 82 C2. Leurs datations respectives confirment cette parenté et l'on peut émettre l'hypothèse d'un transfert de l'habitat de l'une à l'autre.

Il n'y a donc pas ici de site important, occupé en continu, et dont on pourrait cerner et interpréter de façon significative les éventuels hiatus : l'histoire de ce petit replat dans la longue durée, est marquée par de fréquents déplacements des habitats et l'interruption de l'un d'entre eux ne peut être interprétée dans le sens d'un abandon durable du secteur.

b) La cohérence avec les données écologiques

Pour cette longue période, les données palynologiques font défaut pour la tourbière de Maurà en raison d'un hiatus entre la fin du Néolithique et les VIIIe-IXe s. ap. J.-C.

La tourbière du Pla de l'Orri enregistre, pour l'Age du Bronze, une augmentation progressive de la fréquentation par les troupeaux, en deux phases : un démarrage vers 2300/ 2100 av. J.-C., puis une affirmation vers les XVe-XIIIe s. av. J.-C. La concordance avec les résultats archéologiques est notable, surtout pour la deuxième période où les indices d'une ouverture des forêts avoisinant la tourbière et l'installation d'un site en contrebas (85) sont synchrones (respectivement 3000 BP, âge estimé, et 3107± 45 BP).

De l'Age du Fer au haut Moyen Age, la palynologie n'enregistre que de faibles variations, où l'on perçoit cependant deux dynamiques divergentes. 1) En altitude, une recolonisation durable des pinèdes subalpines s'amorce vers les Ve-IVe s. av. J.-C. et, malgré un bref essor pastoral vers 2000 BP, se maintient durant l'Antiquité ; en leur sein, une activité demeure cependant : une charbonnière, située à 200 m en aval du Pla de l'Orri, est datée de la fin du Ier siècle de notre ère (Gif-10920). 2) Sur la plaine et le piémont, la forêt montagnarde est dans un premier temps touchée par des déforestations (diminution du sapin, du hêtre et du chêne), puis se reconstitue durant le haut Moyen Age. A un niveau plus local, l'anthracologie met en évidence des évolutions plus significatives : l'Orri d'en Corbill est exploité, en continu ou en pointillé, pendant toute la période et particulièrement au haut Moyen Age, et l'étude des charbons de bois des différents sols d'habitat montre, d'une occupation à l'autre une progression des landes.

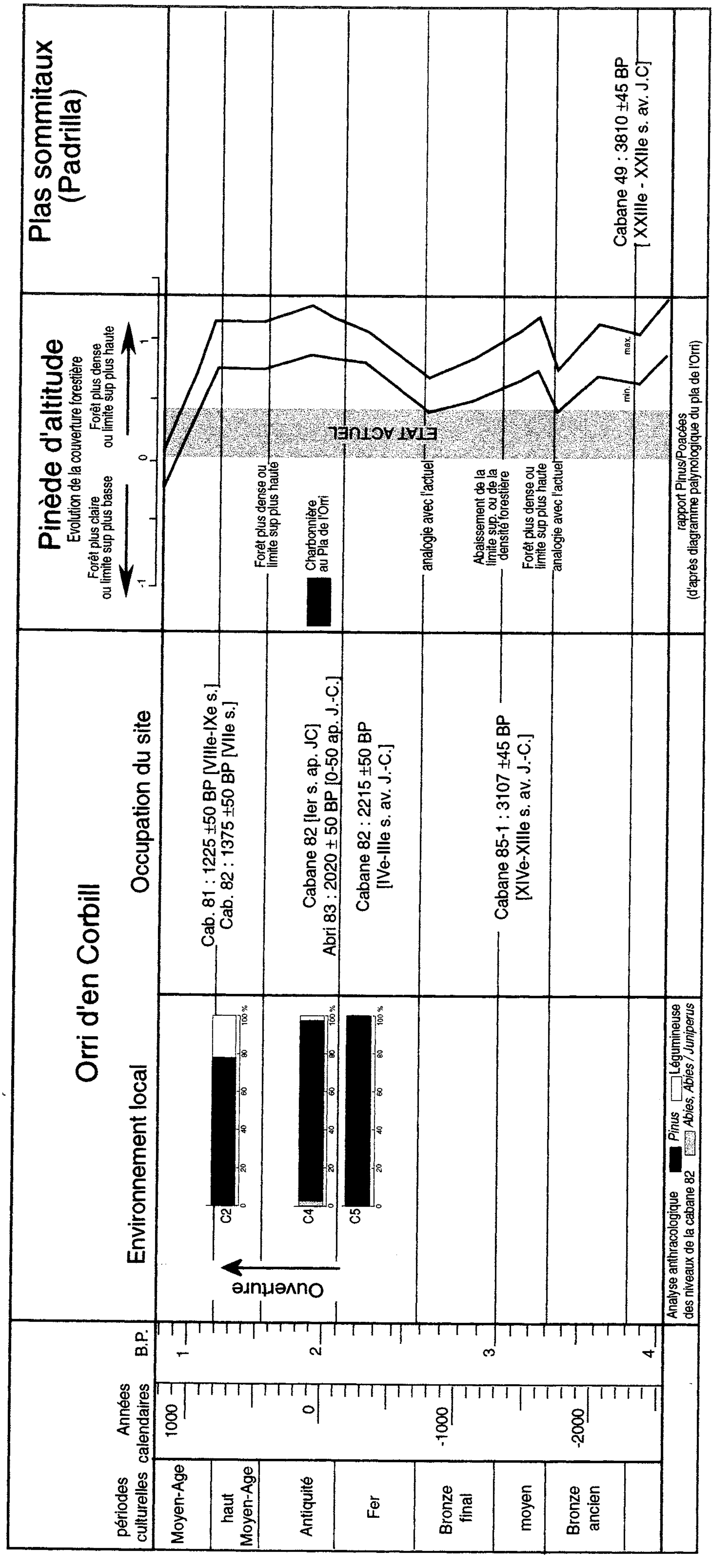

Fig. 3 : Rythmes et dynamiques d'exploitation de la montagne d'Enveig : de l'Age du Bronze au haut Moyen Age.

Devant des résultats si discordants, il faut recourir à une analyse plus fine qui pondère spatialement chacun de ces indices. Des phénomènes contemporains et en apparence contradictoires peuvent alors s'expliquer (fig. 3). L'Orri d'en Corbill présente en effet la particularité d'être situé dans une zone de transition. Même en période de recul pastoral, le secteur ne cesse d'appartenir à la zone parcourue par les troupeaux. Par ailleurs, l'endroit peut apparaître aussi comme l'ultime prolongement de la zone agricole. Il se révèle ainsi pouvoir participer d'un mode d'exploitation mixte faisant alterner, dans un système de type essartage, pastoralisme et agriculture précaire. Cette hypothèse est alors conciliable avec des données qui témoignent globalement d'une faible pression humaine, et localement d'un impact réel des activités humaines.

3 - DE L'AN MIL A NOS JOURS : LES CHRONOLOGIES RADIOCARBONE AU CRIBLE DES TEMPS HISTORIQUES (fig. 4)

a) Les sites et leurs datations

Quatre sites, tous localisés sur la partie la plus haute de la montagne, ont fait l'objet de 9 mesures ^{14}C échelonnées de l'an mil au XVIIIe siècle. Cinq autres ensembles qui n'ont pas été datés mais dont le matériel ou l'organisation permettent d'approcher la chronologie sont également attribuables à cette période.

* Datée du XIe siècle (Ly-5337), la cabane de Maurà 22 présentait, quand elle fut fouillée, une typologie encore inédite (ovale de pierres au pied d'un rocher). Depuis, d'autres cabanes ont pu être rattachées à ce type, et *grosso modo* à cette période, notamment la cabane 49 dans sa phase la plus récente.

* Le site de La Padrilla 42 est un ensemble complexe et important, comprenant une cabane de pierre sèche à plusieurs pièces et plusieurs enclos dont un couloir servant à la traite des brebis. Une première datation (Ly-5530) confirma l'hypothèse d'une parenté chrono-typologique avec l'établissement de Maurà 16, attribué par 2 monnaies au XVe s., mais la fouille devait, à La Padrilla, montrer de nombreux remaniements, jalonnant en fait une occupation quasiment continue du XIIIe au XIXe siècle. Parmi les 5 datations supplémentaires, qui ont permis de caler dans une chronologie absolue cette stratigraphie de référence, quatre sont parfaitement cohérentes. Ly-7538 est en revanche visiblement vieillie et doit être écartée puisqu'elle concerne la couche 3 de la structure 1, qui surmonte de plusieurs niveaux la couche 6, datée à deux reprises du XVe siècle (Ly-5530 et Ly-7495).

* La datation des cabanes 13 et 79 devait permettre de préciser le moment de l'apparition dans les habitats des banquettes de pierres, qui semblent un marqueur chronologique fiable. Les deux datations (Ly-7537 et Ly-7542) confirment plus qu'elles n'affinent les premières hypothèses, le phénomène étant supposé marquer la fin du XVIIe ou le début du XVIIIe siècle. Du moins sont-elles parfaitement concordantes.

Dans leur état actuel, qui reste lacunaire, ces données archéologiques laissent envisager trois phases médiévales : XIe et XIIe siècles : cabanes en matériaux légers, adossées à des rochers ; XIIIe s. : installation d'un grand site dans la construction duquel domine encore, probablement, le bois ; XVe siècle : apparition des grands établissements pastoraux en pierres sèches qui, avec d'importants remaniements ou de nouvelles typologies, marqueront toute la période moderne et contemporaine.

b) La cohérence avec les données écologiques

Les courbes des indicateurs de l'activité humaine, pour les deux tourbières, s'harmonisent et montrent une expansion médiévale très forte, en deux temps (en parfait accord avec les sources historiques) :

1) Amorce des déforestations et essor des activités pastorales entre le IXe et le XIe s. D'un point de vue local, il existe une cohérence remarquable entre la datation de la cabane 22 et celle d'un niveau de charbons - attribuable à une déforestation d'une pinède à crochets (analyse anthracologique) - conservé dans la tourbière de Maurà, située à 200 m en aval de ce site (Gif-9576).

2) Apogée de l'activité pastorale à la fin du XIIIe siècle et durant une partie du XIVe siècle.

Postérieurement, les données palynologiques font unanimement apparaître une phase de recul des activités humaines. Le point d'inflexion se situe au XIVe siècle et cette déprise se prolonge durant le XVe siècle : baisse des indicateurs anthropiques, hausse du pin qui montrerait une reprise forestière consécutive à la diminution locale de la pression pastorale. La reprise s'amorce au XVIe siècle au Pla de l'Orri, plus tardivement à Maurà.

Or de cette forte récession, l'archéologie ne trahit rien puisqu'elle rend compte au contraire d'un mouvement continu de consolidation, de pérennisation et d'expansion des sites.

Cette discordance ne peut tenir ici qu'à la grossièreté de la maille chronologique : d'un côté, en effet, le maximum de l'effondrement démographique et économique des années 1370-1420 reste pour l'instant imperceptible dans la seule séquence archéologique qui couvre cette période ; de l'autre, la palynologie au contraire amplifie cette crise et l'étend dans la durée parce qu'elle en saisit les effets selon une temporalité propre aux phénomènes écologiques : les filtres ne sont pas les mêmes, selon que l'on mesure en générations d'arbres ou en générations d'hommes et certains décalages chronologiques peuvent, à l'image de celui-ci, révéler non une incohérence mais précisément cette complexité.

CONCLUSION

Cette série de près de 30 mesures dont les résultats sont dans l'ensemble extrêmement cohérents confirme qu'en l'absence de traceurs culturels, le recours aux datations radiocarbone offre le seul moyen de replacer, dans la longue durée des sociétés rurales, les césures principales de l'histoire d'un paysage et d'un système pastoral. Mais si globalement, les transformations de l'environnement et celles des sites suivent un même rythme d'évolution, certains décalages ou certaines contradictions demeurent, toutefois, entre les différentes séquences. Ils permettent alors d'affiner la perception des processus et des interactions à l'œuvre au sein de ces phénomènes d'anthropisation du milieu montagnard.

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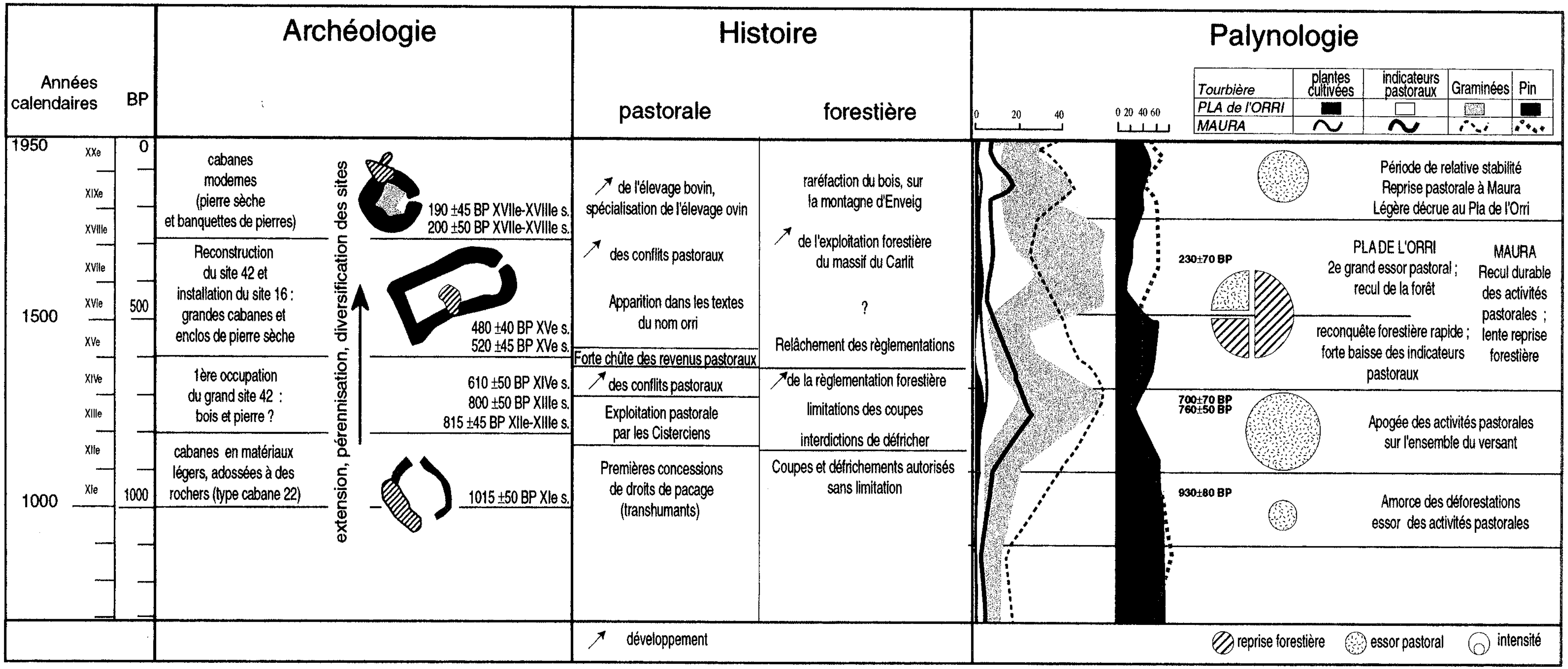

Fig. 4 : Rythmes et dynamiques d'exploitation de la montagne d'Enveig : du Moyen Age à nos jours.

Actes du colloque « C14 Archéologie », 1998, p. 419-423.

DATATION PAR LE RADIOCARBONE DES ATELIERS DE POTIERS MÉDIÉVAUX DE CABRERA D'ANOIA EN CATALOGNE

Ignaci PADILLA, Jacques THIRIOT **, Jacques EVIN*** et Joan MESTRES*****

Résumé : Les principaux résultats des fouilles des ateliers de montagne de Cabrera sont rappelés rapidement. Plusieurs grottes, abris et aires de travail permettent de définir une évolution type des installations. Près de 40 fours sont disposés en séries parallèles que l'archéologie n'arrive pas à différencier chronologiquement. Treize échantillons de charbon de bois ont été étudiés pour le moment ; ils suggèrent une certaine logique dans l'évolution spaciale des fours et des ateliers.

Abstact : The main results obtained by excavating the mountain workshop of Cabrera are submarised. Grottoes, rock-shelters, working areas lead to the definition of a special type of evolution. Almost 40 ovens laying in parrallel series cannot be chronologically separated by the archaeological data. 13 dated charcoal samples indicate a rather logical spacial evolution for the ovens and the work-shops.

Mots-clés : Datation radiocarbone, four de potier, atelier, Catalogne, Espagne, Moyen-Age.

Key-words : Radiocarbon dating, potter-oven, work-shop, Catalonia, Spain, Middle Age.

INTRODUCTION

L'éperon barré du *Castrum* de Cabrera surplombe la vallée encaissée de l'Anoia à quelques 50 km au nord-ouest de Barcelone. Les ateliers de potiers médiévaux sont installés à proximité dans une zone à relief accentué et sous abris rocheux à une altitude moyenne de 350 m. Leur importance régionale est probable. Le caractère nouveau de cette officine «de montagne» a motivé une fouille avec l'aide de la Généralité de Catalogne et du Ministère français des Affaires étrangères, en associant d'autres équipes pour les études complémentaires et en particulier pour les datations par le radiocarbone et l'archéomagnétisme (Lopez & Nieto, 1979 ; Leenhardt *et al.,* 1993 et 1995). L'essentiel des résultats obtenus est résumé ici alors que l'étude d'ensemble de la documentation recueillie n'est pas achevée et qu'on attende encore des résultats d'analyse. Mais, en l'absence de fouille exhaustive, les datations radiocarbone permettent de formuler différentes hypothèses pour l'organisation générale et la chronologie de ces ateliers à poteries grises des IX à XVe siècles.

LES DONNÉES ARCHÉOLOGIQUES

LE SITE ET LA RÉPARTITION DES ESPACES FOUILLÉS

Le substat du site est constitué par du granite plus ou moins altéré sous des strates de travertin. L'ensemble est fracturé en différents endroits et constitue le substrat du plateau et le socle du *castrum.* Face à l'érosion, les couches plus tendres du granite sont minées et provoquent la chute du chapeau de travertin dont les blocs viennent s'empiler petit à petit dans la pente. Dans cette zone à fort relief ne laissant que peu de surface horizontale à cet artisanat (le plateau ne semblant pas être occupé par les potiers), l'occupation des zones disponibles est intensive. Le relief d'origine est même transformé petit à petit par l'exploitation des matériaux, par la construction quasi permanente de nouveaux fours dans des zones vierges et par la libération de nouveaux espaces.

La fouille a été faite sur trois zones du site (fig. 1) : deux abris, un au sud, l'autre au nord, séparés par un sondage dans la zone médiane. L'étude précise des abris a

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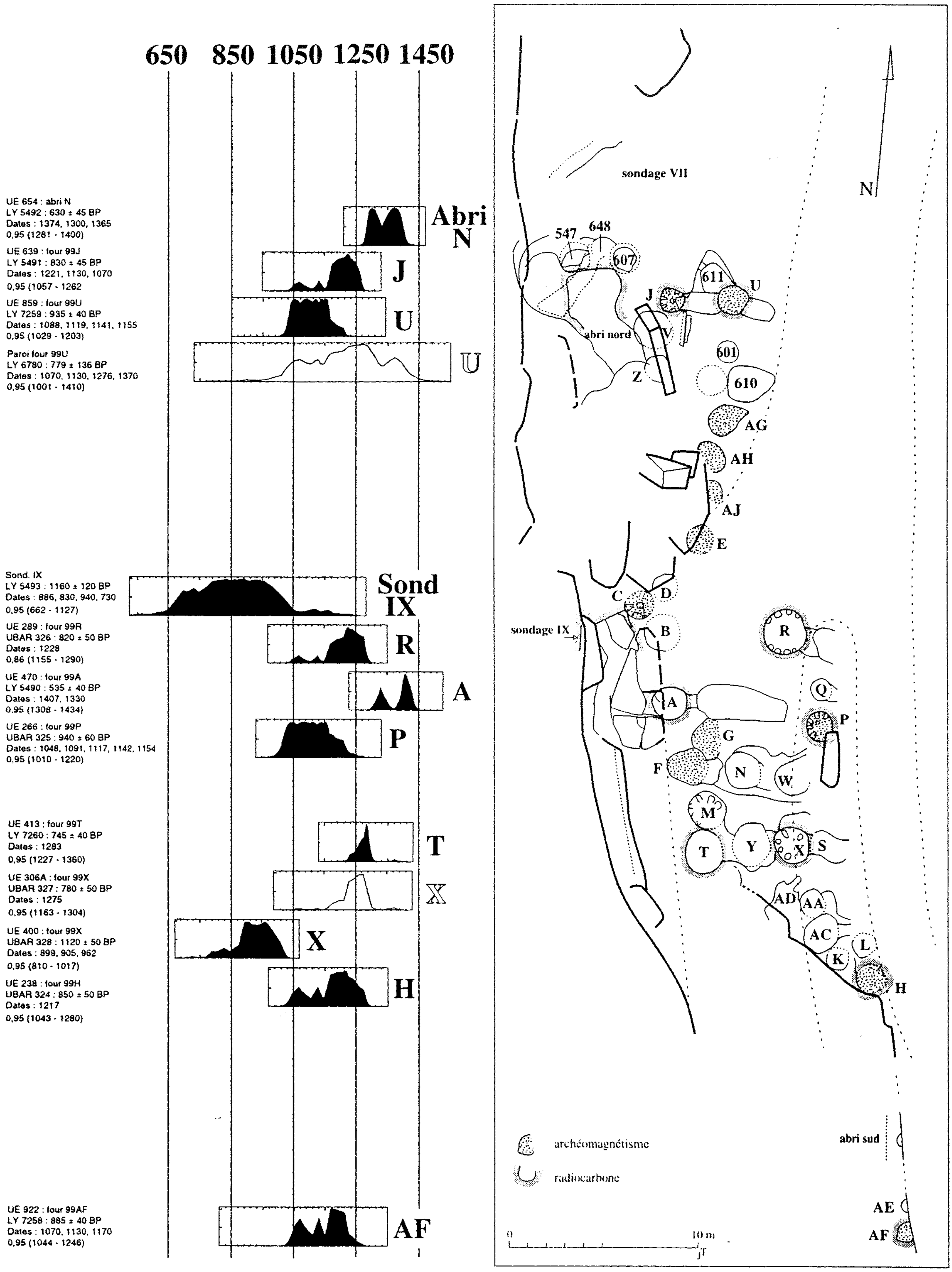

Fig. 1 : Plan simplifié des zones fouillées du site de Cabrera d'Anoia et des points de prélèvements des échantillons pour les datations radiocarbone et les mesures d'archéomagnétisme.

surtout été menée au nord. Des indices ont été relevés dans la zone médiane et la fouille, en dernier lieu, d'un abri totalement conservé au sud vers le *Castrum* a permis de généraliser les observation faites dans les autres zones.

Le sondage IX (fig. 2) : Comme la trace de la paroi fermant l'abri est conservée sur quelques dizaines de centimètres de hauteur, une grotte peut donc être restituée en «remontant» à leur place originelle les blocs de travertin, les blocs de granite trouvés en-dessous et la paroi. Les couches terreuses d'occupation donnent peu de renseignements sur l'utilité d'un tel espace confiné : extraction d'argile maigre, stockage de l'argile, séchage des poteries ou remisage de matériel (présence de plaques de schiste). La progression des fours sur une ligne de plus grande pente aboutit au creusement d'un dernier four (four C) dans la paroi de la grotte. Son fonctionnement déstabilise le granite aboutissant à la destruction du four et de la paroi de la grotte pour la transformer en abri ouvert. Le sol de l'abri est constitué des couches d'occupation de la grotte surmontées de remblais provenant de ces destructions.

L'abri nord : La fouille a été particulièrement difficile à cause de l'identité de matériau entre le substrat géologique, les blocs de remplissage après abandon, les sables d'érosion durcis, les matériaux éventuels de construction et la matière première travaillée par les potiers. Plusieurs grottes (ou une grotte évolutive) sont assez bien marquées. La progression pourrait s'accompagner de l'avancée des fours Z, puis V, puis 607 et 547 qui entraîne la destruction progressive de la paroi de la grotte. Les traces de l'occupation dans cet abri sont rares : des tas de mottes d'argile granitique de diverses couleurs, un percuteur de quartzite, une nappe argilo-sableuse qui pourrait indiquer la position d'une tournette et des fragments des plaques de schiste utilisées sur la girelle pour le façonnage des pots.

L'abri sud : La fouille a mis en évidence un atelier encore bien conservé où la progression grotte/abri et la trace des derniers fours a pu confirmer le schéma évolutif envisager dans les autres parties du site.

L'ÉVOLUTION DE L'OCCUPATION DU SITE

Dans ce relief accentué de pied de falaise, des plans horizontaux sont créés artificiellement par le creusement puis l'abandon de fours et par l'évolution des grottes en abris. Pour trouver de la place les potiers sont contraints de se déplacer au pied et le long de la falaise. De plus ils élargissent l'espace libre en perçant des grottes en arrière du front de falaise. Lorsque la totalité de l'espace a été utilisée par les fours successifs et que les derniers fours ont entamé la paroi de la grotte au point de la faire disparaître, l'abri ainsi formé constitue un espace approximativement plan qui est transformé en atelier. L'évolution s'achève avec l'écroulement de l'abri.

LES FOURS

Le façonnage des pots fait appel au modelage au colombin sur la tournette d'une pâte granitique cuite en atmosphère réductrice dans des fours. Pour la chronologie même relative des différents fours et des installations, la céramologie est en fait peu utile.

Deux types de fours, de petit et de grand diamètre, paraissent utilisés en même temps, les petits étant les plus nombreux. Ce sont des fours circulaires à tirage vertical qui sont taillés dans le substrat granitique suivant les lignes de plus grande pente. L'accès au foyer par tranchée ou fosse plus large se fait toujours en aval du four. L'abandon d'un four donne la place d'un accès à un nouveau four en amont dans une zone vierge.

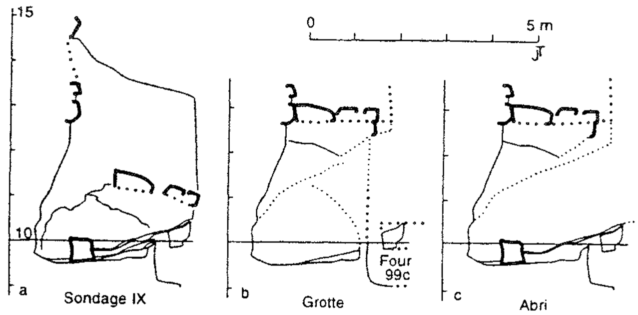

Fig. 2 : Le sondage IX : coupe et essais de restitution de la grotte et de l'abri en ce point du site.

L'évolution de l'implantation des fours est fixée par la stratigraphie de remplissage des fosses et des dépotoirs. Il apparaît une certaine chronologie relative de séries de 4 à 5 fours. Près de 40 fours ont été dégagés plus ou moins complètement dans la zone étudiée.

LES DATATIONS RADIOCARBONE

LA SÉLECTION DES DATES

D'après les intervalles de temps obtenus par les 13 datations radiocarbone (fig. 1 et tab. I), la période d'activité de la zone étudiée peut s'étaler du VIIe au milieu XVe siècles, mais une durée plus courte est possible. En effet deux datations ont des fourchettes très larges : Ly-6780 (780 +/- 135) sur le carbone de la paroi du four U, dans l'abri nord et Ly-5493 (1160 +/- 120) sur une très petite quantite de charbon dans le sondage IX.

L'ANALYSE PAR GROUPE DE DATES

Une fois éliminées ces deux datations à marge trop large, à partir des 11 autres datations on peut faire l'analyse suivante en tenant compte de la position de chaque four dans la série de fours auquel il appartient. La numérotation des groupes ci-dessous suit la position des ensembles de fours dans le site, du Nord au Sud. elle n'implique aucune chronologie car les fours de différents groupes peuvent se chevaucher dans le temps.

- **Groupe I** : le four J, qui n'est pas tout à fait en fin de sa série, est comparable au four R du groupe II tandis que le four de l'abri nord est très récent et pourrait correspondre à l'abandon des derniers fours (607 et 547).
- **Groupe II** : les fours P et R, qui ne sont pas en début de leur série paraisent l'un (P) un peu antérieur et l'autre (R) contemporain du four H qui est à la fin de la série du groupe suivant, tandis que le four A, qui est en fin de série, est plus récent que ce four H. Ceci semble, d'une part prouver la progression vers le nord des ateliers et d'autre part dater la transformation en abri de la grotte correspondant aux fours A, B et C. Le sondage IX, qui correspond à une grotte, est nettement plus ancien et son utilisation en grotte pourrait correspondre au groupe suivant.
- **Groupe III** : pour le four X, qui n'est pas le premier de la série, il y a deux datations (UBAR-328 et UBAR 327), il semble préférable de ne prendre en compte que

GROUPE I	GROUPE II	GROUPE III	GROUPE IV
	Sondage IX : Ly-5493 1160 +/- 120 BP (662 à 1127) ap J.C.	Four X : UBAR-328 1120 +/- 50 BP (810 à 1107) ap J.C.	
Four U : Ly-7259 935 +/- 40 BP (1029 à 1209) ap J.C.	Four P : UBAR-325 940 +/- 60 BP (1010 à 1220) ap J.C.		
Four J : Ly-5491 830 +/- 45 BP (1057 à 1262) ap J.C.	Four R : UBAR-326 820 +/- 50 BP (1049 à 1290) ap J.C.	Four H : UBAR-324 850 +/- 50 BP (1043 à 1280) ap J.C.	Four AF : Ly-7258 885 +/- 40 BP (1044 à 1246) ap J.C.
Four U : Ly-6780 780 +/- 35 (1001 à 1410) ap J.C.		Four T : Ly-7260 745 +/- 40 BP (1227 à 1360) ap J.C.	
Abri N : Ly - 5492 630 +/- 45 BP (1281 à 1600 ap J.C.		Four X : UBAR-327 780 +/- 50 BP (1063 à 1304) ap J.C.	
	Four A : Ly-5490 535 +/- 40 BP (1308 à 1434) ap J.C.		

Tab. I : Les datations radiocarbone.

la première en raison de la position du four dans le site. Il serait donc antérieur de plus d'un siècle aux autres fours et se trouverait contemporain de la grotte du sondage IX. Les fours T et H, en fin de série, concordent approximativement, le four H pouvant être le plus ancien. Ils correspondent à la transformation en abri de la grotte correspondant aux fours M et T.

- **Groupe IV** : le four AF, en fin de série, a la même datation que le four H. Donc les séries du four AF, d'une part, et T, X, et H, d'autre part, peuvent avoir la même date de fin ils n'ont pas forcément la même date de début.

LA SYNTHÈSE DE L'ENSEMBLE DES DATES

De ces constats, on peut proposer plusieurs états successifs de la zone médiane du site (fig. 3) :

- Phase 1 : au débouché d'une faille majeure, un premier atelier, sous abri peu profond et complété par des grottes assez profondes, utilise la pente d'accès pour le séchage des pots. Les fours sans doute assez dispersés vers le nord s'avancent vers la falaise. Dans la pente, les fours abandonnés sont recouverts par les dépotoirs.

- Phase 2 : l'achèvement des premières séries de fours entraîne le déplacement de l'abri et de l'aire de séchage sur ces fours abandonnés. Les dépotoirs progressent. Les fours semblent se développer au nord. De nombreux fours dateraient de cette période (J, U, P, H et AF).

- Phase 3 : l'ouverture de la grotte du sondage IX en abri et le creusement d'une autre au nord entraîne un déplacement général de l'ensemble vers le nord (dates des fours Abri nord et A) qui se serait produit à la fin de l'occupation du site.

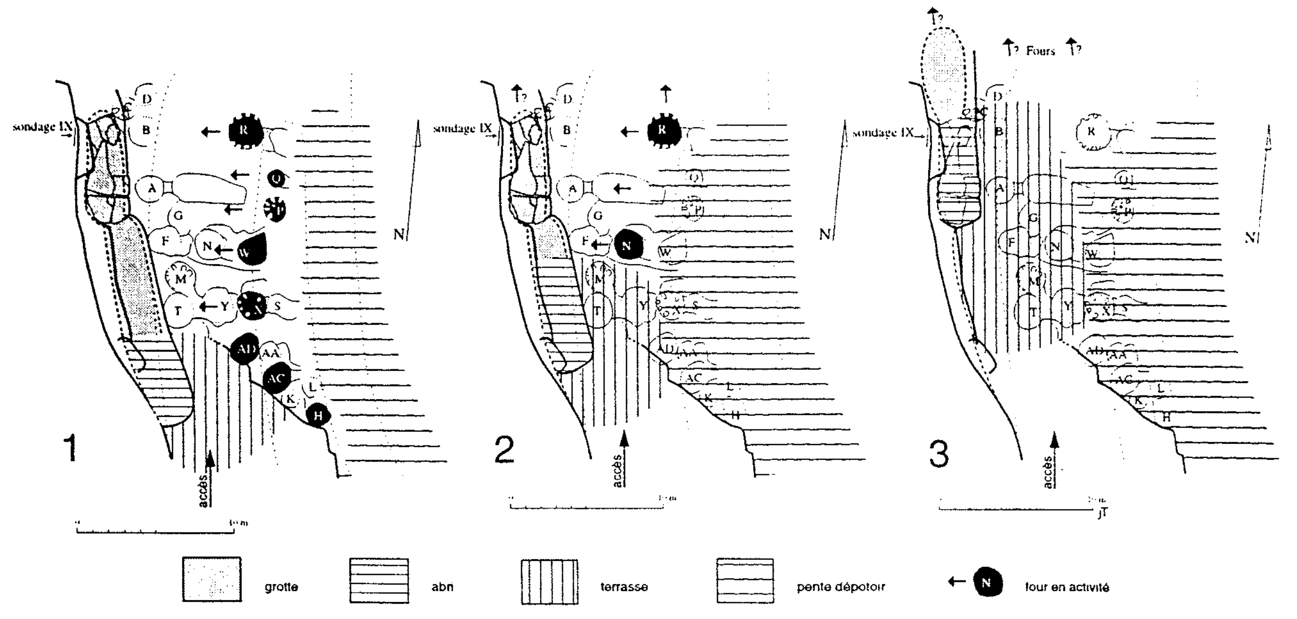

Fig. 3 : Proposition d'évolution en trois phases d'une partie des ateliers.

CONCLUSION

Ainsi la fouille de plusieurs séries de fours et la datation d'une dizaine d'échantillons ont permis de suivre l'évolution d'occupation d'un atelier, situé en zone montagneuse et adapté à un relief accentué. Elles ont conduit à mettre en évidence un modèle nouveau d'implantation d'activité médiévale artisanale en terrain accidenté qui se distingue bien de celui que l'on trouve sur terrain plat ouvert où les implantations de four sont plus libres de s'étendre.

Les datations de laboratoire permettent d'organiser et de séquencer l'évolution spatio-temporelle des installations et des productions. Elles seront ultérieurement complétées par une série d'analyses archéométriques pour lesquelles des prélèvements ont déjà été effectués (fig. 1). On voit que l'interprétation des datations est ici étroitement liée aux informations archéologiques.

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BUILDING ARCHAEOLOGY, ^{14}C AND THERMOLUMINESCENCE : TWO EXAMPLES COMPARISON

Nicola GALLO, Laura FIENI**, Marco MARTINI*** and Emanuela SIBILIA****

Abstract : Among the various elements that constitute buildings, the binding is the only one which cannot be re-employed, and therefore its dating has a particular interest. If the direct dating of the mortar by means of ^{14}C presents some difficulties, the dating of the charcoals, laying inside, is practiced. However problems arise due to indeterminate factors related to the direct association between the age of the charcoals and the mortar age. The use of another archeometric technique, thermoluminescence, is complementary to the ^{14}C method in particular circumstances in which mortars contain lateritious fragments (Castello Aghinolfi) or in the cases in which we want to check, in the lateritious masonry, the belonging of the bricks and that of the mortar to the same period (Battistero del Duomo di Milano). In both cases the necessity of working under strict stratigraphic control, in order to avoid interpretation risks for the archeometric data is detected in its whole importance.

Résumé : Parmi les différents éléments qui composent les bâtiments, le liant est le seul qui ne peut pas être réemployé. Pour celà la datation du mortier avec le C14 donne quelque difficulté ; on pratique la datation des charbons qui se trouvent à l'intérieur. Il existe toutefois des problèmes dus aux facteurs d'indétermination concernant l'association directe entre l'âge des charbons et celle du mortier. Le recours à une autre technique archéométrique, la thermoluminescence, se révèle complémentaire à celle du C14 dans les circonstances particulières dans lesquelles les mortiers présentent à l'intérieur des briques broyées (Castello Aghinolfi) ou dans le cas où l'on veuille vérifier dans les maçonneries en brique l'appartenance des briques et du mortier à une même période (Baptistère du Dôme de Milan). Dans les deux cas, on relève dans toute son importance la nécessité d'opérer sous un strict contrôle stratigraphique afin d'éviter des risques d'interprétation de l'élément archéométrique.

Key-words : Radiocarbon, thermoluminescence, mortar, brick.

Mots-clés : Radiocarbone, thermoluminescence, mortier, brique.

INTRODUCTION

Building archeology has its basis in the stratigraphic reading of the structures which retain, more often than not, evident traces of their historic past. The stratigraphic interpretation permits the individualization of the different building phases and associates them into sequencial order, following logical paths. The main problem is to link the different construction phases, traceable in the same building, to a real historic chronology ; being able to therefore understand the monument history by analyzing the material aspects. Often natural, political, historic or military events leave indelible signs in the architecture. Extensions and abandonments of the structure, but above all demolitions and reconstruction, correspond to actions associated to each other in temporal horizons which vary from a period of centuries to days. Dating therefore of the single stratigraphic units is one of the most frequent problems for one who studies architecture archeology. As a result, in the field of direct dating, the topic of absolute dating is considered to be among the most interesting because it can provide a chronologic frame of reference. Ceramic fragments, bricks, lateritious products, charcoals, wooden beams, epigraphs, etc. represent absolute chronological indicators, when subjected to archeometric studies (epigraph exempted). However, these chronological indicators when found in monuments necessitate critical interpretation. It is possible for example to find buildings with epigraphs not indicating real events, ancient bricks re-employed, recent wooden beams substituting original beams, ancient or more recent ceramic fragments fixed

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in ancient wall structures. It is in these cirmcustances that data obtained from archeometry requires careful analysis. It is helpful to observe that in masonry buildings the various archeometric datable elements form aggregated objects, held together by a single component, the binding, that unlike the other components, cannot be re-employed. The ability to direct date the mortar considerably reduces the margin of error inherent to re-employment events. The direct dating of the calcium carbonate, through radiocarbon or thermoluminescence techniques, may pose more than a few problems according to scientific references, and may result in significant margin of error. However, chronological indications may be taken from the mortar by way of analysis of the matrix components traceable and archeometrically datable such as lateritic fragments and charcoals. In this case too however there are associated problems, some due to interpretative factors and others due to possible material re-employment as in the previous cases. The carbon fragments, traceable in the mortar, usually are associated with the combustion process utilized in limestone firing, a process necessary to obtain the oxidation of the calcium. Some carbon fragments may remain in the lime and become mixed with the final product : the mortar. There are now two problems requiring interpretation related to the degree of the dating credibility as a function of the archeologic event. The first pertains to the relationship between the examined charcoal and its position inside the tree structure. The second pertains to the time passed between the tree death and its wood combustion. With regard to the first problem, it is known that if the fragment came from the central rings of a large tree trunk, the dating would refer to not the tree felling but rather to the period in which there was less equilibrium between the ^{14}C present in the atmosphere and that present in the ring of that sample. With regard to the second problem, we can observe that even if a special combustible could have been used, we cannot exclude the fact that nonusable wood or old beams could have been burned. The time elapsed between the death of the tree and its employment as a combustible is not quantifiable and it can therefore present an indeterminate situation. Even ceramic fragments present inside the mortar and datable with thermoluminescence present the risk of having been reused : that is, old or ancient brick fragments included in the mortar. In conducting research, it may be useful, when possible, to associate dating techniques in order to conceive the most valid scheme. In order to obtain more reliable datings of the binding it is possible to use thermoluminescence on the lateritious fragments, if present, in addition to ^{14}C on the charcoals included in the mortar itself. Analysis of this type at Castello Aghinolfi have revealed unexpected stratifications within the mortar. In the case of brick masonry, it is useful to employ both these techniques, applying thermoluminescence to bricks and the ^{14}C to the small charcoals included in the mortar to verify similar age of the two components. The experience has provided useful knowledge in the case of Battistero di San Giovanni alle Fonti di Milano.

THERMOLUMINESCENCE DATING : A SHORT SUMMARY

After demonstration of feasibility in 1960, TL came to fruition as a dating technique during the seventies and has reached in recent years a great number of successful results. TL dating techniques are complementary to Radiocarbon dating : while the latter is applied to organic materials, by means of TL dating all clay materials submitted to some kind of heating in the past can be dated. The basic principlesand procedures which are the basis of TL dating have been thoroughly discussed in various papers and books : a complete bibliography can be found in Aitken (1985). In the following we will just report a simplified description of the method, briefly summarising the main experimental sources of uncertainty. Most clay constituents are thermoluminescent, (they «store» electrons in deep traps when alpha, beta and gamma radiation passes through them). A heating of the clay releases the electrons from the traps, and the excess energy is delivered in form of light : thermoluminescence. The act of pottery firing reduces the previous «geological» TL of the constituent minerals to zero : subsequently the TL signal increases with age, the growth rate depending on radioactivecontent of the pottery and of burial soil. Once the total level of TL in a sample measured, and therefore the related quantity of absorbed radiation, and the radioactivity content of both ceramic paste and burial soil known, the basic age equation for TL dating is : AGE (years) = Total Absorbed Dose/Annual Dose Rate.

The total absorbed dose is obtained from the measure of the sample TL, calibrated by artificial irradiation. Its evaluation can be difficult or even impossible when spurious thermoluminescence, an intrinsic non dose-dependent emission (Martini *et al.*, 1988) is present, and in the presence of irregular fading, a leakage of trapped electrons during antiquity, due to the instability of high temperature peaks (Wintle, 1978). In order to obtain the annual dose-rate, three main quantities must be determined : alpha, beta and gamma dose-rates. Additional correction factors take into account possible radioactive disequilibria and environmental situations : namely the precise contribution of thorium vs. uranium (TH/U ratio), the extent of radon escape and the water content of the sherd (water absorbs radiation, reducing the effective dose). Difficulties in calculating or estimating this last quantity is one of the main sources of uncertainty in TL dating and in the resulting final date that otherwise can be calculated with an error of ± 5- 9% (Aitken, 1985).

EXPERIMENTAL DETAILS AND DATING RESULTS

TL dating analyses were performed on the samples described in table 1. The samples were dated using the fine-grain technique (Zimmermann, 1971). Their thermoluminescence properties appear quite good, except for D1225, whose TL sensitivity was so low to prevent the evaluation of the total absorbed dose, probably as a consequence of the high temperature reached by the sample. In all the other samples, spurious TL is absent, reproducibility is high and the fading tests performed at 200°C revealed the stability of TL high temperature peaks.

Alpha and beta dose-rates are obtained by total alpha counting and flame photometry ; gamma dose-rates derive from radioactivity measurements of excavation soils and, for Milano, from a direct in situ measurements with ionisation chamber for ambiental dosimetry. For the sample D1223 we measured a potassium content higher than 5 %, while the usual concentration in ceramic is lower than 2 %. In such a case, the sample must be rejected, due to a possible contamination.

On the basis of the laboratory tests on sherd porosity and from the available information on the humidity of

Site	Sample	Description	Position	Stratigraphy	Total Absorbed Dose (Gy)	Annual Dose-Rate (mGy/y)	Age (Years)	TL Date
Castello Aghinolfi								
	D1173	ceramic	prospect E	USM 8 T5	3.52±0.11	5.48±0.39	644±57	1353±57 AD
	D1174	ceramic	prospect E	USM 8 T6	2.63±0.17	3.97±0.29	664±59	1333±59 AD
	D1222	ceramic	prospect E	USM 8 T1	3.26±0.20	5.10±0.35	629±64	1369±64 AD
	D1223	ceramic	prospect E	USM 8 T2				
	D1224	ceramic	prospect E	USM 8 T3	3.34±0.14	5.42±0.28	616±50	1389±50 AD
	D1225	scoria	prospect E	USM 8 T4				
Duomo di Milano excavations, Baptistry								
	D1148	ceramic	angular pillar		8.52±0.57	5.27±0.49	1619±155	378±160 AD
	D1149	ceramic	angular pillar		10.37±0.84	6.50±0.29	1596±150	401±150 AD

Tab. 1 : Description of samples.

the sites, the following percentages of water for the attenuation due to the H_2O content during burial have been assumed : sherds 15+20 % ; soils 18+5 %.

Tab. I reports, for each sample, the Total Absorbed Dose, the Annual Dose-Rate, the derived Age and the corresponding TL date, together with the overall error. There will be a probability of 68 % that the true age lies within the limits indicated by the error, and a 95.5 % probability that it lies within limits twice as wide.

CASTLE AGHINOLFI OF MONTIGNOSO

This ancient installation constitutes an interesting case study due to its characteristic and particular architectural structure and from a very rich written documentation which provides evidence of a historic past, animated by political and military events that occurred between the early middle ages to the end of the 18th Century. An initial investigation based on a study of stonework construction, has concluded that the octagonal tower is the oldest portion. The octagonal tower, 20 m in diameter contains an internal smaller tower. The stone walls were not constructed in a continuous period and reveal numerous modifications and resurfacing episodes that are easily identifiable. The architectonic important stonework produced many historic questions about its interpretation, about the workers who realized it and above all, about the customer who requested it. The absence of a date, even approximate, made difficult any possible explanation or assessment of the building phases. The research is documented in independent but unrelated studies. The following sources have been analysed : written documentation, architectural and stylistic elements, construction techniques, archeological excavations, sectional stratigraphy and archeometric information.

WRITTEN DOCUMENTATION

The most ancient written documentation dates from the VIII century where two parchments dated in the middle of the same century, appeared a citation of "Castellum Aghinolfi". The written sources, chronolistic and certified, do not report direct information connected with the existing medieval existing structures or more specifically, the aforementioned tower. Information of interest arises from these analysis of these sources : during the period between the middle of the XI century and the middle of the XII century, the castle is frequented by illustrious people. This circumstance gives to the fortification not only military but also residential status, as would be decerned by the characteristics of the octagonal structure. In 1063, Anselmo da Baggio, bishop of Lucca and Pope, known as Alessandro II, was at the Aghinolfi castle. In the following century, between 1138 and 1144, Lucca conquered the castle and it became the site where the archbishop of Pisa, Cardinal Baldovino, a very important figure of religious Italy of the XII century, was imprisoned.

ARCHITECTONIC AND STYLISTIC ELEMENTS

The large dimension and the bichrome decoration suggests that the structure has, in addition to a military function, a residential function as well due to its architectural similarity to a palace-residence typical of the period from the early middle ages to the middle of the XIII Century. There are considerable problems with determining stylistic datings and to set in time this kind of architecture whose historic and architectonic importance, even today, is little known. In the absence of sufficient information, we can only consider that in extra-urban areas, residential towers of polygonal shape do not appear in fortifications toward the end of the XIII Century.

THE BUILDING TECHNIQUE IN THE MOST ANCIENT PHASES

The most ancient building phases display a particular "pseudoisodoma" masonry structure divided into horizontal lines showing medium-large dimension blocks, obtained from a tender cavernous and carefully squared limestone. The good finish level of the blocks allow the fulfilment of almost perfect junctions. With a comprehensive analysis it is possible to conclude that the kind of apparatus establishing the oldest building phases, characterizes, in the military works of Liguria and Tuscany, masonry structures belonging to a period not prior to the end of the XII century.

ARCHEOLOGIC EXCAVATION

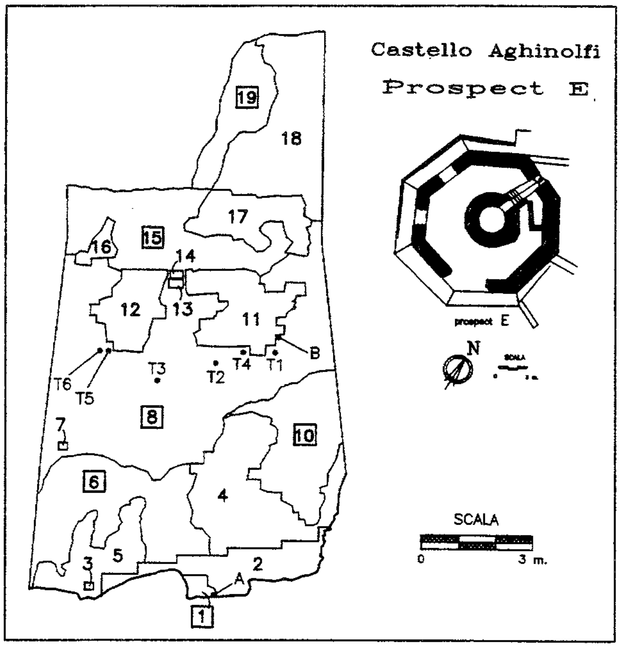
In the summer 1997 a first excavation, in the vicinity of the foundations of the prospect "E", was performed by ISCUM to obtain ground stratigraphic information. The excavation, whose results will be carefully explained elsewhere, brought the foundations to light individualizing some levels of use with metallic findings : interesting but useless for any dating.

BUILDING STRATIGRAPHY AND ARCHEOMETRIC DATA OBTAINED FROM THE BINDINGS

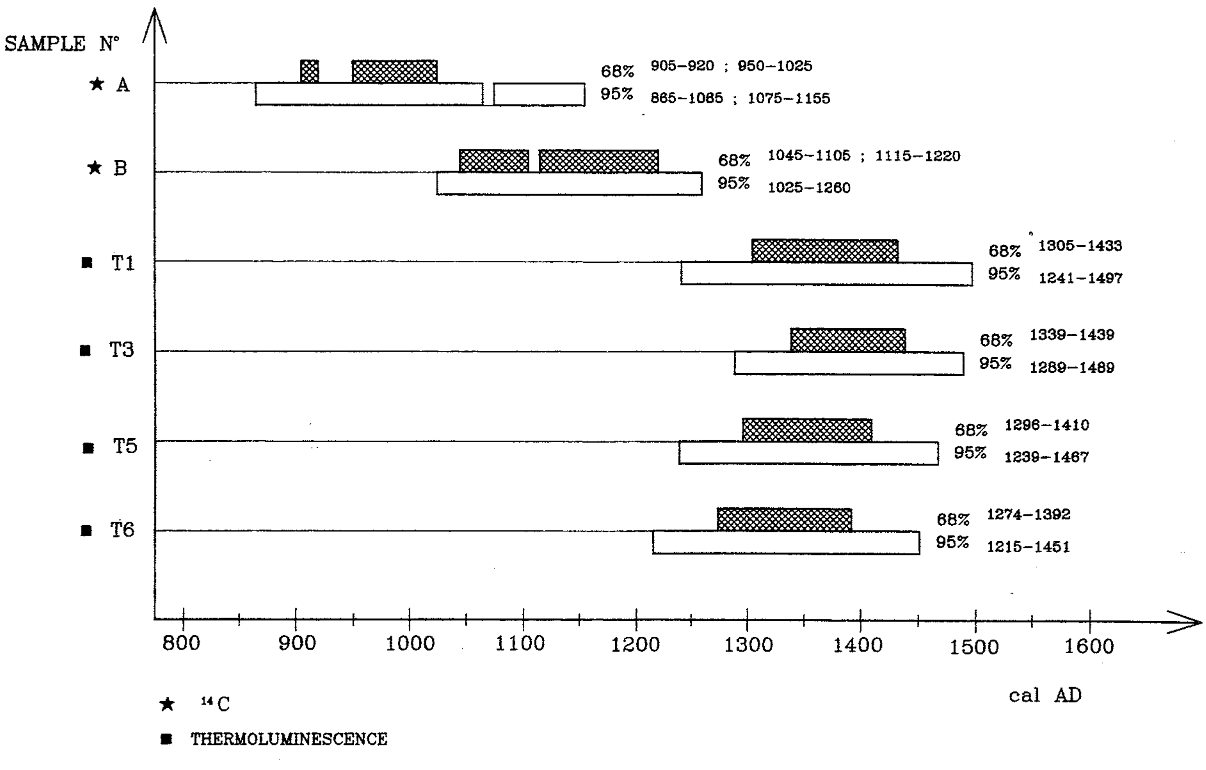
In order to obtain chronological information from the archeometrically datable elements included in the bindings, the drafting of a stratigraphic survey was done to obtain an organic and rational reference for the final discussion of the results.

Among the stratigraphic prospectives, the one indicated with the letter "E" appears to be the most interesting to study because it is characterized by different building phases and the decay of large portions of the mansory surface, with the consequent exposition of inner nucleus : the filling. The stratigraphic analysis indicates the presence, in the prospective, of different stratigraphic units taking part of many building phases. The most ancient building phase corresponds to USM n. 2, 12, 11, 13, 14, 7 (Pic. 1). These units are not placed homogeneously : some are the foundations while others are at a height of 5-6 m from the ground and are separated from each other by USM n. 8, 6,10, corresponding either to gaps or to later modifications (USM n. 5, 4) having masonry surfaces distinguished by irregular paths. Some wall portions, visible in section, reveal a stratified mortar where it is possible to find, even if not frequent, some carbon fragments. The A and B charcoals have been respectively collected from the stratified mortar used in the external masonry surface ashlars in correspondence of a wall section in the USM n.11 and from the mortar of the foundations layer USM n.2. Samples have been associated to a careful analysis of the USM of belonging in order to guarantee a correspondence between charcoal and building phase. The dating of the samples is reported in the table 2.

The collection of and the interpretation of the ceramic fragments (lateritious and crockery) were more difficult and complicated. The careful observation of the mansonry filling permitted the isolation of some ceramic fragments whose placement context provided some unexpected interpretative difficulties. The fact is that in a historic period not defined by traditional sources, the original masonry surface was demolished to be replaced later and modified. On the inner nucleus surface, deprived of its original masonry surface, possibly after war events, a second masonry surface (today missing), which left portions of more recent mortar hardly visible to the naked eye, has been built. The sampled brick fragments were subjected to a mineralogic investigation of the mortars forming the layer contexts of the samples ; the results of



Pic. 1 : Stratigraphic analisys of prospect E : charcoal samples A, B, lateritious samples T1, T2, T3, T4, T5, T6.



Tab. 2 : Castello Aghinolfi. Archeometric dating : ^{14}C and Thermoluminescence comparison.

this preliminary investigation revealed a different composition of the mortar adhering to the fragments, different from that existing in the original settlement. Six fragments were sampled ; two of these T5 and T6 are rough ceramic and they were placed in the original filling but inserted in a late limited plaster, individualized in its contours only through a mineralogic analysis. Lateritious fragments, useful for the thermoluminescence analysis, have not been found in the nucleus made up of mortar similar, for composition and granulometry, to the layer one belonging to the most ancient building phases. The T3 fragment, a brick fragment, was extracted from a portion of mortar belonging to a reconstruction (the only one adhering to the filling and visible to the naked eye) in order to obtain a useful chronologic reference about a building phase, openly not original, and following the first phases of building from which the charcoals had been taken. On the whole we have six dated elements coming from the binding (tab. 2). The datings of two charcoals do not seem to be in agreement and, since it can appear anomalous, the charcoal taken from the foundations seem to belong to a period following the other taken from the high part of the walls. However on the basis of the margin of error of the research methodology itself, and according to the sample reliability, we can say that the two wall tracts belong to the same building phase, probably the original, extending back to a period between the middle of the XI century and the middle of the following century. The chronological interval coincides with a period in which the written sources detect that the settlement was frequented by affluent people according to the residential, stylistic and functional characters of the octagonal building. The ^{14}C analysis data detect a substantial disagreement with the results of thermoluminescence performed on the lateritious fragments belonging to the XIV century. However the mineralogic analysis, performed on the mortars sticking to the examined samples, reveals their belonging to late rebuildings (not documented in the written sources) and to a period between the XIV and the XV centuries.

The Aghinolfi castle study experience confirms the importance of the archeometric data because it permits to reveal and to set historic events otherwise undeterminable ; it also underlines the necessity of working with several dating means – thermoluminescence, ^{14}C etc. – under a strict logic and stratigraphic control without which the data can result misleading.

SAN GIOVANNI ALLE FONTI DI MILANO, BAPTISTRY

The «San Giovanni alle Fonti» Baptistery belongs to the vast episcopal whole of Milan whose remains are still visible today in the Cathedral and, more precisely, in the museum set below the parvis.

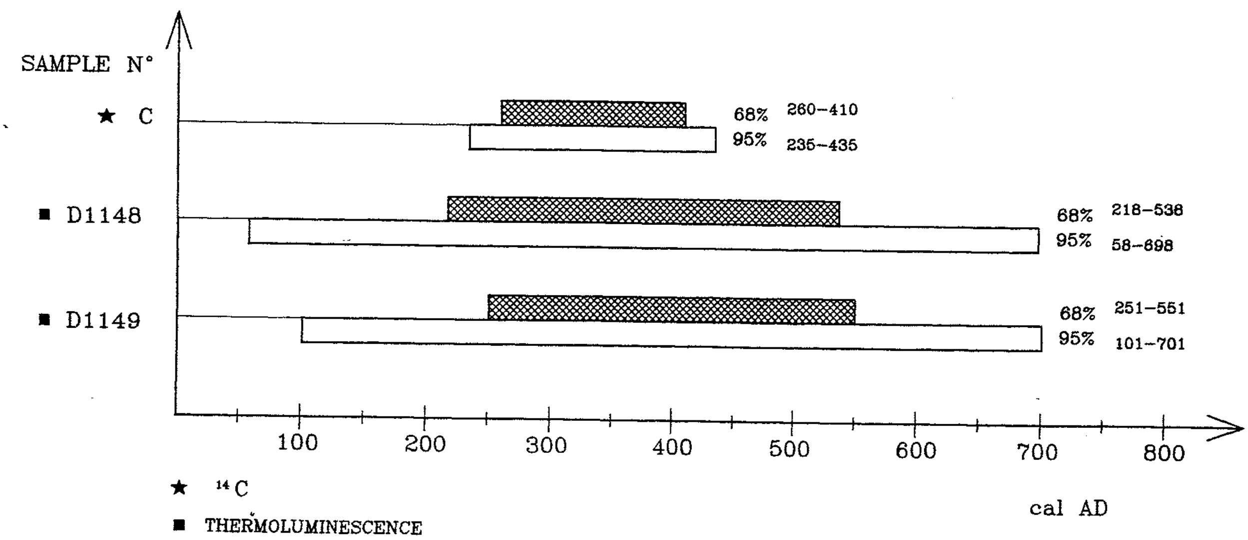
Well-known by the scholars of the Palaeochristian Age, it has been traditionally attributed to the building activity promoted by the bishop Ambrogio (374-379 A.D). In spite of the attention which, during the past, the fine arts scholars have been giving to it, the Baptistry came really to light with the archaeological excavations lead by M. Mirabella Roberti in 1960-62.

The «Anno Ambrosiano» celebrations held in 1997, made possible another excavation which led to the recent hypothesis formulated about the development of the episcopal whole of Milan. In that circumstance, they made the geometrical survey (in 1:20 scale) of the remaining portions of the wall ; the stratigraphical analysis of the high parts and the original yard has been totally dated. For the first time, the building phases - which involved the Baptistry for its one thousand years usage - could be clearly distinguished (with a rigid method) and the building techniques - adopted at the moment of the building - have been, deeply, studied. Once the work of analysing the stonework was complete, it was necessary to determine the ancient portion in order to answer the questions by archeologists.

THE STRUCTURE

The Baptistery structure is formed by a long stone octagonal perimeter, of 7.40 meters per side, with an interior alternatively set by eight square and semicircular niches, and it has been destroyed in part up to a man's proportion at the time of its demolition, in the fourteenth century.

The building structure, still visible today, was built through a lateritius double curtain, constituted nearly entirely by recovering bricks, filled up with a lime cement, heaps of stones and broken bricks.



Tab. 3 : Battistero di San Giovanni alle Fonti. Archeometric dating : ^{14}C and Thermoluminescence comparison.

The external corners of the octagons are underlined by powerful tonalite prisms, surmounted by typical lateritious parastades shaped at 225° to which correspond, at the interior, eight dihedral pillars in lateritious but shaped at 135° ; the interior still keeps an ancient floor in opus sectile and the big octagonal baptismal bathing-pool. The building stratigraphy has been performed starting from the elements which were sited at the lower level rising, little by little, to the higher one, recording precisely the lateritious size, the setting of the brick lines and mortar junctions, the kind of materials employed and constantly relating the outside to the inside stratigraphical units. During the stratigraphic analysis of the foundation system under the pillars, corner parastades, the external walls behind the semicircular niches and those about on the four accesses, dihedral internal pillars appeared to belong to a sole building phase, whereas the baptismal bathing-pool, visible today and the paving with the opus sectile are thought as being subsequent. Phases even younger were found next to the entrances.

The stratigraphical analysis - well supported by the mineralogical and petrographical analysis of the mortars, the caementa and the plasters - is the investigation which permitted the dating of the building phases, of the baptistery, from the foundation up to the demolition.

Given that there does not exist a mensiochronological curve of the «Palaeochristian Milan» - which relate to the measures of the few found entire bricks to - the absolute dating of the most ancient yard has been done using two different archaeometrical methodologies, thermoluminescence and ^{14}C. In the first case, during the survey of the baptistery building characters, it has been observed that in the building of the dihedral pillars and of the corner parastades, had been put lateritious elements obtained by the shaping of the entire bricks, of a sesquipedale provinciale modul (44.4 x 29.4 x 6-8.5 cm). It has been thought that it could be more convenient to proceed in the dating using thermoluminescence which, for two different analysed samples, has provided a range spanning from the year 379 B.C. (+/-155 years) to 394 B.C. (+/- 162 years). If these two dates led already to abscribe the original building to the bishop Ambrogio Age, the problem of the possible re-employment of the lateritious remained without answer. It has been by the use of ^{14}C to eliminate any doubt about the baptistery dating. In the first junction of mortar, immediately above the foundation level, two little pieces of charcoal, remains of the lime stone firing which detected a dating concordant to the datings expressed by thermoluminescence have been collected.

In conclusion, the dating obtained with the Radiocarbon allowed to abscribe - with certainty - the building of the baptistery' structure to the building activity promoted by Sant'Ambrogio to desume very precious elements for the study of the Palaeochristian building techniques.

Stonework is in itself very complex and unlike other ancient finds or pieces of handwork its functional use may extend over centuries. Moreover, its continuous use leads to alterations which change its original formal aspects. Thus, a dynamic research tool is required which can adapt to and exploit every piece of historical evidence provided by the materials. This research tool may involve the association of archeometric dating techniques. However, in the light of the two case studies examined in this report, it appears necessary to reduce the uncertainty which, in the case of thermoluminescence, is due to the probable reuse of existing bricks or ceramic fragments and, in the case of ^{14}C, to the correlation between the death of the plant cells and their use as fuel. An additional contribution to the dating of old monuments could be to use the ^{14}C test on slaked lime granules «bottacioli» which are often found in the mortar of historical buildings. These are in fact almost always present in old stonework and their nucleus contains no inert matter (sand) which is known, if it has a limestone base, to alter the results of the ^{14}C test.

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Interesting the data published by Van Stryndonk, 1997.

Interesting the data published by Van Stryndonk, 1997.

Alessio *et al.*, 1985, p. 81-134 ; Waterbolk, 1971.

However from the sketchy news and oral tradition we know that the use of big dimensioned wood for the firing of the limestone is not frequent and young wood, branches and shrubs were usually used as combustible, Tamagno, E., 1987, p. 61, 69.

Gallo, 1997, p. 63-71.

The dig, managed by the Institute of material culture of Genova, has been directed by Prof. Tiziano Mannoni and Aurora Cagnana, Cagnana 1997.

The sample has been analyzed by Beta Analytic Inc. in 1996 and it provided the following informations : Measured C14 Age 1060 +/- 70 BP, C13/C12 = -25.0, Conventional C14 Age 1060 +/- 70 BP.

The sample has been analyzed by Beta Analytic Inc. in 1998 and it provided the following informations : Measured C14 Age 930 +/- 50 BP, C13/C12 = –27.0, Conventional C14 Age 890 +/- 50 BP.

Monneret De Villard U. 1917, Mirabella Roberti M. 1963, Krautheimer R., 1965, Mirabella Roberti M., Paredi A., 1974, Lusuardi Siena S., 1990.

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For the complete edition of this work see : Fieni L., *et al.*, 1998.

The sample has been analyzed by Beta Analytic Inc. in 1997 and it provided the following informations : Measured C14 Age 1690 +/- 50 BP, C13/C12 = –24.2, Conventional C14 Age 1710 +/- 50 BP.

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RAPPORT DU GROUPE DE TRAVAIL : LES LIMITES DE MÉTHODE DU CARBONE 14 APPLIQUÉE A L'ARCHÉOLOGIE

What's in a ^{14}C date.

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1 - INTRODUCTION

Accurate age information is critical to archaeological interpretation. It follows directly that archaeologists need a detailed understanding of the powers and the limitations of the methods for providing this all-important data, and that they must make detailed evaluations of the dating procedures for the archaeological problem at hand. Too often this has not been done, and at any given moment there seems to be some major archaeological interpretation under intense debate because of chronology. Are the 'dates' right, or are they not ? These debates themselves are often clouded by an incomplete understanding of the dating methods in question.

^{14}C dating is a primary case in point. It remains the single most widely-used method by which archaeologists obtain chronological information on the events of the past. While the method seems simple in principle, it is complex in detail, and proper application requires an understanding of that complexity. However, it is not our purpose here to provide another review of the ^{14}C method, nor to give a detailed discussion of present capabilities and limitations. There are many excellent books and manuals on ^{14}C dating which are directed at the archaeologist and we presume here that the reader is familiar with the topic in general. In this paper, we approach the topic from a somewhat different angle to provide a frame-work which we believe will aid ^{14}C users to both understand and evaluate the method and the data obtained. We begin with a review of the basic definition of the ^{14}C time-scale, we define some new terminology to help make this definition more explicit and then we go on to examine the assumptions which need to be satisfied to provide reliable ^{14}C age determinations for the archaeological problems of interest. Next we review the methods by which these ^{14}C ages can be correlated with calendric time and interpreted within their archaeological context. Finally we dedicate a paragraph to the quality assurance of ^{14}C dating.

2 - A REVIEW OF THE ^{14}C TIME-SCALE DEFINITION

At its most basic level, a radiocarbon date is only a measurement of a chemical concentration in the specimen under study. The amount of the radioactive isotope ^{14}C in the sample is determined relative to the amount of stable carbon. These ^{14}C concentration measurements are at present made using one of two methods ; the older 'decay-counting' method and the newer 'accelerator mass spectrometry' or 'AMS' method. There seems to be some confusion that these two are fundamentally different methods, and one hears arguments from proponents of both that one provides intrinsically 'better' dates than the other. This is false, as both methods provide exactly the same basic information.

These ^{14}C concentration measures, however made, are formally related to an internationally defined ^{14}C age scale by a number of explicit assumptions as given in Stuiver and Polach (1977). Somewhat re-stated, these are :

I) The substance to be dated is presumed to have been in isotopic equilibrium with the carbon dioxide of its contemporary atmosphere, such that its ^{14}C concentration is representative of that atmosphere.

{Note : This fundamental part of the definition in effect states that the material in question must have incorporated carbon from the atmosphere either directly (e.g. terrestrial plants) or very nearly so (e.g. animals which eat the plants). This requirement must be borne in mind by the user, as samples which do not meet it require special attention.}

II) The atmospheric concentration of ^{14}C is assumed to have been constant.

{Note : This assumption stems from the earlier days of ^{14}C dating. It was required in order to produce a ^{14}C time-scale matching as nearly as possible the calendrical scale. It is no longer a critical part of the time-scale definition, since we now have considerable detailed information linking the ^{14}C and the calendrical scales.}

III) The effect of differential transfer of the carbon isotopes (isotopic fractionation) between atmosphere and specimen are accounted for by measuring the stable isotope ratio $\delta^{13}C$-value) of the sample and normalizing to the value $\delta^{13}C = -25‰$ on the PDB scale.

{Note : This is the so-called 'isotopic fractionation calibration' which is usually done by the measuring laboratory either from a measured stable isotope value or from an estimate. To that extent this is a laboratory problem, but it is very valuable to the user to understand these stable isotope data as they can point out deviations from the critical assumptions.}

IV) The age calculation is made using the so-called «Libby» half-life (5568 years) for ^{14}C decay.

{Note : This is a calculational requirement for the laboratory, and the user need not be concerned other than to ensure that this standard was met. It is of no consequence that this old value is known to be inaccurate, as these assumptions define a time-scale.}

V) The calendrical date AD1950 is used as the zero point for the ^{14}C time-scale ; i.e. the isotopic concentration of the specimen is compared to that of the AD1950 atmosphere. The ^{14}C concentration of the atmosphere in AD 1950 is defined by that of a standard reference material available from the US National Bureau of Standards. The calculated result is then given in ^{14}C years BP, where BP means «Before AD1950» and the estimated age uncertainty is given as one standard deviation.

{Note : The user need not be concerned with details of the definition of the laboratory reference standard other than to ensure that this requirement is met. Most, if not all ^{14}C labs use this standard or one linked to it.}

With these explicit assumptions, the ^{14}C laboratory converts a measured isotopic concentration to a «conventional ^{14}C age». These assumptions and procedures thus explicitly define the ^{14}C time scale, with results measured in ^{14}C years, which are not necessarily the same as calendrical years. Note that the term 'conventional ^{14}C date' thus defined has a very specific meaning which is independent of the method of measurement and is used to describe the results from both β-counting and AMS laboratories. The term «traditional ^{14}C date» has been suggested to describe measurements by the older method, as have the more explicit terms «β-decay ^{14}C date and «β-counting ^{14}C date».

This is a complicated set of assumptions, but only some of them need be kept in mind in the application of the method, while the others are the concern of the laboratory.

3 - DEFINING A NEW TERM TO AID IN APPLICATION

How then to go about choosing samples and interpreting results to ensure that we obtain reliable age data ? To help this process, we define here a new term, the radiocarbon (or ^{14}C) event, as follows :

«The isolation of some carbon-containing substance from the reservoir(s) from which its carbon was obtained.»

In colloquial terms, the ^{14}C event starts the radiocarbon clock. This is usually described as the «death» of some biological organism, but that is a very over-simplified view. For example, some organic tissues may be isolated long before the 'death' of the organism itself, and some inorganic materials may also be ^{14}C dated. Like any other event, ^{14}C events may be of varying duration. A seed is formed and isolated from the atmosphere within a few weeks, while a large tree taken as a whole may represent an 'event' spanning several centuries. A sample may also contain carbon representing very different ^{14}C events. Sediment cores often contain carbon resulting from several different depositional processes, and so defining the ^{14}C event for a given slice of the core may be difficult. 'Sample contamination' is another example, in that the original material (e.g. the collagen in a bone) represents one event, while a later carbon-containing 'contaminant' in it represents another.

It is critical to realize that the ^{14}C event(s) represented by a sample may or may not be directly associated with the archaeological (or human) event of interest. Further, the ^{14}C event may or may not directly fulfill the requirements for a conventional ^{14}C age. Thus, before a sample is dated, the nature of the ^{14}C event, its connection to the human event and to the defined ^{14}C time-scale requires detailed examination. Such examination leads naturally to the problems encountered in applying ^{14}C dating.

4 - APPLICATION

One can evaluate the application of ^{14}C dating to an archaeological problem following two sets of considerations. One, more general, set focuses on the relation between the event to be dated and the material remains. A second, more specific, set looks into the relation between the archaeological material and the practical situation in the field.

4.1 - GENERAL CONSIDERATIONS

4.1.1 - Archaeological or human event of interest

Defining the human event of interest is of paramount importance. Archaeologists must make explicit to themselves and to others just what past human event is to be dated, and to what end. The event could be some specific past occurrence of short duration, such as a burial, the manufacture of an artifact, or a volcanic eruption which destroyed a town. Or, it may be more general and of greater duration, as in the period of deposition of some stratum in a site, or the period of occupation of a village. The chronological problem for which an answer is required must be specified. A most important part of this specification is an estimate of the chronological accuracy which must be attained.

4.1.2 - Can ^{14}C provide the age information required

The next step is to determine whether the ^{14}C method can be expected to provide the data to answer the questions posed. Of first importance, how does the nature of the ^{14}C time scale and its correlation to the calendrical time scale affect the interpretation ? For general chronological placement, the ^{14}C scale itself may be adequate. On the other hand, ^{14}C dating may not provide adequate precision if the problem is to correlate an event of unknown age with an historical event, or if it is to provide relative ages for events of short duration, such as the times of occupation of the different houses in a village. These considerations need examination at the outset, as there is no sense in applying a tool to a task for which it is unsuited. The user must thus be familiar with current measurement capabilities and the current calibration data linking the ^{14}C and calendrical time-scales.

4.1.3 - What is the ^{14}C event for each of the materials

This topic is best discussed using some of the common dating materials as examples.

Wood and charcoal : Wood results from a tree's annual formation of tissue from carbon dioxide extracted directly from the atmosphere. This material is usually retained as a structural component until the final death of the tree per se. These annual rings are isolated from the atmosphere shortly (2-3 years) after formation, and so there is a specific ^{14}C event of about that duration for each ring. A large tree thus represents a large number of individual ^{14}C events if considered ring-by-ring, or it represents a single event of longer duration if considered as a group of rings. The ^{14}C event is thus directly connected to the tree growth, and only indirectly to subsequent use of the wood by humans. The same arguments apply to charcoal. As with wood, the ^{14}C event is that of the formation of the original tree rings, not the burning of the wood to cook a meal.

Both wood and charcoal may absorb large amounts of contaminants (other carbonaceous materials) while buried in a site. As a whole, such a sample has a very poorly-defined ^{14}C event. Fortunately, ^{14}C laboratories have developed reliable methods for removing this extraneous material.

Bone : Bone is an animal tissue consisting primarily of an 'inorganic' part, calcium hydroxyapatite ('apatite') and an organic part, proteinaceous collagen. Both contain carbon resulting from the animal's diet, but not necessarily the same parts of its diet. The timing of tissue deposition and that of any subsequent tissue replacement are not well-understood, and so the ^{14}C event can only be specified as a period within the animal's lifetime. Whether this is a problem depends on the animal and the question to be asked. For example, the duration of the ^{14}C event for a lamb is much shorter than that for an adult human. Thus, bones from a sacrificed lamb found in the grave goods of a human burial are more directly connected to the burial event than are the bones of the human.

Bone is also susceptible to contaminants which destroy the definition of the ^{14}C event. Bone apatite is notorious in this respect, as it can exchange carbonates with the environment to the extent that the ^{14}C event becomes entirely undefined. Fortunately, there has been a great upsurge of work on bone collagen as a result of the new capabilities made possible by AMS dating, and so it has become a dating material of choice.

Shell : The carbon in a sea-shell results from the direct uptake of carbonates from the water in which the animal lives and subsequent deposition as calcium carbonate. The ^{14}C event is thus defined as the life-span of the organism. As this is usually limited to a few years, the event is well-defined. However, as with bone apatite, shell is notorious for post-depositional exchange of these carbonates with environmental carbonates, and the event definition is lost.

Other materials : The advent of AMS dating, with its much reduced sample size requirement has meant that many materials which were previously inaccessible to ^{14}C dating may now be routinely measured, making it easier for the archaeologist to choose samples for measurement which have ^{14}C events closely associated with the event of interest. Single seeds, threads of cloth and individual hairs have all been dated using the AMS method. For such samples, the ^{14}C events are extremely specific, and there is the additional advantage that the laboratories can be much more selective in dealing with contaminants.

Archaeological ^{14}C dating is also not limited to organic materials. Fresh mortar hardens by a chemical reaction involving the combination of CaO (lime) with atmospheric CO_2 to form calcium carbonate. The ^{14}C event for mortar is thus this uptake time, which may range from several months to centuries, depending on the thickness of the wall. If carbonate-containing aggregates or sands were added to the mortar, the event definition becomes very confused.

4.1.4 - How is each ^{14}C event associated with the human event

The association between the ^{14}C event and the human event of interest must be examined with great care, as there must be a known link of specified magnitude connecting the two events. Again, this is best discussed using some illustrations. A small branch used as an arrow shaft will have ^{14}C event (the few-year growth of the branch) and human event (the construction of the arrow) closely connected in time, as will charcoal made from burning young tree branches in a cooking-fire and the meal itself. On the other hand, an oak timber used (or re-used) to construct a building may have a ^{14}C event separated from the human construction event by several centuries. As well, charcoal can persist for millennia in the soil, and so the presence of charcoal in a site does not necessarily reflect human activity, but may simply indicate past natural burning.

In many cases, the ^{14}C event for a bone or a shell is closely associated with the human event and in this respect it is a dating material of choice. For example, the ^{14}C events for a clam shell, a sheep bone and a seal bone found in a kitchen midden reflect the time of growth of the clam, the sheep and the seal, times unlikely to precede by many years the consumption of the animals as food. A human bone from a grave-site reflects part of the life-span of the human, not the time of burial, but as with the animals, the difference can be estimated if it is important to the interpretation.

The small samples now possible to measure through AMS dating can be ideally suited because they can be chosen for the direct association between their ^{14}C and human events. There are many possibilities which are now within the realm of measurement capability : As examples, measuring a single seed of a domesticated plant dates agricultural practise, and a ^{14}C date for a single human hair establishes human presence at that time.

4.1.5 - Does the material for which the ^{14}C event has been identified meet the requirements for a conventional ^{14}C age ?

The nature of the ^{14}C event must be such that the substance to be dated satisfies the definition of a conventional ^{14}C age, and in particular the requirement that it contains only carbon from its contemporary atmosphere. Measures on plant tissue (wood, charcoal, seeds etc) thus satisfy the ^{14}C age definition, as the carbon was obtained directly from the atmosphere during tissue formation by the plant.

That is not the case for bone or shell, as the carbon under consideration comes from the animal's diet, not directly from the atmosphere. For the sheep mentioned above (or any terrestrial herbivore) which ate grass or recent hay formed directly from the carbon dioxide of its contemporary atmosphere, this is of only minor consequence, as the carbon transit time between atmosphere and sheep is a few weeks or months at most.

However, that is not true for the sea shell or seal, which obtained their carbon from the ocean. Since the deep ocean has circulation times measured in centuries, the carbon transit time between atmosphere and animal may also be measured in centuries, and a correction must be made to account for this effect to provide ^{14}C ages in conventional ^{14}C years. Unfortunately, there is no single correction to be made, as different parts of the world oceans have different correction factors depending on oceanic circulation at the time. Similar complex considerations govern fresh-water organisms which obtain their carbon from lakes or streams.

The situation is even more complicated for a human who obtained part of his food from the sea and part from the land. To determine the conventional ^{14}C age for his bones, the relative amounts of the dated bone material which came from the land and from the sea must be estimated. Fortunately, in some circumstances it is becoming possible to provide such estimates from considerations of the bone collagen stable isotope ratio, or $\delta^{13}C$ value. This consideration must be extended to include any subsequent conversion of the conventional ^{14}C age to a calendrical age, as the calibration curves for oceanic samples differ from those for terrestrial samples.

4.2 - FIELD STRATEGY TO OBTAIN THE MATERIALS RELEVANT FOR DATING THE HUMAN EVENT

One can't deny that a considerable number of aberrant results are due to problems related to the sampling in the field. The soil from which organic samples are taken during excavations is generally not a static but rather a dynamic system in which different kinds of pre- and post-depositional processes are or have been active. These processes can be of natural (e.g. floralturbation, faunalturbation, cryoturbation, ...) as well as of anthropogenic origin (e.g. trampling, digging of pits, ...). Some of them are responsible for the migration and contamination of organic matter that is commonly used for ^{14}C dating human events. Even ^{14}C samples which are stratigraphically and spatially closely related or associated to the archaeological features to be dated can give dates that are not compatible with the relative date obtained on the basis of stratigraphical or typological observations. It is therefore of crucial importance that, before taking ^{14}C samples or making a selection among different kinds of samples taken in the field, the field-archaeologist gets a clear picture of all soil processes which occurred before, during and after the human event he wants to date by means of ^{14}C. This will allow him to make a clear distinction between residual and intrusive material and samples which are contemporaneous with the archaeological event.

Residual material can be defined as organic matter that is already present at the site or in the soil before the human event to be dated. Palaeolithic and Mesolithic sites for example are commonly situated in fluviatile and aeolian sediments which might include organic material that is naturally produced prior to the human occupation. In some instances, in particular when dealing with fluviatile environments, the organic residue can be produced away from the site and transported to it by water. In the case of multiple occupation sites organic matter from an older occupation can get mixed, for example through bioturbation or human digging, with the remnants of a younger, overlying occupation. In most of these cases the dating of residual samples will result in ^{14}C dates that are too old compared to the human event to date.

Intrusive material on the other hand consists of organic matter that entered the archaeological layer or feature after the human event. Well known is the percolation of especially smaller organic fragments (seeds, small charcoal fragments, fruit pips, ...) to underlying layers caused by a variety of burrowing animals and insects such as worms, badgers, moles, ants, termites and many others. Even human activities, such as trampling, can be responsible for the downwards migration of organic matter in the soil. Generally a too young date is obtained when intrusive material is ^{14}C dated.

In some cases the words residual and intrusive lose their meaning completely. In large buildings (from prehistoric megalithic structures to medieval churches and fortresses) the outer standing walls of the structures, although often modified, remain while the not so permanent parts of the structures like roofs and furniture (habitational or funeral) undergo a lot of changes during the long use of such constructions. Often the content of large monuments reflects only the last stage of their use, the final event. Evidence of former events, like the construction of the monument or its primer use are in most cases found in secondary deposits like mixed debris layers, foundation (reparation) trenches or even outside the monument. Stratigraphy and consequently the concept of residual or intrusive remains becomes useless. A dating strategy for such sites must take into account the possibility of «hidden» events, phases in the use or disuse of the monument that are not visible in the archaeological records.

The dating of samples from questionable origin is another possible cause of aberrant results. For some organic materials it is very difficult or even impossible to determine whether their presence on the site is the result of human or natural events. In the case of charcoal that is found scattered over the site or that is not directly associated to a distinct anthropogenic feature such as a hearth, the distinction between naturally produced charcoal, for example resulting from forest fires, and humanly produced charcoal can't be made. Bones on the other hand can be brought to the site, before or after the human occupation of the site, by carnivores. It is therefore recommended to preferably use humanly modified bones, for example fragments with clear cut marks, decorated fragments or bone tools, for absolute dating.

At last aberrant results can in some cases be explained by a bad or doubtful spatial association of the ^{14}C sample and the archaeological event to date. Basically organic samples originating from archaeological features (hearth, pit, ditch, ...) are much more reliable compared to scattered samples.

Nevertheless aberrant results are not fully excluded, in particular at non-stratified sites which have known several occupations. Samples from a post-hole that doesn't constitute part of a house-plan, an isolated storage or rubbish pit at a settlement or a hearth or hearth-pit that isn't associated to a cluster of lithic artifacts can produce deviating ^{14}C dates indicating re-occupation of the site. In certain cases deviating ^{14}C dates may reveal «hidden» occupation phases at a site which are not suspected in the archaeological data because they didn't produce archaeological evidence or the archaeological evidence has vanished completely.

Lastly the search for a good sample implies also that during sampling the field-archaeologist tries to get information about the physical and chemical quality of a candidate sample. Questions like : «is the sample well preserved ?» or «is there a possibility of contamination ?» are necessary to select the best possible sample. Often laboratories receive samples that are so badly preserved that it is impossible to separate the contaminants from the carbon related to the event. Site information gathered during fieldwork can help the laboratory to understand field conditions and adapt laboratory pretreatment.

5 - ANALYSIS OF THE ^{14}C DATES

5.1 - FROM THE ^{14}C TO THE ASTRONOMICAL TIME SCALE

Age determination by the ^{14}C method is based on the clock of radioactive decay, since the amount of ^{14}C left in any sample is determined by how much was there during the life of the organism, and how long it is since death. The amount of ^{14}C in terrestrial organisms during their life is very similar to that present in the atmosphere. Although roughly constant this does vary because of fluctuations in solar activity and geomagnetic field strength. This causes the ^{14}C timescale to be different from the calendar timescale. True calendar ages can therefore not directly be deduced from the ^{14}C timescale which is based on the amount of ^{14}C in the sample. ^{14}C dates are always expressed in years BP (Before Present) where «Present» is defined as 1950.

Calibration is the process of transforming a ^{14}C date (in BP) into an historical age - after calibration, denoted as 'calBC', 'calAD' or occasionally 'calBP'. The two timescales BP and calBC/AD are related through a calibration curve which has been obtained by measuring ^{14}C from samples of known absolute age. The best independent method for finding these absolute ages throughout the Holocene is dendrochronology : by accurately measuring ^{14}C from absolutely dated treerings, high precision calibration curves have been obtained. In the 1986 calibration issue (Radiocarbon, vol. 28 no.2B), Stuiver and Pearson constructed a curve (bidecadal, i.e. 20 treering intervals) which acquired the status «recommended». In 1993, a second calibration issue was published (Radiocarbon, vol. 35 no.1) including a wealth of new data, such as a treering curve into the preboreal, and some corrections to the 1986 data set. However, no formal recommendations were made which caused some confusion.

Part of the discussion 1986/1993 was on possible 'local effects' in calibration curves, because of systematic differences between wood from the USA west coast and from Europe. In theory this is possible but such effects are very small (not larger than 20 BP), on the borderline of what is possible to measure, and negligible for most archaeological applications. The only local effect one agrees on is a systematic difference of about 40 BP between the Northern and Southern hemisphere, the south being older (i.e. depleted in ^{14}C). Following the 1997 Radiocarbon conference in Groningen, it was decided to produce a third calibration issue, planned for 1998 (Stuiver and van der Plicht, 1998). This will include a new, recommended averaged calibration curve for general use. It incorporates new ^{14}C data corrections (albeit very small), and some dendrochronological corrections as well. A floating preboreal pine-tree chronology is wiggle matched to the revised absolute chronology ; this part is not expected to change much in the near future.

Apart from absolute and floating tree-ring chronologies, the calibration curve is extended into the late glacial by dating corals by both ^{14}C and U-series isotopes. The U-series dates are considered absolute ; the ^{14}C dates are obtained for marine material, from which the atmospheric calibration curve is derived assuming a 400 year reservoir age. A third possible calibration data set is formed by ^{14}C measurements from laminated sediments or varves. Since all existing datasets are not absolute and have to be matched to tree-ring and/or U-series curves and since varve counting is problematic, these records are at present not included in the calibration curve.

For calibration purposes, computer programs have been developed by several laboratories. The most widely used ones are the programs from Seattle, Oxford an Groningen. Intercomparisons have shown that the differences in calibrated results from these (and other) programs are negligible. The main differences are only in graphical output presentation, or special options such as wiggle matching or Bayesian analysis.

5.2 - STATISTICAL ANALYSIS OF ^{14}C

From an archaeologist's point of view, calibration is not simplifying the interpretation of a ^{14}C date. While uncalibrated (BP) dates correspond to relatively simple mathematical equations (Gaussian distribution) and notations ($\mu \pm \sigma$) this is not the case anymore after calibration. Due to the presence of wiggles and depending on the position of the ^{14}C event on the time scale the probability curve, representing the samples' real age, may become bimodal, trimodal or even a plateau in the curve may occur. Often the 1 and 2 σ ranges will split in different peaks, each making a relative contribution to the probability distribution. This means that the age of the sample can be somewhere on the real time axis in the ranges covered by the peaks and is unlikely to be in the zones of low probability situated in the troughs between the peaks. In practice however, if no supplementary information is available, the archaeologist has little to gain by using this complex notation and will quote the whole range which is in most cases larger than in the uncalibrated (BP) time scale.

In other words the date range after calibration is not only defined by counting statistics but is also «wiggle» dependant. This leaves the investigator with a time scale wherein zones of higher and lower precision succeed each other. Different events within relatively short periods may be dated with different degrees of precision. The fact that archaeologists feel uncomfortable about this has been expressed on many occasions.

It is a fact that ^{14}C gives relatively unprecise dates if one takes into account that in the real world the human event, the archaeologist is interested in, took - in most cases - place within one day. Fortunately ^{14}C is often only one of the many forms of chronological evidence available to the archaeologist. Traditionally people faced with this complexity have relied on logical deductions embedded in the text of site reports. This has the strength of allowing a subtle balancing of the evidence in the light of experience and expertise. However, with the results of the ^{14}C evidence given as probability distributions or ranges, it is extremely difficult to gain a good instinct for reliable interpretation and the fine detail of the evidence is often lost in the process.

To assist in the interpretative process Bayesian analysis can be used (Litton and Buck, 1995). To understand this we need to look back at the process of calibration itself. There is an underlying assumption in calibration that each year is a priori equally likely. If we have other evidence, such as the sequence of events in a site, this assumption is manifestly invalid. Modification of the probability distributions and ranges can be achieved by incorporating constraints on, for example, the order of the events. The results of this sort of analysis should, of course, be treated as part of the interpretation of the evidence as opinions might vary on the security of the sequences and associations within any site. It is, also vital here to consider the relationship between the ^{14}C event and the events which are actually of interest. In addition to modification of the estimates for the ^{14}C event such analyses can provide estimates (with confidence ranges) for events which are only indirectly dated ; this is probably their greatest strength.

There are several statisticians able to perform such analysis and, in addition, the Oxford calibration program is able to deal with a wide variety of models (such as mixtures of sequences and phases, termini ante quem, tree rings etc.). The very specific case of wiggle matching of tree ring sequences is dealt with by a variety of programs. The advantage of these programs being generally available is that it allows the users of ^{14}C to experiment with ideas and methods. The disadvantage is that misuse is all too easy and in general it is best to get the advice of the authors or someone else experienced in their use before publication of all but the simplest analysis.

Special attention must be paid to events situated at both ends of the ^{14}C time scale. Samples containing about 2 % of modern carbon or less (>30,000 BP) may be subject to errors of modern contamination that are difficult to estimate. A adapted dating strategy is needed to cope with this problem. Supplementary information to check on the reliability of the result can be obtained through archaeological correlations (eg : stratigraphic or cultural relationships), material evidences (eg : comparing dates on different materials) or laboratory information (eg : analysing different chemical components, stable isotope measurements).

The problems related to the younger part of the ^{14}C time scale, the historical times (Van Strydonck, 1997), are of a completely different nature. If one compares the ^{14}C results with historical records, the dating method seems irrelevant. Even dates from high-precision laboratories will, after calibration, leave the archaeologist or the art-historian in most cases with an uncertainty of at least one century. This can be very frustrating for investigators who tend to think more in years than in decades when describing an event in the past. So absolute dating with ^{14}C gives unprecise dates for well-documented Medieval sites. On the other hand objects out of context (eg : museum objects) or isolated structures (eg : wells) need a ^{14}C date more often than has been presumed. Yet relative dating is opening a much broader perspective. Not in the first place for ranking objects or events, but mainly because it enables the comparison of possibilities. This approach is linking up historical archaeology and history. Events like battles, funerals, building activities, etc. described in ancient texts or even legends can be compared with the presumed material remains of the event. In fact, ^{14}C no longer merely provides a date, but gives a probability that an object is linked to an historical event.

6 - QUALITY ASSURANCE OF ^{14}C DATING

The fundamental fact of ^{14}C dating is that it is based on a random process, by which we mean that the decay of the ^{14}C atom occurs randomly. Historically, radioactive decay is known to have a random nature and the number of counts observed is assumed to follow a Poisson distribution. This fact has important implications for our understanding and interpretation of a ^{14}C age. The age is calculated from an observed number of counts (or decays) in a fixed time and so a ^{14}C age is a single realisation from a random process. By this we mean that if we measure the same sample on many occasions (i.e. repeatedly count) under identical conditions and each time, calculate the age, then we will not get exactly the same result. There would be a distribution of ages. This simple (and most unrealistic situation) explains the most important fact about ^{14}C dating and why there will be an irreducible level of variation in the results.

Consider a more realistic scenario ; imagine a sample which can be identically split (the split must be identical in every way), this means the sub-samples are perfectly homogeneous. Each sub-sample will be dated in a single laboratory, i.e. each sub-sample will undergo a pretreatment process, followed by a chemical process before entering the counting phase. The calculated ages for the sub-samples will not be identical. One simple measure of the variation in the results is the square of the standard deviation which measures the scatter in the results around the mean value. Since we have split the sample into identical sub-samples, each one should have exactly the same true age for which the average of all the results should be a good estimate. If we were to compare this measure of variation, with that observed in the first scenario (simply repeating the counting), then it should be at least as great, since we have introduced additional sources of variation (namely the pretreatment and chemical synthesis).

Finally, and more realistically, we might imagine small differences in the ^{14}C content between the sub-samples. Thus the final source of variation in the results would be the differences in sub-samples. In this way, we have described the components of variation and their contribution to the variation in ^{14}C dates. The next stage is to consider how an individual laboratory estimates this variation.

Laboratories quote the calculated age of the sample and also give an associated error, which is a measure of the variation from the above sources associated with the particular sample. In its simplest form, this error is based on the uncertainty on the counts for sample, standard and background, i.e. the random nature of the decay process (Poisson error). In addition, however, the error quoted with a ^{14}C date will in many cases also include a laboratory's estimate of the variation due to the factors discussed above (a measure of the reproducibility of the result). This may be estimated in a number of ways, but is likely to involve the use of in-house standards (including known-age material) and the statistical evaluation of replicated experiments.

If we consider the calculated age and its error, what does it mean ? To understand, we have to make recourse to probability based arguments. In a simple way, we imagine that the calculated age is a good estimate for the true unknown ^{14}C age, then we might imagine that age $\pm 2\sigma$ error provides a range of plausible values for that true age. With probability arguments, it is possible to define plausible in this context as saying that 95 out of 100 such intervals will include the true, unknown value. This does not say that any particular interval contains the true, unknown value but describes the long-run properties of the procedure used in calculating the interval.

The calculated age is an estimate of the true, unknown age. We can define properties we would like this estimate to have. The key properties of the estimator are that it should be accurate (i.e. not biased) and that it should be precise.

Accuracy, says that on average the estimate will equal the true, unknown value. This does not mean that each individual result will exactly equal the true value. If the average is not equal to the true age, then we would describe the difference (average - true) as the bias. Bias is always relative to a fixed quantity such as the true, unknown age.

In addition, we will also have a measure of the error or uncertainty on the estimator, this is commonly known as the precision of the estimator, and we would like this to be as small as possible (in numerical terms) (i.e. increased precision).

The goal in estimation is to have both an accurate and precise estimator, but this may not always be possible and the estimator may be biased and precise, or even biased and imprecise. Accuracy and precision are theoretical quantities, so evaluation of properties of the estimator is dependent on a mathematical model (such as a Poisson model). To illustrate accuracy and precision in a very simple context, consider an archery target. Our archer will be unbiased if the arrows he fires cluster around the bull's eye, but will be biased if the arrows cluster off-centre. His shooting will be precise, if all the arrows land close together but imprecise if the arrows are widely dispersed over the target.

One additional component of variation can be introduced when the 'same' sample is measured in several laboratories, and which introduces the question of comparability of results from different laboratories. There have been numerous discussions of the difficulties which might arise when trying to use dates obtained in different laboratories or even in the same laboratory but at different times. We might expect to see some differences in the results, and it is of interest to consider the scale of variation, and further, if we have known age material, to consider whether there is evidence of laboratory bias, and the relationship which the quoted errors have to the observed variation in results. This concern is one part of a quality assurance for ^{14}C laboratories, and is not a new concern since notably the ^{14}C tree-ring chronology is based on results from a small number of different laboratories. Quality assurance for ^{14}C laboratories has a number of aspects (Long and Kalin, 1990) :

i) it must evaluate accuracy of a laboratory for routine dating purposes ;
ii) it must evaluate precision for a laboratory based on sub-sampling and subsequent analysis ;
iii) it must permit identification of problems for action ;
iv) it must provide the basis of consumer confidence.

Individual laboratories already as part of their routine laboratory procedure carry out quality assurance checks, but in addition over the past 15 years, the ^{14}C community has voluntarily undertaken additional, independent cross-checks (Gulliksen and Scott, 1995 ; Scott *et al.,* 1998).

All the cross-checks have had as their primary goal, the investigation of the comparability of results. In each case, participating laboratories have been provided with a sequence of samples including wood, shell, peat and bone. The materials have been collected and prepared in bulk and in most cases have been of natural origin. Results of the analyses have been studied for evidence of any laboratory bias and for variation in results. Laboratories and users alike have benefited from the exercises. In almost all cases, there has been evidence of additional variation in the results and also there has been evidence of systematic offsets (biases), or differences amongst some laboratories. Additional reference materials have been prepared and made available as part of a quality assurance programme. The ^{14}C user community must accept that uncertainty in a ^{14}C result is fundamental, but can also expect that the ^{14}C laboratories are doing their utmost to ensure that the results are of highest quality through rigorous quality assurance protocols and independent checking.

7 - CONCLUSION

Successful application of ^{14}C dating requires detailed consideration of the many complex requirements which must be met to satisfy the assumptions underlying the method. While some of these requirements are the sole responsibility of the ^{14}C laboratory, most are not, and they must be carefully evaluated by the archaeological user if reliable chronological information is to be obtained. In particular, the archaeologist must carefully specify the chronological questions of interest, and must then carefully identify, choose and evaluate samples which can be expected to provide reliable answers to those questions. This is not a task which can simply be delegated to the «scientific experts» at the measurement laboratory, but it is also the responsibility of the user. We hope that the approach outlined here will aid users by providing a framework for these complex evaluations.

8 - SUGGESTIONS FOR FURTHER READING

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Qu'est ce qu'il y a dans une date ^{14}C

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(traduction par J. EVIN)

1 - INTRODUCTION

Avoir une chronologie fiable est de première importance dans l'interprétation archéologique. Il en découle que les archéologues ont besoin de bien comprendre les possibilités et les limites des méthodes pour tirer le meilleur parti des données et ils doivent faire une évaluation détaillée des procédures de datation appliquées aux problèmes archéologiques. Trop souvent cela n'a pas été fait et, parfois, il a pu y avoir eu des débats passionnés sur des problèmes archéologiques majeurs à cause de la chronologie. Est-ce que les dates sont justes ou pas ? Ces débats sont souvent obscurcis par une mauvaise compréhension des méthodes de datations.

La méthode du Radiocarbone est souvent mise en cause ; pourtant elle reste de loin la méthode la plus utilisée par les archéologues pour obtenir des informations de chronologie sur les événements du passé. Alors que la méthode semble simple dans son principe, elle est en réalité complexe si on l'examine en détail et, pour l'appliquer correctement, une bonne prise de conscience de cette complexité est requise. Cependant, notre propos n'est pas ici de faire une nouvelle revue de la méthode ni d'ouvrir une discussion approfondie sur ses possibilités et ses limites actuelles. Il existe d'excellents livres et manuels (en langue anglaise surtout : N.D.T.) sur la méthode de datation par le radiocarbone à l'usage des archéologues et nous supposons ici que le lecteur est assez généralement familiarisé avec ce sujet. Dans ce papier nous aborderons le sujet sous un angle quelque peu différent pour apporter un canevas qui, nous le croyons, aidera les utilisateurs du C-14 à, tout la fois, comprendre et apprécier la méthode ainsi que les données obtenues. Nous commencerons par une révision de la notion de temps Carbone 14 et nous définirons un terme nouveau pour rendre cette notion plus explicite. Puis nous en viendrons à examiner les conditions qui doivent être satisfaites pour obtenir des datations radiocarbone fiables pour les problèmes archéologiques dignes d'intérêt. Ensuite nous verrons les moyens par lesquels ces datations radiocarbone peuvent être corrélées avec le calendrier en années réelles et interprétées dans le contexte archéologique. Finalement nous consacrerons un paragraphe au « label de qualité » des datations C-14.

2 - RÉVISION DES DÉFINITIONS DE L'ÉCHELLE DES TEMPS CARBONE 14

En principe une date radiocarbone est d'abord et seulement une mesure de concentration chimique dans le matériau étudié. La teneur en l'isotope radioactif ^{14}C dans l'échantillon est déterminée par rapport à celle de l'isotope stable. Ces mesures de teneur en ^{14}C sont maintenant faites par l'une des deux méthodes : la plus ancienne, celle « des compteurs de radioactivité », la plus récente, celle « des accélérateurs ou S.M.A. ». Il semble qu'il y ait une certaine confusion car elles pourraient être fondamentalement différentes si l'on entend les arguments de certains qui prônent une méthode comme intrinsèquement meilleure que l'autre. Ceci est absolument faux car les deux méthodes donnent exactement la même information.

Ces mesures de concentration en ^{14}C, quelque soit leur moyen de mesure, sont étroitement reliées à une échelle en âges Radiocarbone définie internationalement par un certain nombre de principes qui sont définis par Stuiver et Polach (1977) ; elles peuvent se redéfinir ainsi :

i/ La matière à dater est supposée avoir été en équilibre isotopique avec le dioxyde de carbone de l'atmosphère contemporaine de sa formation, et donc on suppose que sa teneur en ^{14}C est représentative de celle de cette atmosphère.

(Il faut bien noter que cette partie essentielle de la définition insiste sur le fait que le matériel en question doit avoir incorporé le carbone soit directement, pour les plantes terrestres, soit presque directement pour les animaux puisqu'ils mangent les plantes. Cela doit bien rester à l'esprit de celui qui emploie les datations de sorte que des échantillons qui ne remplissent pas cette condition nécessitent une attention spéciale).

ii/ La teneur en ^{14}C de l'atmosphère est supposée avoir été constante.

(Il faut bien noter que cette assertion date des tous débuts de la méthode du Radiocarbone. Elle fut choisie afin de donner une échelle des temps ^{14}C qui s'ajuste au plus près à l'échelle des temps calendaires. Ce n'est plus un point important de la définition de l'échelle du temps puisque nous avons maintenant des informations détaillées sur l'écart entre l'échelle des temps ^{14}C et celle des temps calendaires).

iii/ L'effet de transfert, différent suivant les divers isotopes du carbone : c'est le fractionnement isotopique, entre l'atmosphère et le matériel étudié qui est pris en compte par la mesure du rapport isotopique « delta » ^{13}C de l'échantillon et normalisé à la valeur de «delta » ^{13}C = - 25 ‰ sur l'échelle de référence P.D.B.

(Il faut bien noter que cette correction d'effet isotopique est généralement faite par le laboratoire d'analyse, soit par la mesure exacte du rapport isotopique, soit par son estimation. Ce sujet est un problème de laboratoire, mais il y a intérêt à ce que celui qui utilise les dates comprenne le sens de ces données sur les isotopes stables car elles peuvent mettre en évidence des déviations par rapport aux présupposés de la méthode).

iv/ Le calcul de l'âge est fait en utilisant la période de décroissance du ^{14}C dites « demi-vie de Libby » de 5568 ans.

(Il faut bien noter qu'il s'agit d'une convention de calcul pour le laboratoire et l'usager n'a pas d'autre chose à faire que de s'assurer que cette règle est bien appliquée. Il n'est d'aucune importance qu'il soit maintenant bien établi que cette ancienne valeur est inexacte, elle rentre malgré tout dans la définition du temps Radiocarbone).

v/ La date calendaire 1950 après J.-C. a été choisie comme année zéro de l'échelle des temps Radiocarbone. Cela veut dire que la concentration isotopique du matériel est comparée à celle de l'atmosphère de l'année 1950. La concentration en ^{14}C de l'atmosphère de l'année 1950 est définie par celle d'un produit standard de référence, disponible au Bureau Américain des Standards (N.B.S.). Les résultats calculés sont alors donnés en année ^{14}C « BP » où BP signifie « avant l'année 1950 » et la marge d'incertitude sur cette estimation de l'âge correspond à une déviation standard.

(Il faut bien noter que l'utilisateur n'a pas à s'occuper de la référence exacte du standard employé par le laboratoire si ce n'est à s'assurer qu'il y en a bien un. La plupart des laboratoires, si ce n'est tous, ont le standard N.B.S. ou un standard qui lui est directement lié).

Avec ces présupposés bien précis, le laboratoire de radiocarbone convertit une mesure de teneur en radiocarbone en un « âge conventionnel ». Ces règles de procédure définissent ainsi explicitement l'échelle des temps Radiocarbone avec des résultats exprimés en années ^{14}C qui ne sont pas nécessairement les mêmes que les années de l'échelle calendaire. Il faut bien noter que le terme de « date conventionnelle » a ainsi une définition bien particulière qui est indépendante de la méthode de mesure et qui est valable pour les résultats aussi bien des laboratoires de comptage de radioactivité et que de ceux utilisant la méthode des accélérateurs. Le terme de « date traditionnelle » a été proposé pour qualifier les résultats provenant de la plus ancienne méthode de mesure mais les termes « date par décroissance bêta » ou « date par comptage des bêta » sont plus explicites.

Il y a là un ensemble compliqué de présupposés, mais seulement certains d'entre eux doivent être gardé à l'esprit quand on applique la méthode tandis que les autres ne concernent que les laboratoires.

3 - DÉFINITION D'UN NOUVEAU TERME POUR AIDER À L'APPLICATION

Comment arriver à choisir les échantillons et à interpréter les résultats pour s'assurer que nous obtenons des données chronologiques fiables ? Pour aider dans cette recherche nous définissons ici un nouveau terme, « l'événement Radiocarbone (ou ^{14}C) », comme suit :

« l'isolement d'une matière carbonée donnée à partir du ou des réservoirs d'où elle a tiré son carbone »

En bref on peut dire que l'événement Radiocarbone représente le point de départ de l'horloge radiocarbone. Ceci est généralement décrit comme la « mort » de l'organisme biologique considéré, mais c'est une manière simplifiée de voir les choses. Par exemple certains tissus organiques peuvent être isolés longtemps avant la mort de l'organisme lui-même et certains matériaux inorganiques peuvent aussi être datés par le ^{14}C. Comme d'autres événements, les événements radiocarbone peuvent être de durée variable : une graine est formée et isolée de l'atmosphère en peu de semaines tandis qu'un gros arbre pris dans son ensemble peut représenter un événement s'étendant sur plusieurs siècles. Un échantillon peut aussi contenir du carbone représentant différents événements radiocarbone. Des carottes sédimentaires contiennent souvent du carbone provenant de plusieurs processus de sédimentation différents et il peut être alors difficile de définir l'événement radiocarbone d'une lamelle de sédiment de cette carotte. La contamination d'un échantillon est un autre exemple parce que le matériel originel (par exemple le collagène dans un os) représente un événement alors qu'un polluant carboné qu'il contient en représente un autre.

Il est crucial de réaliser que le ou les événements représentés par un échantillon peut être ou ne pas être directement associés à l'événement archéologique (ou humain) intéressant. De plus, l'événement ^{14}C peut ou non remplir les conditions requises pour un âge ^{14}C conventionnel. Ainsi, avant que l'échantillon soit daté, la nature de l'événement radiocarbone, sa connexion à événement humain et avec l'échelle des temps Radiocarbone demandent un examen détaillé. Un tel examen conduit naturellement aux problèmes rencontrés dans l'application de la méthode de datation par le radiocarbone.

4 - APPLICATION

On peut évaluer l'application de la méthode du carbone 14 à un problème archéologique en suivant deux types de considération. L'une, plus générale, se focalise sur la relation entre événement à dater et le matériel qui reste. L'autre, plus spécifique, examine la relation entre le matériel archéologique et la situation dans le gisement.

4.1 - CONSIDÉRATIONS GÉNÉRALES

4.1.1 - Événement archéologique ou humain intéressant

Définir l'événement humain intéressant est d'une importance considérable. Les archéologues doivent comprendre et faire comprendre aux autres quel événement humain du passé doit être daté et à quelle fin. L'événement peut être une action passée de courte durée, telle qu'une inhumation, la fabrication d'un outil ou une éruption volcanique qui a détruit une ville. Mais il peut aussi être beaucoup plus général et d'une longue durée, comme la période de dépôt d'une couche dans un site, ou la durée d'occupation d'un village. Le problème chronologique pour lequel il faut une réponse doit être bien défini. Une bonne part de cette définition consiste en une estimation de la précision qui doit être atteinte.

4.1.2 - Est-ce que le ^{14}C peut fournir l'information désirée

L'étape suivante est de déterminer si on peut s'attendre à ce que la méthode du ^{14}C fournisse les réponses aux questions posées. En premier lieu il s'agit de savoir comment l'échelle des temps radiocarbone et sa corrélation avec le temps calendaire influe sur l'interprétation. Est-ce que l'échelle des temps radiocarbone peut convenir pour un positionnement chronologique général ? D'autre part, la datation par le radiocarbone peut ne pas donner la précision suffisante si le problème est de corréler un événement d'âge inconnu avec un événement historique, ou s'il s'agit de fournir les âges relatifs à un événement de courte durée, tel que les temps d'occupation des différentes maisons dans un village. Ces considérations doivent être examinées en priorité car cela n'a pas de sens d'utiliser un outil pour une tache pour laquelle il n'est pas adapté. L'utilisateur doit ainsi être familiarisé avec les possibilités des mesures courantes et les données de calibration liant l'échelle des temps ^{14}C à celle des temps calendaires.

4.1.3 - Quel est l'événement radiocarbone de chaque matériel ?

La meilleure façon de traiter cette question est de prendre pour exemple quelques-uns des matériaux de datation les plus courants.

4.1.3.1 - Les bois et charbons de bois : le bois provient de tissus ligneux de formation annuelle à partir de dioxyde de carbone directement extrait de l'atmosphère. Ce matériel est généralement conservé comme un composant structurel jusqu'à la mort de l'arbre lui même. Les cernes de croissance annuels sont rapidement (2 à 3 ans) isolés de l'atmosphère après leur formation donc il y a un événement radiocarbone spécifique dont la durée est à peu près celle de chaque cerne. Un gros arbre représente ainsi un grand nombre d'événements radiocarbone individuels si on le considère cerne par cerne ou bien il ne représente qu'un seul événement de plus longue durée, si on le considère comme un ensemble de cernes. L'événement radiocarbone est ainsi directement en liaison avec la croissance de l'arbre et seulement indirectement avec son emploi ultérieur par des humains. Le même argument peut être appliqué aux charbons de bois. Comme avec les bois, événement radiocarbone est celui de la formation des cernes de l'arbre et non pas celui du brûlage du bois pour faire cuire un repas.

Aussi bien le bois que le charbon de bois peuvent absorber de grandes quantités de contaminants (d'autres matières carbonées) quand il a été enseveli. Somme toute un tel échantillon a une pauvre définition de l'événement radiocarbone. Heureusement les laboratoires de radiocarbone ont développé des méthodes fiables pour enlever les matériaux polluants.

4.1.3.2 - Les ossements : l'os est un tissu animal constitué essentiellement d'une partie inorganique, l'hydroxyapatite calcique (« apatite ») et d'une partie organique, le collagène protéinique. Toutes les deux contiennent du carbone provenant de l'alimentation de l'animal, mais pas nécessairement de la même partie de son régime alimentaire. Le moment de formation d'un tissu et celui de son tissu de remplacement ne sont pas bien compris, ainsi l'événement radiocarbone peut seulement être situé pendant la durée de vie de l'animal. La difficulté que cela représente dépend de l'animal et la question se doit d'être posée. Par exemple la durée de l'événement radiocarbone d'un agneau est nettement plus courte que celle d'un être humain. Ainsi les os d'un agneau sacrifié et trouvé dans le matériel funéraire de la tombe d'un homme sont beaucoup plus directement en rapport avec l'inhumation de l'homme que ses propres os.

L'os est aussi susceptible d'être contaminé, ce qui détruit la définition de l'événement radiocarbone. L'apatite de l'os, c'est bien connu, peut échanger des carbonates avec l'environnement à tel point que l'événement radiocarbone devient complètement indéfini. Heureusement il y a eu beaucoup de travaux sur le collagène des os en raison des nouvelles possibilités de la technique de datation par accélérateur, si bien qu'il est devenu un matériel de choix pour la datation.

4.1.3.3 - Les coquilles : le carbone d'une coquille marine provient directement des bicarbonates de l'eau dans laquelle l'animal vit et de son dépôt sous forme de carbonate de calcium. L'événement radiocarbone est ainsi défini comme s'étendant sur la durée de vie de l'organisme. Comme celle-ci est généralement limitée à peu d'années, l'événement est bien défini. Cependant, comme avec l'apatite des os, la coquille peut avoir, après son dépôt, un échange de ses carbonates avec ceux de l'environnement et, alors, la définition de l'événement radiocarbone est perdue.

4.1.3.4 - Les autres matériaux : l'introduction de la méthode de datation par les accélérateurs qui a recours à des échantillons de taille nettement réduite, a conduit à ce que de nombreux matériaux qui étaient jusque là inaccessibles à la datation par le radiocarbone peuvent maintenant être mesurés en routine. Cela rend plus facile aux archéologues de choisir pour la datation des échantillons qui ont un événement radiocarbone étroitement associé à l'événement intéressant. Des graines isolées, des fils de vêtements et des cheveux d'individus ont tous bien été datés par la méthode des accélérateurs. Pour de tels exemples, l'événement radiocarbone est très spécifique avec en plus l'avantage que le laboratoire peut être très sélectif dans le traitement des contaminations.

La datation archéologique par le radiocarbone n'est pas limitée au matériel organique. Le mortier frais se durcit par une réaction chimique qui implique la combinaison de CaO (chaux) avec le CO_2 atmosphérique pour former du carbonate de calcium. L'événement radiocarbone pour le mortier est ainsi le temps de la combinaison qui peut durer de quelques mois à plusieurs siècles, suivant l'épaisseur du mur. Si des agrégats contenant des carbonates ou des sables furent ajoutés au mortier, la définition de l'événement devient très confuse.

4.1.4 - Comment chaque événement ^{14}C est-il associé à l'événement humain ?

L'association entre l'événement radiocarbone et l'événement humain intéressant doit être examiné avec un grand soin, car il doit y avoir un lien d'une certaine importance reliant ces deux événements. Cela sera encore mieux illustré par quelques exemples. Une petite branche utilisée pour faire un arc aura un événement radiocarbone (les quelques années de croissance de la branche) et un événement humain (la construction de l'arc) très proches dans le temps, comme l'aura un charbon de bois provenant de la combustion d'une jeune branche d'arbre employée dans le foyer avec le repas qui a été cuisiné. Par contre une poutre de chêne employée (ou réemployée) pour la construction d'un bâtiment peut avoir un événement radiocarbone séparé de plusieurs siècles de l'événement humain que représente la construction. De même un charbon peut perdurer plusieurs millénaires dans le sol et la présence de charbons dans un site ne traduit pas forcément une activité humaine mais peut simplement indiquer un incendie naturel ancien.

Dans beaucoup de cas l'événement radiocarbone pour un os ou une coquille est étroitement associé à l'événement humain et, pour cela, ce sont de bons matériaux de datation. Par exemple les événements radiocarbone d'une coquille de cardium, d'un os de mouton ou d'un os de phoque trouvés dans un amoncellement de reste de cuisine correspondent au moment de la croissance du cardium, du mouton ou du phoque, moment qui n'a sûrement pas précédé de beaucoup le moment de la consommation de l'animal comme nourriture. Un os humain provenant d'une sépulture correspond à une partie de la durée de vie de l'homme inhumé et non pas au moment de son inhumation, mais, comme pour l'animal cette différence peut être évaluée, si cela est important pour l'interprétation.

Les petits échantillons dont la mesure est maintenant possible par l'accélérateur peuvent très bien convenir parce qu'ils peuvent être choisis à cause de l'association directe entre leurs événement radiocarbone et humains. Il y a pour cela de nombreuses possibilités qui sont compatibles avec les capacités de mesure : par exemple mesurer une seule graine d'un plante domestique date une pratique agricole et la date d'un seul cheveu établit le moment d'une présence humaine.

4.1.5 - Est-ce que le matériel à partir duquel l'événement archéologique a été défini remplit les conditions d'un âge ^{14}C conventionnel ?

La nature de l'événement radiocarbone doit être tel que la substance à dater satisfasse la définition d'un âge ^{14}C et en particulier la condition qu'il ne contienne que du carbone de l'atmosphère contemporaine de sa formation. Les mesures sur des tissus végétaux (bois, charbons de bois, graines, etc...) satisfont à cette définition de l'âge radiocarbone car le carbone est obtenu directement à partir de l'atmosphère pendant la formation de la plante.

Ce n'est pas le cas pour les os ou les coquilles car leur carbone vient de l'alimentation de l'animal et non directement de l'atmosphère. Pour le mouton cité plus haut (ou pour n'importe quel herbivore terrestre) qui a mangé de l'herbe ou du foin formé directement à partir du dioxyde de carbone de l'atmosphère contemporaine, cela a une influence minime car le temps de transit entre l'atmosphère et le mouton est de quelques semaines ou au maximum de quelques mois.

Cependant ce n'est pas vrai pour la coquille marine ou la baleine qui prend son carbone dans l'océan. Comme dans l'océan les temps de circulation des eaux se chiffrent en siècles, le temps de transit du carbone entre l'atmosphère et l'animal peut aussi se mesurer en siècles et une correction doit être faite pour tenir compte de cet effet afin d'obtenir un âge en années ^{14}C conventionnelles. Malheureusement ce n'est pas toujours la même correction car les différentes parties des océans du monde ont différents facteurs de correction qui dépendent des circulations océaniques à l'époque. Des considérations aussi complexes régissent les organismes d'eau douce qui tirent leur carbone des lacs ou des rivières.

La situation est même encore plus compliquée pour un être humain qui tire une partie de son alimentation de la mer et une autre de la terre. Pour déterminer l'âge ^{14}C conventionnel de ses os on doit estimer les proportions relatives de leurs constituants provenant de la mer et de la terre. Heureusement, dans certaines circonstances, il est possible de faire une telle estimation à partir de l'examen du rapport des isotopes stables, c'est-à-dire du « delta »^{13}C. Cette considération doit aussi être généralisée pour prendre en compte la conversion ultérieure de l'âge radiocarbone en âge calendaire car la courbe de calibration des échantillons océaniques diffère de celle des matériaux terrestres.

4.2 - STRATÉGIE DE TERRAIN POUR OBTENIR DES MATÉRIAUX PERMETTANT LA DATATION DE L'ÉVÉNEMENT HUMAIN.

On ne peut contester qu'un grand nombre de résultats aberrants sont dus à des problèmes liés aux prélèvements dans le site. Le sol d'où sont extraits les échantillons organiques pendant les fouilles n'est en général pas un système statique mais plutôt un système dynamique où différents processus de pré- ou post-déposition ont été actifs. Ces processus peuvent être naturels (par exemple la bio- ou la cryo-turbation) ou bien des perturbations d'origine anthropique (par exemple les piétinements, le creusement de trous). Quelques-unes de ces perturbations sont responsables de migrations et de contaminations des matières organiques employées pour dater par le radiocarbone les événements humains. Même des échantillons radiocarbone qui sont stratigraphiquement ou spécialement très liés ou associés à des faits archéologiques à dater, peuvent donner des dates qui ne sont pas compatibles avec la date obtenue sur la base des observations stratigraphiques ou typologiques. Il est donc très important que, avant de prélever des échantillons pour le radiocarbone ou de faire la sélection entre plusieurs types d'échantillon prélevés sur le terrain, l'archéologue de terrain acquière une vision claire de tous les processus pédologiques qui se sont produits avant, pendant et après l'événement humain qui doit être daté par le radiocarbone. Cela lui permettra de faire une distinction claire entre du matériel intrusif ou résiduel et des échantillons qui sont contemporains de l'événement archéologique.

Le matériel résiduel peut être de la matière organique qui était déjà présente dans le sol avant l'événement humain à dater. Les sites du Paléolithique ou du Mésolithique, par exemple, sont communément situés dans des sédiments fluviatiles ou éoliens qui peuvent contenir du matériel organique produit naturellement avant l'occupation humaine. Dans quelques cas, en particulier quand on a à faire à des environnements fluviatiles, le résidu organique peut avoir été formé loin du site et y avoir été transporté par l'eau. Dans le cas de sites à occupations multiples, de la matière organique provenant d'une occupation ancienne peut venir se mélanger, par exemple par bioturbation ou par creusement de trous par l'homme, avec les restes d'une occupation récente sus-jacente. Dans la plupart de ces cas la datation des échantillons résiduels va donner des dates ^{14}C qui seront trop anciennes par rapport à l'événement humain à dater.

Le matériel intrusif peut aussi consister en matières organiques qui sont entrées dans le niveau ou la structure archéologique après l'événement humain. On connaît la percolation de très petits fragments organiques (graines, petits fragments de charbon de bois, pépins de fruits) dans les niveaux sous-jacents à cause des terriers d'animaux ou d'insectes tels que les vers de terre, les blaireaux, les taupes, les fourmis, les termites et beaucoup d'autres. Même les activité humaines, telles que les piétinements, peuvent être responsables d'une migration « per descensum » de matières organiques dans le sol. Généralement une date trop jeune est obtenue quand du matériel intrusif est daté par le radiocarbone.

Dans quelques cas les mots « résiduel » ou « intrusif » perdent toute leur signification. Dans de grands édifices (depuis les structures mégalithiques préhistoriques jusqu'aux églises et aux forteresses médiévales) les murs extérieurs des structures, bien que souvent modifiés, restent, tandis que les parties les moins permanentes des structures, comme les planchers ou les mobiliers (d'habitation ou funéraires) subissent tout un lot de changements durant le long usage de ces constructions. Souvent le contenu des grand monuments ne traduit que la dernière étape de leur utilisation, l'événement final. Les preuves d'« événements antérieurs », telle que la construction du monument ou sa première utilisation se trouvent dans la plupart des cas dans des dépôts secondaires tels que des niveaux de débris mélangés, dans des tranchées de fondation (ou de réparation) ou même en dehors du monument. La stratigraphie et par conséquent le concept de restes résiduels ou intrusifs devient sans objet. Une stratégie de datation pour de tels sites doit prendre en compte la possibilité d'« événements cachés », de phases d'utilisation ou d'abandon du monument qui ne sont pas visibles dans les restes archéologiques.

La datation d'échantillon dont l'origine est douteuse est une autre cause possible de résultats aberrants. Pour quelques matières organiques il est très difficile ou même impossible de déterminer si leur présence dans le site est due à des événements humains ou naturels. Dans le cas de charbons retrouvés dispersés sur tout un site ou qui ne sont pas directement associés à des traces clairement anthropogéniques, tel qu'un foyer, la distinction entre des charbons produits naturellement, par exemple par des feux de forêt, et des charbons produits par l'homme ne peut pas être faite. Les os, d'autre part, peuvent avoir été apportés dans le site, avant ou après son occupation, par des carnivores. Il est donc recommandé d'employer, pour les datations, de préférence des os présentant des traces humaines, par exemple des fragments avec des marques claires de décarnisation, des fragments décorés d'outils en os.

Enfin des résultats aberrants peuvent dans quelques cas être expliqués par une mauvaise ou douteuse association spatiale des échantillons radiocarbone avec l'événement archéologique à dater. En principe des échantillons provenant de structures archéologiques (foyers, fosses, fossés) sont beaucoup plus fiables que des échantillons éparpillés.

Cependant des résultats aberrants ne sont pas complètement à exclure, en particulier dans des sites non stratifiés qui ont connu plusieurs occupations. Des échantillons provenant de trous de poteaux qui ne constituent pas une partie d'un plan de maison, un lieu de stockage isolé ou un puits d'ordures dans un site ou un foyer ou un foyer en fosse qui n'est pas associé à un groupe d'objets lithiques peuvent produire des dates ^{14}C indiquant une réoccupation du site. Dans certains cas des dates ^{14}C peuvent révéler des phases d'occupation « masquées » dans un site qui ne sont pas soupçonnées par les données archéologiques parce qu'elles n'ont pas produit des témoins archéologiques ou que ceux-ci ont complètement disparus.

Finalement la recherche d'un bon échantillon implique aussi que durant l'échantillonnage l'archéologue de terrain essaye d'obtenir des informations sur les qualités physiques ou chimiques d'un échantillon prévu. Des questions telles que : « est-ce que cet échantillon a été bien conservé ? » ou « est-ce qu'il y a des possibilités de contamination ? » sont nécessaires pour sélectionner le meilleur échantillon. Souvent les laboratoires reçoivent des échantillons si mal conservés qu'il est impossible de séparer les contaminants du carbone relié à l'événement. Des informations recueillies durant le travail de terrain peuvent aider le laboratoire à comprendre les conditions de gisement et à adapter le traitement.

5 - ANALYSES DES DATES RADIOCARBONE

5.1 - DE L'ÉCHELLE DU TEMPS RADIOCARBONE À CELUI DU TEMPS ASTRONOMIQUE

La détermination d'un âge par la méthode du Radiocarbone est basée sur l'horloge de la décroissance radioactive puisque que la teneur en ^{14}C restant dans tout échantillon dépend de la teneur qu'avait l'organisme durant sa vie et du temps qui s'est écoulé depuis sa mort. La teneur en ^{14}C dans un organisme terrestre durant sa vie est très proche de la teneur actuelle dans l'atmosphère. Bien qu'assez constante, celle-ci varie à cause des fluctuations de l'activité solaire et de l'intensité du champ magnétique terrestre. Cela amène l'échelle des temps Radiocarbone à être différente de l'échelle des temps calendaires. De vrais âges calendaires ne peuvent donc pas être directement déduits de l'échelle des temps ^{14}C qui est basée sur la teneur en ^{14}C dans l'échantillon. Les dates radiocarbone sont toujours exprimées en années B.P. (« Before Present ») où le « Présent » est, par convention, l'année 1950 après J.-C.

La calibration est la procédure de transformation d'une date Radiocarbone (en BP) en un âge historique dénommé après calibration « calBC » (« av. J.-C. » : N.D.T.) « calAD » (« ap. J.-C. » : N.D.T.) ou éventuellement « cal BP ». Les deux échelles de temps BP et cal BC/AD (av./ap. J.-C.) sont reliées par une courbe de calibration qui a été obtenue par la mesure du Radiocarbone d'échantillons d'âge absolu connu. La meilleure méthode indépendante pour trouver ces âges absolus durant l'Holocène est la dendrochronologie : par la mesure précise du ^{14}C de cernes de croissance d'arbres, des courbes de calibration d'une haute précision ont été obtenues. Dans le volume « Calibration » de la revue Radiocarbone (1986, vol. 28 n°2B) Stuiver et Pearson ont construit une courbe bidécade, c'est-à-dire par tranche de 20 cernes, qui a acquis le statut de « courbe recommandée ». En 1993, une seconde courbe a été publiée (Radiocarbon, vol. 35 n°1), avec une profusion de nouvelles données dont une courbe pour le Préboréal et quelques corrections de l'ensemble des données de 1986. Cependant aucune recommandation officielle n'a été faite, car elle aurait créé quelque confusion.

Il y a eu discussion entre 1986 et 1993 sur la possibilité d'un « effet local » des courbes de calibration, à cause de différences systématiques entre du bois provenant de la côte Ouest des Etats-Unis et du bois provenant de l'Europe. En théorie cela est possible mais de tels effets sont très petits (pas plus de 20 années BP), à la limite de ce qu'il est possible de mesurer et sont négligeables pour la plupart des applications archéologiques. Le seul effet local sur lequel on est d'accord est une différence systématique d'environ 40 ans entre les hémisphères Nord et Sud, le Sud étant plus ancien (déficit en ^{14}C). Après la conférence internationale radiocarbone de 1997 à Groningen, il fut décidé de construire une troisième courbe de calibration, prévue pour 1998 (Stuiver and van der Plicht, 1998). Celle-ci comprendra une nouvelle courbe moyenne qui sera recommandée pour un emploi généralisé. Elle prendra en compte de nouvelles corrections de données ^{14}C (de portée très faible) et aussi quelques corrections de données dendrochronologiques. Une chronologie flottante pour le pin du Préboréal est ajustée grâce à ses micro-variations pour réviser la chronologie absolue ; cela ne changera pas beaucoup dans le futur.

En dehors des chronologies absolues flottantes de cernes d'arbres, la courbe de calibration est étendue aux temps glaciaires par la datation de coraux à la fois par le ^{14}C et les isotopes de la série de l'Uranium. Les dates par la série de l'Uranium sont considérées comme absolues ; les dates Radiocarbone sont obtenues sur du matériel marin à partir desquels la courbe de calibration atmosphérique est déduite en supposant un effet réservoir de 400 ans. Un troisième ensemble de données de calibration est constitué par des mesures de radiocarbone sur les sédiments laminés ou « varves ». Puisque toutes les données existantes ne sont pas absolues et doivent être ajustées aux courbes basées sur les cernes d'arbre ou la série de l'Uranium et puisque les comptages de varves sont problématiques, ces derniers ensembles de données ne sont pas encore pris en compte dans la courbe de calibration.

Pour la calibration, des programmes informatiques ont été développés par plusieurs laboratoires. Les plus largement utilisés sont ceux de Seattle, Oxford et Groningen. Des intercomparaisons ont montré que les différences entre les résultats calibrés à partir de ces programmes (et d'autres) sont négligeables. Les principales différences sont seulement dans les sorties de présentations graphiques ou dans quelques options spéciales de prise en compte des concordances de déformations ou d'analyse Bayesienne.

5.2 - ANALYSE STATISTIQUE DU ^{14}C

Du point de vue des archéologues, la calibration ne simplifie pas l'interprétation des dates radiocarbone. Alors que des dates non calibrées (BP) correspondent à des équations mathématiques relativement simples (distribution gaussienne) et à des notations « mu » +/- « sigma », ce n'est plus le cas après la calibration. En raison de la présence de micro-variations et suivant la position de l'événement ^{14}C sur l'échelle des temps, la courbe de probabilité, représentant l'âge réel des échantillons, peut devenir bimodale ou trimodale et même, un plateau dans la courbe peut se produire. Souvent les plages de 1 et 2 « sigma » vont se diviser en différents pics, contribuant à une distribution irrégulière des probabilités. Cela signifie qu'il est plus probable que l'âge de l'échantillon se trouve sur l'axe du temps réel dans une plage couverte par les pics et a peu de chance de se situer dans les zones de faible probabilité localisées dans les dépressions entre les pics. En pratique, cependant, s'il n'y a pas d'informations supplémentaires, l'archéologue a peu d'intérêt à utiliser une représentation complexe et fera mieux de prendre en compte la plage totale qui est dans la plupart des cas plus grande que celle de l'échelle des temps non calibrés.

En d'autres termes la plage de dates après calibration n'est pas seulement définie par des comptages statistiques mais dépend aussi des micro-variations dans la courbe de calibration. Cela conduit l'utilisateur à une échelle de temps où des zones de hautes et basses précisions se succèdent. Différents événements dans d'assez courtes périodes peuvent être datés à des degrés différents de précision. Le fait que les archéologues se sentent peu à l'aise dans une telle situation a été exprimé en maintes occasions.

C'est un fait que le Radiocarbone donne des dates assez imprécises si on considère que, en réalité, l'évènement humain qui intéresse l'archéologue n'a eu lieu, dans la majorité des cas, qu'en un seul jour. Heureusement le ^{14}C n'est souvent qu'un des nombreux témoins de la chronologie dont disposent les archéologues. Traditionnellement ceux qui ont à faire face à cette complexité sont dans une démarche de déduction qui est intégrée dans le texte des rapports sur le site. Ceci a l'avantage de permettre une subtile pondération des données à la lumière de l'expérience et de l'expertise. Cependant avec les résultats des données radiocarbone sous forme de distributions de probabilités ou de plages de dates, il est extrêmement difficile d'avoir une bonne intuition d'une interprétation fiable et le petit détail de ces données est souvent perdu dans la procédure.

Pour aider dans le processus d'interprétation, les analyses Bayesiennes peuvent être employées (Litton and Buck, 1995). Pour comprendre cela nous avons besoin de revenir en arrière sur la procédure de calibration elle-même. Il y a un présupposé sous-jacent à la calibration qui est que chaque année a, a priori, une égale probabilité. Si nous avons d'autres données, comme par exemple une séquence d'événements dans un site, ce présupposé n'est manifestement plus valable. Des modifications dans les distributions des probabilités et les plages de dates peuvent être faites par l'incorporation de contraintes, par exemple, sur l'ordre des événements. Les résultats de cette sorte d'analyse seront traités naturellement comme une partie de l'interprétation des données, car les opinions peuvent varier sur la fiabilité des séquences et des associations dans n'importe quel site. Il est aussi essentiel de considérer la relation entre l'événement ^{14}C et les événements qui sont en fait dignes d'intérêt. En plus de la modulation de l'intérêt pour l'événement ^{14}C, de telles analyses peuvent fournir des estimations (avec des intervalles de confiance) pour des événements qui sont datés seulement indirectement ; ceci est probablement leur plus grande force.

Il y a plusieurs statisticiens qui sont capables de faire de telles analyses et, de plus, le programme de calibration d'Oxford est capable de traiter une grande variété de modèles (tels que les mélanges de séquences et de phases, les « termini ante quem », les cernes des arbres etc...). Le cas très particulier de l'ajustement par les micro-variations des séquences de cernes d'arbres est traité dans plusieurs programmes. Leur avantage est généralement qu'ils sont facilement accessibles et qu'ils permettent aux utilisateurs du radiocarbone de tester expérimentalement des idées ou des méthodes. Leur désavantage est qu'une mauvaise utilisation est très possible et en général il est mieux de demander conseil aux auteurs, ou à quelqu'un d'expérimenté dans leur usage, avant la publication de la plus simple de ces analyses.

Une attention spéciale doit être apportée aux événements qui se situent aux deux extrémités de l'échelle du temps ^{14}C. Des échantillons contenant à peu près 2 % de carbone moderne ou moins (sup./= 30 000 BP) peuvent être affectés d'erreurs dues à des contaminations modernes qu'il est difficile d'estimer. Une stratégie spéciale de datation est nécessaire pour se sortir de ce problème. Des informations supplémentaires pour vérifier la fiabilité du résultat doivent être obtenues par les corrélations archéologiques (les relations culturelles ou stratigraphiques, par exemple), par l'analyse du matériel (en comparant les dates sur différents matériaux, par exemple) ou par les informations des laboratoires (en analysant différents composants chimiques ou en mesurant les isotopes stables, par exemple).

Les problèmes liés à la partie la plus récente de l'échelle des temps ^{14}C, les temps historiques (Van Strydonck, 1997), sont de nature complètement différente. Si on compare les résultats radiocarbone avec les données historiques, la méthode de datation semble sans rapport. Même les dates des laboratoires de grande précision conduiront les archéologues ou les historiens de l'art, dans la plupart des cas, à une incertitude d'au moins un siècle après calibration. Cela peut être frustrant pour des chercheurs qui ont tendance à penser plutôt en années qu'en décades quand ils rendent compte d'un événement du passé. Ainsi la datation absolue par le radiocarbone donne des dates imprécises pour des sites médiévaux très bien documentés. Mais des objets sortis de leur contexte (par exemple des objets de musée) ou des structures isolées (comme des puits, par exemple) nécessitent une datation ^{14}C plus souvent qu'on ne l'a cru. En outre la datation relative ouvre de bien plus grandes perspectives, non pas d'abord pour l'ordonnancement des objets ou des événements, mais surtout à cause du fait qu'elle rend possible des comparaisons. Cette approche lie entre elles l'Archéologie historique et l'Histoire. Des événements tels que des batailles, des inhumations, des constructions de bâtiments, etc... décrites dans des textes anciens ou même dans des légendes, peuvent être comparées avec du matériel qui est supposé être des restes de ces événements. En fait le radiocarbone ne fournit plus vraiment une date, mais indique la probabilité pour qu'un objet soit lié à un événement historique.

6 - LABEL DE QUALITÉ EN DATATION ^{14}C

La caractéristique fondamentale de la datation par le radiocarbone est qu'elle est basée sur un phénomène régi par les lois du hasard et cela veut dire que la décroissance du radiocarbone se fait aléatoirement. Historiquement la décroissance radioactive est connue pour avoir un caractère aléatoire et le nombre de coup observé est supposé suivre une distribution de Poisson. Ce fait a d'importantes implications pour la compréhension et l'interprétation d'un âge radiocarbone. L'âge est calculé à partir d'un nombre de coups observés (ou décroissance) à un moment donné et ainsi un âge ^{14}C est une seule observation à partir d'un processus régi par le hasard. Par cela nous signifions que si nous mesurions le même échantillon plusieurs fois (c'est-à-dire par des comptages répétés) dans des conditions identiques, et si à chaque fois on calculait l'âge, nous n'obtiendrions pas exactement le même résultat. Il y aurait une distribution des âges. Cette situation simple (et très irréaliste) explique la plus importante caractéristique du ^{14}C : un inévitable degré de variation dans les résultats.

Considérons un scénario plus réaliste : imaginons qu'on découpe un échantillon (avec des découpes toutes absolument semblables), les fragments d'échantillon seront alors parfaitement homogènes. Chaque fragment d'échantillon sera daté dans un seul laboratoire ; c'est-à-dire que chaque échantillon suivra une procédure de prétraitement, suivi d'une préparation chimique avant d'entrer dans la phase de comptage. Les âges calculés pour chaque fragment d'échantillon ne seront pas identiques. Une simple mesure de la variabilité des résultats est le carré de la déviation standard qui mesure la dispersion de tous les résultats autour de leur valeur moyenne. Puisque nous avons découpé l'échantillon en fragments d'échantillons identiques, chacun aura exactement le même âge réel pour lequel la moyenne de tous les résultats donnerait une bonne estimation. Si nous devions comparer cette mesure de la variabilité avec celle observée dans le premier scénario (la simple répétition des comptages) elle serait au moins aussi grande dans la mesure où nous avons introduit des sources supplémentaires de variation (à savoir les prétraitements et la synthèse chimique).

Finalement, et de façon plus réaliste, nous pourrions imaginer des petites différences entre les teneurs en ^{14}C des différents fragments d'échantillon. Ainsi la cause finale de variation des résultats sera ces différences entre les fragments d'échantillons. De cette manière nous avons décrit les composants de variation et leur contribution à la variabilité des dates ^{14}C. Le stade suivant est de considérer comment un laboratoire donné estime cette variation.

Les laboratoires indiquent l'âge calculé de l'échantillon et donnent aussi l'erreur associée qui est une mesure de la variation des sources citées ci-dessus liée à l'échantillon particulier. Dans sa forme la plus simple cette erreur est basée sur l'incertitude inhérente au comptage de l'échantillon, du standard et du bruit de fond ; c'est-à-dire sur le caractère aléatoire du processus de décroissance (erreur de Poisson). De plus, l'erreur citée avec une date ^{14}C inclura aussi dans beaucoup de cas une estimation du laboratoire sur les facteurs discutés ci-dessus (une mesure de la reproductibilité des résultats). Cette estimation peut être faite de plusieurs manières, mais elle implique l'emploi de standards internes au laboratoire (comprenant par exemple la mesure de matériaux d'âge connu) et l'évaluation statistique d'expériences répétées.

Si nous considérons l'âge calculé et son erreur, qu'est-ce que cela signifie ? Pour le comprendre nous devons avoir recours à des arguments basés sur la probabilité. D'une manière simple nous imaginons que l'âge calculé est une bonne estimation de l'âge ^{14}C vrai inconnu ; alors nous pouvons imaginer que l'âge +/- l'erreur à 2 « sigma » fournit une plage de valeurs plausibles pour cet âge réel. Avec des arguments de probabilité, on définit comme plausible que 95 pour 100 de ces intervalles contient la valeur vraie et inconnue. Cela ne dit pas que cet intervalle particulier contient la valeur vraie et inconnue mais décrit les propriétés à longue portée de la procédure employée pour calculer l'intervalle.

L'âge calculé est une estimation de l'âge vrai inconnu. Nous pouvons définir des propriétés que nous voudrions que cette estimation possède. Les propriétés clés de l'estimation sont qu'elle soit exacte (c'est-à-dire non biaisée) et qu'elle soit précise. L'exactitude signifie que, en moyenne, l'estimation sera égale à la valeur vraie inconnue. Cela ne signifie pas que chaque résultat individuel sera exactement égal à la valeur vrai inconnue. Si la moyenne n'est pas égale à l'âge vrai, alors nous décrirons la différence (moyenne-âge vrai) comme le biais. Le biais est toujours relatif à une quantité fixe telle que l'âge vrai inconnu.

De plus, nous aurons aussi une mesure de l'erreur ou de l'incertitude sur l'estimation, qui est communément connue comme la précision de l'estimation, et nous voudrions qu'elle soit la plus petite possible en termes numériques (c'est-à-dire la meilleure précision). Le but est d'avoir une estimation à la fois exacte et précise, mais ce n'est pas toujours possible et l'estimation peut être biaisée et précise ou même biaisée et imprécise. L'exactitude et la précision sont des quantités théoriques, aussi l'évaluation des propriétés de l'estimation dépend d'un modèle mathématique (tel que le modèle de Poisson). Pour illustrer l'exactitude et la précision dans un contexte simple, considérons une cible de tir à l'arc. Notre archer ne sera pas biaisé si les flèches qu'il tire se groupent autour de l'oeil de la cible, tandis qu'il sera biaisé si les flèches se regroupent hors du centre. Son tir sera précis si toutes les flèches sont proches les unes des autres et imprécis si les flèches sont largement dispersées sur toutes la cible.

Une composante supplémentaire de variation peut être introduite quand le « même » échantillon est mesuré dans plusieurs laboratoires et, ainsi, est mis en évidence la question de compatibilité de résultats provenant de laboratoires différents. Il y a eu de nombreuses discussions sur les difficultés qui peuvent surgir quand on essaye d'utiliser des dates obtenues dans différents laboratoires ou même dans le même laboratoire à des moments différents. Nous pouvons nous attendre à quelques différences dans les résultats et il est intéressant de considérer l'échelle des variations et, pour aller plus loin, si nous avons un matériel d'âge connu, de considérer s'il y a un biais entre les laboratoires et la relation qu'a l'erreur donnée avec la variation observée dans les résultats. Cette affaire s'intègre dans « l'assurance qualité » des laboratoires de radiocarbone et ce n'est pas nouveau puisqu'il est bien connu que la chronologie radiocarbone/cernes d'arbres est basée sur un petit nombre de laboratoires différents. Le label de qualité pour des laboratoires de radiocarbone a plusieurs aspects (Long and Kalin, 1990) :

i/ il doit évaluer l'exactitude d'un laboratoire pour les datations en routine ;

ii/ il doit évaluer la précision d'un laboratoire en tenant compte du prélèvement et des analyses qui suivent ce prélèvement ;

iii/ il doit permettre d'identifier les problèmes pour pouvoir agir ;

iv/ il doit fournir les bases de la confiance du consommateur.

Déjà chaque laboratoire dans le cadre de sa procédure de routine conduit des recherches sur ce label de qualité, mais, en plus, ces dernières quinze années, la communauté Radiocarbone a volontairement entrepris des intercalibrations supplémentaires et indépendantes (Gulliksen and Scott, 1995 et Scott *and al.*, 1998).

Toute la recherche d'intercalibration avait eu comme premier but une investigation sur la possibilité de comparer des résultats. Dans chaque cas, les laboratoires participants ont été pourvus d'une série d'échantillons comprenant du bois, des coquilles, de la tourbe et des os. Le matériel avait été collecté et préparé en gros et, dans la plupart des cas, avait une origine naturelle. Les résultats ont été étudiés pour mettre en évidence n'importe quel biais de laboratoire et pour examiner leur variabilité. Les laboratoires, et aussi les usagers, ont été les bénéficiaires dans ces opérations. Dans la plupart des cas il a été mis en évidence des variations supplémentaires dans les résultats, des effets de déviation systématique (biais), ou des différences parmi certains laboratoires. Des matériaux supplémentaires ont été préparés et rendus disponibles dans le cadre d'un programme d'assurance qualité. La communauté utilisatrice du ^{14}C doit accepter que l'incertitude d'un résultat ^{14}C est fondamentale, mais peut aussi attendre à ce que les laboratoires fassent de leur mieux pour s'assurer que les résultats sont de la plus haute qualité à travers un protocole rigoureux d'assurance qualité et une recherche indépendante.

7 - CONCLUSION

L'application réussie de la datation par le radiocarbone requiert l'examen détaillé d'exigences complexes qui doivent être satisfaites pour que les présupposés à la base de la méthode soient satisfaits. Alors que certaines de ces exigences sont de la seule responsabilité des laboratoires de radiocarbone, d'autres ne le sont pas et elles doivent être clairement évaluées par les archéologues utilisateurs si on veut obtenir des informations chronologiques fiables. En particulier l'archéologue doit bien spécifier les questions chronologiques qui l'intéressent et doit clairement identifier, choisir et apprécier des échantillons qui sont susceptibles de fournir des réponses fiables à ces questions. Ce n'est pas une tache qui peut être simplement déléguée à un « expert scientifique » au laboratoire de mesure, mais c'est aussi de la responsabilité de l'usager. Nous espérons que l'approche esquissée ici aidera les usagers en leur fournissant un canevas pour ces évaluations complexes.

8 - SUGGESTIONS POUR DE PLUS AMPLES LECTURES

i/ En langue anglaise (N.D.T.) :

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LONG, A. and KALIN, R.M., 1990 - A suggested quality assurance protocol for radiocarbon dating laboratories. *Radiocarbon,* 32(3), 329-334.
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EVIN, J., - Materials of terrestrial origin used for the radiocarbon dating - les matériaux d'origine terrestre utilisés pour la datation par le radiocarbone : Comptes rendus du 1er Colloque C14 et Archéologie, Groningue, Août 1981 : *Pact Journal*, 8, 155-171.

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EVIN, J., 1992 - Les Datations par le radiocarbone en géologie et en archéologie : fiabilité de la méthode selon l'origine et l'état des matériaux. *Documents du Laboratoire de Géologie de Lyon*, n°122, 99 p.
EVIN, J. et OBERLIN, C., 1998 - La méthode de datation par le radiocarbone : *in Les méthodes de datation en laboratoire pour l'Archéologie*, Editions Erance.

Actes du colloque «C14 Archéologie», 1998, p. 449-451.

RAPPORT DU GROUPE DE TRAVAIL SUR LES PÉRIODES HISTORIQUES

L'utilisation du ^{14}C pour les périodes historiques

R. COLARDELLE, G. DÉMIANS D'ARCHIMBAUD, PH. LEVEAU, M. MANGIN, CH. OBERLIN, J. THIRIOT et E. ZADORA-RIO

Depuis dix ou quinze ans, grâce aux progrès des méthodes d'analyse qui ont amélioré la précision et la fiabilité des datations (Oberlin, Evin, 1996, 243-255), le ^{14}C est de plus en plus largement utilisé pour les périodes historiques. Pour l'Antiquité et le Moyen Age, le ^{14}C est principalement utilisé actuellement lorsque le mobilier archéologique fait défaut ou est encore insuffisamment connu, en particulier pour le haut Moyen Age (surtout entre le VIIIe et le Xe s.). Son utilisation a permis de grands progrès dans l'archéologie funéraire. Un usage nouveau, peut-être appelé à se développer, est apparu dans le domaine de la céramique et d'une manière générale pour la datation du mobilier.

L'objectif de cette introduction est double : d'une part, présenter les principaux champs d'application des analyses du ^{14}C pour les périodes historiques ; d'autre part, attirer l'attention des archéologues sur les règles d'utilisation des datations radiocarboniques ; leur respect a sans doute une importance particulière pour les périodes historiques dans la mesure où la précision requise est plus grande. Depuis une vingtaine d'années, les méthodes de fouille se sont affinées et autorisent une meilleure compréhension des phénomènes de stratification, mais la prise de conscience des phénomènes de redéposition de mobilier et des problèmes qu'ils entraînent pour la datation des couches n'a, curieusement, guère touché l'utilisation que font les archéologues des datations ^{14}C qui est souvent trop peu critique : plus personne n'oserait dater une couche avec uniquement une monnaie ou un tesson, mais on le fait couramment encore sur la foi d'une seule analyse de ^{14}C.

1 - LES OSSEMENTS

La datation d'ossements par extraction du collagène a connu un essor rapide et a entraîné un renouvellement important de l'archéologie funéraire. Elle a suscité un intérêt nouveau pour les cimetières médiévaux qui étaient jusque là délaissés par les archéologues en raison, entre autres, des difficultés de datation des sépultures : celles-ci sont en effet le plus souvent dépourvues de mobilier à partir du VIIe-VIIIe s., et les chronologies fondées sur la typologie des tombes sont encore fragiles. Le recours au ^{14}C devrait permettre de l'asseoir sur des bases plus solides, mais il faut prendre garde, dans le cas des tombes construites, aux problèmes de réemploi.

Les sépultures représentent sans doute le cas le plus favorable à l'utilisation du ^{14}C, dans la mesure où il est toujours possible de déterminer si une sépulture est en place, et où la datation d'un os correspond nécessairement à la datation de l'inhumation.

On peut s'interroger, en revanche, sur les datations d'ossements animaux trouvés dans des comblements de fosses : elles ne peuvent donner qu'un terminus post quem pour le comblement, et ne devraient être utilisées pour dater le mobilier associé que si les échantillons sont nombreux et leurs dates concordantes. Si les os sont trop petits pour pouvoir être datés individuellement par les méthodes classiques, il semble préférable d'avoir recours à l'accélérateur plutôt que de réunir plusieurs ossements pour obtenir le poids nécessaire pour une datation par comptage classique.

2 - LES AMÉNAGEMENTS PAYSAGERS ET LE PALÉO-ENVIRONNEMENT

Dans le domaine de l'environnement, l'utilisation du ^{14}C s'est imposée dès l'origine, mais son usage pour les périodes historiques est relativement récent. Des confusions naissant du double sens du mot environnement — milieu ou environ du site —, il importe de rappeler la différence qui existe entre les objectifs des environnementalistes et ceux des archéologues. Ces derniers demandent aux premiers une évaluation des contraintes que le milieu impose ou propose aux sociétés. L'objectif spécifique des archéologues est de replacer un site dans un contexte, d'en identifier les activités en portant une attention particulière sur les aménagements paysagers en relation avec l'habitat, en particulier sur les limites parcellaires (fossés de drainage, rideaux de culture...).

Il convient donc de distinguer trois situations :

L'étude des paléo-environnements. Les protocoles de datation du paléo-environnement relèvent de la compétence des environnementalistes ; les archéologues ont des souhaits mais ils n'ont pas de compétences particulières en la matière.

En revanche, lorsqu'il s'agit d'établir un fait tel que la construction d'un fossé, son curage ou de mettre des aménagements paysagers en relation avec un fait historique, l'établissement d'une chronologie est de la compétence des archéologues.

Entre les deux, se situent les phénomènes d'anthropisation qui sont des processus lents.

Des malentendus doivent être dissipés. Les archéologues des périodes historiques ont souvent le sentiment que les environnementalistes qui ont l'habitude de travailler à une échelle de temps beaucoup plus large qu'eux se contentent d'une précision chronologique inférieure à celle qui est habituelle aux historiens. En fait s'il est vrai qu'il fut un moment dans l'histoire de la discipline où l'on se contentait de quelques dates, celui-ci est révolu. La multiplication du nombre des prélèvements sur les séquences s'accompagne d'une multiplication des dates dont l'obtention est précisément rendue plus aisée par les progrès accomplis dans les techniques de datation. En même temps, des environnementalistes affichent clairement l'objectif de travailler «à une échelle de temps suffisamment précise, de l'ordre de quelques années à 10 ans, nécessaire à la discussion des questions historiques». Cette citation extraite d'un article de J.-L. Borel, J.-L. Brochier et J.-C. Druart concerne le site médiéval de Colletière sur le lac de Paladru dont on connaît la place dans la recherche française en matière de mise en relation des données archéologiques et des données environnementales.

Des principes doivent être rappelés. Au moment où l'affinement des procédures d'étude permet aux environnementalistes de prendre en compte les phénomènes de redéposition, la possibilité d'obtenir des dates sur le contenu des couches de colluvions ou des comblements de fossés ne doit pas faire perdre de vue que ces datations n'apportent qu'un simple terminus post quem. Pas plus que les tessons, les charbons de bois prélevés ne peuvent servir à dater la déposition des couches qui les contiennent. Or régulièrement des archéologues mal informés ou pressés ne prennent pas assez en compte les risques de pollution, dus à une redéposition des charbons de bois : ils confondent rigueur dans la procédure et pertinence de la datation.

3 - LES MORTIERS

Si la datation de la chaux entrant dans la composition des mortiers en est encore au stade expérimental, le recours au ^{14}C est assez fréquent pour dater les charbons de bois contenus dans les mortiers. Ceux-ci sont supposés provenir de la cuisson de la chaux, et dater la construction des bâtiments d'où ils proviennent. Ils peuvent cependant avoir d'autres sources et avoir été incorporés accidentellement dans le mortier ; là encore, le ^{14}C ne donne qu'un terminus post quem, et il faudrait multiplier les analyses avant de pouvoir utiliser les résultats pour dater un édifice ; là encore, il faudrait avoir recours à l'accélérateur pour éviter d'avoir à mélanger les échantillons pour obtenir un poids suffisant.

On peut penser que la fiabilité de l'interprétation archéologique de la datation est plus grande lorsque le charbon de bois provient d'une brindille, moins susceptible de s'être conservée pendant une longue durée qu'une poutre qui se fragmente peu à peu ; une étude xylologique devrait donc être couplée avec l'analyse.

4 - LES STRUCTURES DE COMBUSTION

LES FOURS DE POTIERS

Les céramologues ont coutume de dater des lots de tessons issus d'une fouille d'habitat ou de tout autre gisement par comparaison avec les typologies régionales édifiées de longue date dans un effort collectif où certains jalons sont datés par référence aux données de fouille ou à la chronologie d'autres marqueurs. On aurait tendance à suivre ce schéma pour la datation des structures de production : les typologies indiquent telle époque pour les productions rencontrées dans tel four. En fait, cette démarche soulève plusieurs problèmes évoqués ici rapidement : les productions d'un four, c'est-à-dire une référence pour les typologies, doivent être datées de façon indépendante des typologies classiques afin de jouer pleinement leur rôle de référence. D'autre part, il est nécessaire de bien distinguer, dans la fouille du four, ce qui est production de la structure du remplissage d'abandon qui provient essentiellement de l'atelier mais qui peut être antérieur ou postérieur à l'arrêt de fonctionnement du four et comporter de surcroît des éléments étrangers à la production (céramique employée dans l'atelier ou même importations).

La datation d'un four doit donc être dans la mesure du possible indépendante. C'est pour cette raison que les datations de laboratoire sont requises. La datation par l'archéomagnétisme, malgré ses fluctuations récentes, offre une précision importante pour la période médiévale de l'ordre de ± 20 ans hormis toutefois le haut moyen-âge où la courbe de référence est sous-définie. L'archéomètre a encore besoin de connaître la datation archéologique supposée pour lui faciliter la tâche dans le choix de la période même si la comparaison Inclinaison-Déclinaison et maintenant Intensité du Champ Magnétique Terrestre (CMT) ne laisse subsister que peu d'ambiguïté. Dans ce contexte, pourquoi faire appel au radiocarbone dont les intervalles de précision sont réputés nettement plus larges ? Pour l'archéologue qui ignore parfois tout des productions rencontrées dans un four (phase de production), avoir un intervalle de temps à 95 % où les placer est une assurance non négligeable qui confirmera sans doute généralement les typologies en vigueur si ce type de céramique y figure (céramique connue des autres archéologues. Le cas des productions de Marseille au XIIIe s. découvertes en 1991 et non identifiées alors montre qu'il peut y avoir des manques). Pour l'archéomètre, cet apport du ^{14}C peut l'aider dans sa démarche dans les cas de sous-documentation de la courbe de référence ou surtout en absence de courbe comme en Espagne par exemple. Pour l'archéomètre aussi, il peut y avoir un intérêt de méthode à comparer les résultats apportés par les différentes façons de dater une structure de production.

La banque de données Banadora sur le radiocarbone en France signale seulement 15 mesures concernant apparemment des fours de potiers médiévaux. C'est assez peu mais doit correspondre à l'a-priori ancien des archéologues vis-à-vis du radiocarbone trop imprécis pour le moyen-âge par rapport aux moyens utilisés par eux de façon traditionnelle. 12 d'entre-elles concernent le haut moyen-âge jusqu'au Xe s. et 3 concernent les XIIe-XIVe s. C'est sans doute la preuve que le radiocarbone est utile pour les périodes mal connues en complément d'autres méthodes de laboratoire ici employées rarement comme la thermoluminescence (TL) ou plus souvent l'archéomagnétisme. Les fours à chaux étant difficilement datables par manque de matériel, il est naturel de trouver ici un nombre relativement important de radiodatations (9 mesures).

En Bretagne 4 fours ont fait l'objet de mesures croisées : archéomagnétisme du four et des productions, radiocarbone et thermoluminescence. Sur les 3 radiocarbones effectués, une mesure est en total désaccord avec les autres méthodes qui ont elles-mêmes leurs problèmes (surtout anisotropie pour l'archéomagnétisme). Le risque de pollution du carbone reste présent.

En Espagne, sur environ 50 fours prélevés pour la datation par archéomagnétisme, 18 datations radiocarbone dont 16 à Cabrera d'Anoia ont été réalisés et 6 sont à faire afin d'assurer le calage de la variation du CMT de la Péninsule en prenant appui en partie sur la courbe française de variation du CMT. Le radiocarbone reste d'un emploi assez rare pour ces fours de potiers en Espagne, pratiquement inexistant en dehors des interventions de J. Thiriot.

LES FOURS DE MÉTALLURGISTES

Pour la période allant de l'Age du Fer à la fin du Moyen Age (et parfois au-delà), les sites de production du fer selon le procédé direct (extraction du minerai et réduction de celui-ci en métal brut) sont habituellement situés hors de tout habitat permanent et, de ce fait, souvent dépourvus de tout mobilier archéologique datant. Dans nombre de pays européens -notamment en Scandinavie- l'utilisation systématique du ^{14}C a permis de dresser une courbe précise de l'évolution de la sidérurgie sur plus de deux millénaires. En France, hormis dans le Midi où le mobilier datant existe parfois, comme au Martys dans l'Aude), les fouilles d'ateliers de réduction ne remontent guère à plus de douze ans et rares sont encore les sites publiés où ce mode de datation a été utilisé.

Comme pour les mines d'or du Limousin étudiées par B. Cauuet et datées de La Tène grâce au ^{14}C, la chronologie postulée de quelques sites de réduction, notamment en Bourgogne et en Franche-Comté, a été à l'instar des ateliers de Suisse occidentale, bouleversée par les datations fournies par cette méthode. Ce sont des périodes entières de la production qui ont été révélées (La Tène et haut Moyen Age), alors que jusqu'ici, l'importance des vestiges de la production d'époque romaine masquait, autant au sens propre que figuré, l'existence de la production d'autres périodes historiques.

Grâce aux grands travaux autoroutiers, sur deux sites de production (les Clérinois dans l'Yonne et Aulnet-Truchet dans la Sarthe), des dizaines de bas fourneaux ont été fouillés récemment et ont fourni plus de données techniques que l'Europe n'en disposait pour les périodes antérieures à l'avènement du haut fourneau (XIVe -XVIe siècle). Or, sans la large utilisation du ^{14}C, les dates de fonctionnement des différents types de fourneaux et la durée d'occupation des sites (un millénaire et plus), n'auraient jamais été même soupçonnées. Le premier de ces sites est publié, le second est encore en cours de fouille.

Dans ces cas, le ^{14}C a permis de définir l'évolution d'un site majeur. En outre, les précisions obtenues grâce à cette méthode dans la chronologie des sites beaucoup moins importants — notamment dans l'Est —, a permis de fixer les modalités de la production au niveau de régions entières. Si des moyens suffisants sont disponibles dans le futur, les données actuelles, qui ne sont que des propositions car elles reposent encore sur trop peu d'analyses, serviront de guides pour l'établissement d'une cartographie de l'évolution de la production sur les deux millénaires selon ce procédé de la réduction directe. Cette cartographie pourrait être réalisée dans l'ensemble de la région Est en particulier, où le millier de sites qui y sont actuellement répertoriées reste pour la plupart à dater.

Actes du colloque «C14 Archéologie», 1998, p. 452-464.

RAPPORTS DU GROUPE DE TRAVAIL SUR LA NÉOLITHISATION

Introduction : un corpus de dates radiocarbone pour la néolithisation

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On a rassemblé le corpus des datations ^{14}C s'appliquant à la néolithisation de l'Europe, dans sa conception géographique la plus large. Cette période charnière est caractérisée par le passage des sociétés « prédatrices », les derniers chasseurs-cueilleurs mésolithiques, aux sociétés « productrices », les premiers éléveurs-agriculteurs néolithiques. Ce passage s'effectue progressivement depuis la zone d'invention des techniques agro-alimentaires située au Proche-Orient vers l'Europe et intervient à des moments différents suivant les régions.

La problématique C-14 de la néolithisation tente de répondre à plusieurs questions.

- Tout d'abord, comment retracer la propagation des nouvelles techniques agro-pastorales depuis le Proche-Orient vers l'Europe et l'éventuel recul des traditions mésolithiques ?
- Ensuite, quelles sont les possibilités d'évaluer les distances chronologiques par rapport aux derniers groupes mésolithiques suivant les régions ? Peut-on mieux appréhender les différents groupes culturels, leur durée ainsi que d'éventuels contacts et/ou interactions entre représentants des deux types de société (Müller, 1999) ?
- Enfin, une analyse chronologique fine des extensions géographiques des différents ensembles culturels permettra d'aborder également les concepts d'acculturation et de colonisation (différents modes de diffusion).

Ainsi, la constitution d'un corpus regroupant les données C-14 de la transition du dernier Mésolithique au premier Néolithique servira de base pour affiner notre vision des processus de la néolithisation européenne. Ce corpus s'inscrit dans la lignée de l'étude efffectuée par O. Aurenche, J. Evin et J. Gasco (1987) sur les dates C-14 du Proche Orient.

Pour cela, nous disposons désormais de séries de dates par groupes culturels et par régions qui nous permettront par la suite d'illustrer les différents étapes de l'occupation soit mésolithique soit néolithique et de mettre en évidence les interactions éventuelles au niveau chronogéographique.

En effet, plusieurs corpus de ce type ont déjà été constitués par Ammermamn et Cacvalli-Sforza en 1971, par Breunig en 1987, par Gob en 1990, par Bagolini et Biagi en 1990, par Skeates en 1994 et par Voruz en 1991, sans qu'un corpus comparatif global ait été mis en place, d'où la nécessité d'une mise à jour des données.

L'absence jusqu'alors d'un tel corpus adapté à la problématique de la néolithisation est due à différents facteurs :

- l'organisation de la recherche entraîne une certaine forme d'étude de type régional (corpus limité à une aire géographique précise) ;
- l'approche de type diachrone s'avère être parfois trop rigide notamment en ce qui concerne la dichotomie Mésolithique-Néolithique ce qui aboutit à une interprétation qui ne tient pas compte de la possibilité d'un synchronisme entre groupes de chasseurs-cueilleurs et agriculteurs ;
- malgré la multiplication des donnnées C-14, elles demeurent plus difficilement accessibles car leur publication et diffusion systématiques sont souvent restreintes faute d'un référentiel regroupant l'ensemble des datations les plus récentes.

Notre base de données se fonde sur des références essentiellement bibliographiques en tenant compte des synthèses publiées récemment. Les données existantes ont été complétées par l'intégration de dates publiées récemment ainsi que par des communications orales et des mises à dispositions de documents par J. Evin, J. Guilaine, C. Jeunesse, J.L. Voruz, D. Binder, J. Gasco et J.P. Demoule, que nous remercions.

Pour chaque date, la provenance, le numéro de laboratoire, le type de matériau daté et le résultat en BP ont été enregistrés selon un mode de traitement rigoureux et systématique. Quand aux informations archéologiques, la provenance à l'intérieur du site (couche, structure) ainsi que l'attribution culturelle ont été retenues.

En collaboration avec J. Evin, un premier travail a été effectué concernant la fiabilité physico-chimique des échantillons. Une grille d'analyse développée par le Centre de datation par le Radiocarbone de l'Université Claude-Bernard Lyon-1 a permis de mettre en place certains critères pour définir différents degrés de fiabilité :

- l'expérience des divers laboratoires en datation archéologique ;
- une hiérarchisation de la valeur des différents matériaux qui par leur constitution même sont sujet à caution, tels que coquillage et tourbe, par exemple ;
- la marge d'erreur BP fixée arbitrairement à 150 ans ;
- l'élimination des dates abérrantes.

Par la suite nous avons procédé à une calibration du corpus composé d'environ 1500 dates afin d'homogénéiser et de réactualiser les données. Nous avons utilisé le programme de calibration de la version 3.03.A développé par M. Stuiver et P.J. Reimer (1993) à l'université de Washington (Quaternary Isotope Laboratory). Les dates calibrées sont toujours présentées avec l'intervalle de plus grande probabilité pour 1 sigma et pour 2 sigma.

Pour l'instant la notion de représentativité archéologique des dates C14 ne peut pas vraiment être utilisée comme critère de base. En effet, c'est avec l'élaboration d'une meilleure connaissance de l'ensemble contexte culturel et géographique-corpus des dates C-14 que nous pourrons avoir une vision plus synthétique.

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La néolithisation de l'Europe sud-orientale

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Le gradient des dates C-14 du néolithique le plus ancien s'abaisse plus ou moins régulièrement dans chaque région depuis l'Anatolie jusqu'à l'extrême nord-ouest de l'Europe. Ce constat est l'un des arguments classiques pour une néolithisation du continent d'origine proche-orientale, auquel s'ajoute l'absence d'ancêtres indigènes pour les principales espèces biologiques domestiquées. On a longtemps manqué d'une confirmation dans la typologie des artefacts, d'autant que les fouilles turques se concentraient en Anatolie du sud-est. Tel n'est plus le cas, avec les fouilles d'Ilipinar près d'Iznik, et surtout de Hoca Cesme en Turquie d'Europe, à l'embouchure de la Marica. Ce dernier site est bien le lien manquant qu'on pouvait attendre entre la culture de Hacilar et celle, thessalienne, de Protosesklo.

Si la séquence turque voit se succéder un néolithique précéramique (PPNB), puis un néolithique à céramique monochrome, et enfin une céramique peinte en blanc et rouge, la situation est moins claire dans la péninsule balkanique. Le néolithique dit précéramique d'Argissa n'a jamais été vraiment confirmé, l'outillage lithique ne différant de toute façon pas de celui du néolithique avéré. L'existence d'un épisode initial à céramique monochrome est bien établie en Grèce (Rainbow Ware du Péloponèse, séquences d'Achilleion, Élatée, Chéronée, Frühkeramikum). Elle reste discutée en Bulgarie (Kraïnici, Koprivec, Poljanica) et en Yougoslavie (phase Starcevo 1, etc). On peut interpréter comme des phénomènes marginaux de contact les cas de Franchthi (mésolithique avec espèces domestiquées, suivi d'un néolithique ancien en totale rupture typologique) et de Sidari (lithique mésolithique avec poterie, suivi après un hiatus d'un «impresso» classique). De telles observations sont limitées par notre très faible connaissance du mésolithique balkanique.

On mettra à part la Crête avec l'unique site de Cnossos : à partir d'un néolithique sans céramique apparaîtrait brusquement une céramique sombre incisée et carénée d'excellente qualité, dont le style resterait, selon les dates C14, presque inchangé durant au moins deux millénaires. Sur l'ensemble de la péninsule balkanique, les datations du néolithique à céramique peinte en rouge et/ou blanc suggèrent un essor à l'extrême fin du 7ème millénaire avant J.-C. : Céramique à LJrfirnis de Grèce méridionale, Chéronée, Seskio, Nea Nikomedea, Giannitsa, Kovacevo, Karanovo 1, Anzabegovo, Starcevo, etc (on parle déjà de «néolithique moyen» pour la Grèce du sud et du centre). Une chaîne de comparaisons typologiques et stratigraphiques relativement convaincante, notamment depuis les fouilles de Giannitsa et Kovacevo, relie l'ensemble de la Grèce à la Bulgarie. Dans ce cas, le néolithique à céramique monochrome ou peu peinte (Protoseskio, Hoca Cesme) serait à placer dans la seconde moitié du 7ème millénaire, tout comme les phénomènes de contacts et un éventuel précéramique. La masse des datations élimine, il va sans dire, la fameuse date de Nea Nikomedea (8190 BP) qui fut à la source de bien des hypothèses sur une «autonomie» du néolithique européen, alors qu'elle correspond stylistiquement à un néolithique ancien évolué.

C'est du même moment (fin du 7ème millénaire et début du 6ème) qu'il faut dater les débuts de la céramique imprimée adriatique. Une céramique de style comparable accompagne en effet en Thessalie (stratigraphies de Otzaki et Plateia Magoula Zarkou) les débuts de la céramique peinte, avant de s'effacer. Deux seuls sites à céramique uniquement imprimée sont connus sur la côte adriatique grecque (Choirospilia à Leucate, Sidari à Corfou) ; mais ils abondent évidemment sur la côte dalmate (culture de Smilcic). L'origine des styles imprimés, qui dans les Balkans orientaux accompagnent, sur la céramique grossière et dans des pourcentages variables, l'ensemble des céramiques peintes, reste discutée, les hypothèses les plus diffusionistes cherchant leur origine en Méditerranée extrême- orientale (Mersin, Byblos).

Les stratigraphies récentes (Plateia Magoula Zarkou, Kovacevo, Karanovo 11) montrent un passage progressif de la céramique peinte rouge et blanche du néolithique ancien vers la céramique sombre, carénée, à décors cannelés ou incisés, typique du néolithique moyen balkanique (début du «néolithique récent» de Grèce méridionale et centrale) : Matt painted, Dimini-Tsangli, Vin'ca A, Karanovo 111, Paradimi 1, etc. Il ne s'agit donc pas d'une rupture brutale, accompagnée de changements importants de populations. C'est en revanche un moment d'intensification du peuplement, de plus grande adaptation à l'environnement européen, dont témoigne le début de la colonisation de l'Europe centrale, c'est-à-dire la formation de la Céramique Linéaire en Hongrie, Slovaquie et Bohême. Cet horizon commencerait, au vu de nombreuses dates cohérentes, au début du dernier quart du 6ème millénaire, donnant ainsi une durée d'environ 7 siècles au néolithique ancien à céramique peinte, et une durée maximale d'un millénaire à l'ensemble du néolithique ancien sud-est-européen.

La Méditerranée centrale et occidentale

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INTRODUCTION

On subdivisera, un peu artificiellement, cette zone géographique en trois secteurs : Adriatique et côtes orientales de la péninsule italienne, Tyrrhénienne et Sud de la France, péninsule ibérique.

Sur la base des données existantes, il est important de souligner d'emblée le très faible décalage chronologique constaté entre les premières manifestations du Néolithique en Ligurie, dans les Pouilles et en Dalmatie. Les dates de l'Impressa du Tavolière ne sont guère éloignées de celles de l''Impressa ligure et de ses extensions languedociennes et peut-être même de celles du Cardial franco-ibérique. L'écart des datations entre les côtes de l'Adriatique et le golfe du Lion est sans doute inférieur à trois siècles. Faut-il en déduire qu'après une certaine stagnation entre Grèce et Italie, la diffusion côtière du Néolithique a été particulièrement rapide en Méditerranée de l'Ouest ?

Le texte qui suit met également en relief à de nombreuses reprises (Portes de fer, Karst triestin et bassin du Pô, Haut Aragon, embouchure du Tage) la question de la coexistence de groupes mésolithiques et néolithiques, question qui a généré ici et là l'hypothèse d'un modèle dual de néolithisation. Peut-on en conclure qu'une très forte implantation mésolithique ait constitué un obstacle à la diffusion du Néolithique agropastoral ?

C'est sans doute pour la région tyrrhénienne, l'Italie du Nord et le midi de la France que l'on dispose du plus grand nombre de datations pour le Mésolithique et pour le Néolithique ancien. Paradoxalement des lacunes importantes subsistent dans les régions clé que sont la Dalmatie et l'Italie du Sud.

Les mesures disponibles sont dans l'ensemble peu précises, l'écart type moyen approchant par exemple les 120 ans pour le midi de la France et l'Italie. Seules ont été retenues comme significatives les mesures sur charbons et sur graines dont l'écart type est inférieur à cette moyenne. Par ailleurs, les contradictions observées entre les résultats fournis par différents laboratoires pour des horizons similaires voire des structures identiques, demeurent inexpliquées. De nombreuses mesures, obtenues lors de la fouille de séquences stratigraphiques en grottes ou abris, montrent parfois des incohérences explicables en partie par des mouvements verticaux liés aux creusements de fosses. Une chronologie fiable reste à construire à partir de l'analyse de matériaux de combustion prélevés dans des foyers.

1 - L'ADRIATIQUE

La néolithisation de la Méditerranée centrale est imputable à la culture à poterie imprimée de style adriatique, dont la répartition s'étale des îles de la Grèce occidentale jusqu'à la Sicile, en englobant l'Albanie côtière (Blaz), la Dalmatie et le Monténégro, le sud-est de la péninsule italienne. Sa présence le long des côtes adriatiques de l'Italie centrale correspond à un processus de diffusion secondaire à partir des Pouilles, aire la première touchée lors du franchissement du canal d'Otrante.

Le problème de la formation de ce complexe n'est pas encore clairement élucidé. Sur le site de Sidari (Corfou) et à Skarin Samograd (Yougoslavie), il est postérieur à un horizon à poterie monochrome. A Sidari les datations, trop imprécises, ne peuvent être retenues, tandis que les mesures obtenues à Grivac (6200-6000 av JC) et Skarin Samograd (5700-5500 av. J.-C.) sont contradictoires. On doit globalement considérer que ce complexe occupe dans le temps une position décalée par rapport au premier Néolithique thessalien et crétois dont les dates se placent quelquefois autour de 6800-6500 av J.-C. (Argissa, Franchthi et Knossos « pré- céramiques »).

Si l'on met de côté quelques datations aberrantes, manifestement trop élevées pour du Néolithique ancien (en Italie, Coppa Nevigata : 8150 ± 200 BP ; grotta della Madona : 7555 +/- 85 BP ; Santa Tecchia 6 : 7600 +/- 100 BP, mélanges entre divers horizons ; Casa San Paolo : 7900 +/- 100 BP : même remarque ; en Yougoslavie, Odmut 1 B - Impresso B/Starcevo Il : 7720 ± 85 BP), une certaine cohérence se fait jour des deux côtés de l'Adriatique.

La Céramique imprimée dalmate se développe pour l'essentiel entre 6150 et 5400 av. J.-C. Les mesures se regroupent en trois ensembles : de 6150 à 5950 (Obre la et Gudnja Pecina 1), de 5950 à 5700 (Gospodska Pecina

C, Pokrovnik et Gudnja 1) puis de 5700 à 5400 av. J.-C. (Skarin Samograd 2, Obre Ia, Gudnja 2/3). Ce découpage ne s'accorde cependant pas avec la périodisation proposée par J. Müller, les différentes phases de l'Impresso n'étant pas correctement classées par le radiocarbone.

Le développement de l'Impresso dalmate semble parallèle à celui du Starcevo : phase « ancienne » entre 6150 et 5900 (Anza Ia et I), phase « moyenne » entre 5900 et 5600 (Vrinik 2, Anza 1 et 2, Velska et Starcevo) et phase « récente » entre 5600 et 5450 av. J.-C. Ce parallélisme est attesté par le caractère mixte des assemblages d'Obre (Bosnie) dont les datations sont cependant contradictoires.

Sur les rives occidentales de l'Adriatique, la Céramique imprimée ne semble pas apparaître avant 6000 Av JC. Un groupe de datations « hautes » peut être distingué entre 5900 et 5600 av. J.-C. (Ripatetta, La Defensola, Trasano c2, Coppa Nevigata, Monte Venere 4b/5-6, Scamuso 16b, Rendina 2). Les autres sites, et particulièrement les établissements de Haute Adriatioue, des Marches et des Abruzzes (Maddalena di Muccia, Faenza Fomace Cappuccini, Ripabianca), se placent à partir de 5600 et jusque vers 5000 av. J.-C. Comme sur la rive dalmate, on observe que la périodisation établie sur la base des styles céramiques ne coïncide pas avec la sériation des mesures du radiocarbone. La datation «haute » obtenue pour Scaramello San Vito A illustre bien le fait que le ^{14}C ne sépare pas la phase la plus ancienne de la céramique imprimée des horizons postérieurs (Guadone, Lagnano da Piede, Masseria La Quercia).

La question des liens entre Impressa et substrats mésolithiques est un domaine qui demeure encore peu clair, d'autant plus que la nature des outillages du Néolithique ancien de la péninsule balkanique et particulièrement de sa partie occidentale, reste, à quelques exceptions près, mal connue.

En Dalmatie et dans les Balkans occidentaux, la survivance de groupes mésolithiques semble clairement établie entre 6000 et 5300 av. J.-C, c'est-à-dire pendant toute l'évolution du Starcevo et de la Céramique imprimée : horizons liés peu ou prou au Castelnovien (Breg 3A, Benussi 3, Podosojna) ou à Lepenski Vir (Lepenski Vir Id, Ie et 2 et Viasac).

En Dalmatie et dans le Karst triestin, la Céramique imprimée cède la place, sans doute dès 5450 av. J.-C. à la Culture de Danflo (Gudnja, Pokrovnik).

Le développement du premier Néolithique dans le Frioul se produit entre 5600 et 5300 av. J.-C. (Sanmiardenchia, Fagnigola, Valer). Ce processus secondaire, dont les rapports avec la constitution ou l'évolution de Danilo sont bien établis, est probablement la conséquence d'interactions avec le Mésolithique « castelnovien ». La survivance en plaine du Pô et dans les Préalpes de ce mésolithique final semble clairement attestée entre 6000 et 5500 av. J.-C. (Comunella, Covoloni, Pradestel, Fienile Rossino, Crestoso) et l'on peut y voir un phénomène de résistance à la diffusion du Néolithique ancien méditerranéen. Si la Céramique imprimée n'est assurément pas responsable de la néolithisation du Pô, des relations sont certainement envisageables entre l'Impressa ligure et des groupes encore mésolithiques autour de l'exploitation des silex de Lombardie et de la région de Vérone.

En Italie du sud-est, le lithique de l'Impressa s'apparente parfois au Castelnovien : ainsi à Torre Sabea où s'observent la technique du microburin, l'obtention de lames par pression, la présence de trapèzes à retouche abrupte et troncatures concaves. Mais cet éventuel substrat mésolithique manque singulièrement de consistance si l'on excepte les horizons « castelnoviens » de Latronico qui occupent le 7è millénaire av. J.-C. En Italie méridionale, l'identification des faciès du Mésolithique local constitue donc un problème ouvert.

2 - LE DOMAINE TYRRHÉNIEN ET LE SUD DE LA FRANCE

Un autre débat concerne la propagation vers l'ouest des influences de ce complexe et la part qu'il prend à la constitution des faciès occidentaux : Cardial ou autres. La mutation stylistique assez sensible qui s'opère dans la céramique entre le Sud péninsulaire et la Sicile d'une part, l'Italie centro-occidentale et le bloc corso-sarde de l'autre devrait être étayée par des datations plus serrées.

Dans le secteur tyrrhénien stricto sensu, les dates ne vont pas sans problème. Certaines sont discutables : la date de 7910 +/- 70 BP pour un premier horizon à poterie de la grotte de l'Uzzo (Sicile) correspond sans doute à un mélange avec du Mésolithique. Même observation pour la datation de 8040 +/- 180 BP de la base des niveaux « néolithiques » de la grotte Corbeddu (Sardaigne). Les datations du « Curasien » corse (avec céramique à décor poinçonné) de la grotte de Curacchiaghiu : 7310 +/- 170 BP, 7300 +/- 160 BP, 7600 +/- 180 BP (et même 8560 +/- 170 BP), à très grand écart type, peuvent être le résultat de mélanges avec des occupations ante-néolithiques. La date du Cardial de Basi (7700 +/- 150 BP) est totalement marginale en regard des autres dates du Néolithique ancien corse centrées normalement sur le 6ème millénaire av. J.-C. (Araguina, Casabianda, Revellata, Strette). L'antiquité de certaines dates des sites de l'Uzzo, Corbeddu, Basi, Curacchiaghiu ne trouve aucune explication dans un processus logique de diffusion du système économique néolithique selon un gradient est - ouest. En Calabre, les datations du Stentinello souffrent également d'un important étalement avec notamment une mesure « haute », située entre 5900 et 5600 av. J.-C. BC, à Piana di Curingia, zone H (Acconia).

Dans le midi de la France, le panorama culturel du Néolithique ancien s'est longtemps focalisé sur la longue durée (supposée) d'une civilisation unique à céramique « cardiale» évoluant vers des phases à décor de coquille moins élaboré et/ou à motifs de sillons et d'impressions (Epicardial).

Depuis quelques temps s'est fait jour une évidente complexification fondée sur une définition plus aiguë des faciès du Néolithique ancien. Il est possible de reconnaître :

- un Cardial tyrrhénien ou Cardial géométrique (à décor souvent à base de triangles ou de chevrons) il a été observé en Latium, Toscane, Corse, Sardaigne, Sicile, Ligurie, Côte d'Azur.
- un faciès ligurien ou Impressa géométrique (dont le sillon d'impressions constitue, entre autres éléments, le trait décoratif majeur). Il est propre à la Ligurie et à la Côte d'Azur mais peut atteindre le Bas-Languedoc audois. La présence fréquente d'obsidienne au sein de l'équipement lithique et une assez large distribution géographique donnent l'image d'une forte mobilité et peut-être celle d'une colonisation par voie maritime.

- le faciès inférieur de Pendimoun, connu seulement sur ce site, et dont les affinités italiques ou balkaniques demandent à être précisées.

- le « Cardial » à décor de coquille et dont la Provence centrale et occidentale, le Bas-Languedoc et le Roussillon constituent l'aire d'expansion. Son homogénéité céramique est sans doute relative et devra être affinée au fur et à mesure des nouvelles données.

- l'Epicardial languedocien à céramique à base de faisceaux de sillons et d'impressions, et dont la répartition va de la Basse-Provence et l'Isère au Roussillon avec de nettes implantations dans la Montagne Noire (Gazel, Camprafaud, Poussarou, St Pierre-la-Fage). Des rapprochements avec les horizons « épicardiaux » de la péninsule Ibérique sont manifestes.

- le Roucadourien et (ou) le Pericardial, faciès continentaux développés à la marge géographique du Cardial, sorte de substitut de ce dernier (Causses, Aquitaine, Pyrénées) avec une maîtrise technique et décorative sur céramique moins élaborée.

- Ajoutons les affinités présentées par certaines céramiques cardiales (Leucate), épicardiales (Gazel) ou continentales (Margineda) avec certains faciès du Nord-Est (Ifoguette) qui demandent à être approfondies.

Ce buissonnement a pour effet de poser un certain nombre de questions que l'affinement du ^{14}C pourrait contribuer à résoudre.

- Quand se termine, dans le temps et l'espace, le Castelnovien ou ses faciès parallèles (Gazel/Dourgne) ? La question des chevauchements (sur quelle plage de temps ? dans quelles régions ?) avec les horizons à poterie devrait permettre de mieux cerner les gradients de la néolithisation (par exemple de la Basse-Provence vers les Alpes), l'existence possible d'isolats (?) de chasseurs, les processus de contacts entre Mésolithique et Néolithique ancien.

- Quelle est la position chronologique réciproque et le déroulement dans le temps des faciès tyrrhénien et ligurien, ligurien et Cardial, Cardial et faciès péricardiaux ? Des nuances existent-elles ou s'oriente-t-on vers une contemporanéité globale d'émergence de la plupart de ces horizons du Néolithique ancien ?

- Comment se situe dans le temps le Cardial provençal et languedocien par rapport au « Ligurien »? Tous deux peuvent être côtiers (*cf.* Portiragnes et Leucate) et fournir des datations sub-contemporaines. Mais ne peut-on songer à une plus haute antiquité du «Ligurien » (vecteur de traits italiques comme l'obsidienne, plus orienté vers l'élevage que vers la chasse, avec d'emblée une agriculture affirmée) ? Si le Cardial s'avère comme étant chronologiquement secondaire, ce qu'indique la stratigraphie de Pendimoun, il faudra repenser toute sa genèse. Il pourrait alors davantage s'enraciner en partie dans certains substrats mésolithiques locaux ou dériver d'un des faciès de la céramique imprimée ligure.

- Les faciès périphériques du Cardial (Roucadourien et autres péricardiaux) sont-ils, au départ, contemporains du plus ancien Cardial (on les a même parfois considérés comme plus précoces) ou en position sensiblement secondaire ? Ce point permettrait d'éclairer la progression continentale de la néolithisation, trop imprécise actuellement.

- L'évolution même du Cardial et de ses épigones (Cardial « final » de Provence, Epicardial à sillons du Languedoc) n'est pas claire. Pourquoi l'Epicardial est-il absent de Provence orientale ? Le décor à la coquille enchaînerait-il ici sur les groupes pré-chasséens en faisant l'impasse de l'Epicardial alors qu'en Languedoc et en Espagne (« Cultura de las Cuevas ») la phase récente du Néolithique ancien est occupée, sur plusieurs siècles, par des groupes à poteries de sillons et d'impressions, peu ou prou sans décor à la coquille ?

- Jusqu'à quel point la diversité des styles céramiques dans certaines couches du Néolithique ancien correspond-t-elle à des assemblages primaires ou à des regroupements secondaires ? Ainsi des niveaux du Néolithique ancien des Arene Candide : doit-on les considérer comme culturellement homogènes ou le résultat de passages successifs (ou d'échanges) entre populations « tyrrhéniennes » (à Cardial « géométrique ») et « liguriennes » (à récipients ornés de « sillons d'impressions ») ? La datation d'ensembles « purs » (s'ils existent) permettrait de clarifier cette question. L'homogénéité culturelle possible du contenu d'un gisement incluant des styles céramiques multiples refléterait alors la variabilité de certains ensembles du Néolithique ancien. Il conviendrait donc, dans ce cas de figure, de ne pas assimiler un « style céramique » à un groupe culturel «fermé».

- Reste enfin à expliquer les dates particulièrement « hautes », fréquemment antérieures à 6000 av. J.-C., qui caractérisent dans plusieurs dépressions littorales, de la Basse-Provence au Barcelonais, des horizons sédimentaires marqués par de nettes traces d'anthropisation (souvent liées à des pratiques agricoles). Il s'agit de marques d'intervention sur la nature antérieures de quelques siècles aux toutes premières cultures néolithiques (au sens archéologique de terme) repérées. Quelle explication en donner ?

Sur les côtes italiennes de la Tyrrhénienne, en Ligurie et dans les îles, le Mésolithique récent est pratiquement inconnu. Le Pré-Néolithique corse et sarde et le Mésolithique sicilien, antérieurs à 7000 av. J.-C. semblent totalement dissociés du processus de néolithisation. Dans l'Archipel Toscan (Giglio), les parentés des outillages néolithiques avec un Mésolithique à lames et trapèzes connaissant la technique du microburin doit être confirmée.

Dans le sud de la France et le bassin du Pô, le Mésolithique à lames prismatiques et trapèzes est représenté par différents faciès et étapes reliés au Castelnovien. Douze mesures peuvent être retenues pour le bassin du Rhône et le Piémont pyrénéen, dix autres pour le bassin du Pô et l'Apennin tosco-émilien.

Ce Mésolithique occupe, et occupe seul, tout le 7ème millénaire av. J.-C. En effet, aucune des datations du Néolithique s'inscrivant dans ce laps de temps n'a pu être confirmée. Dans le midi de la France, comme dans le bassin du Pô, ce Mésolithique est encore attesté au milieu du 6ème millénaire av. J.-C. En Languedoc, il s'agit de faciès bien caractérisés par rapport à ceux qui précèdent et bien calés en stratigraphie (Dourgne, Montclus).

Dans l'ensemble, la distribution des dates du Néolithique ancien à céramique imprimée entre les péninsules italique et ibérique est tout à fait comparable à celle que l'on observe de part et d'autre de l'Adriatique et se répartissent en trois groupes (5900 à 5600, 5600 à 5300, 5300 à 4900 av. J.-C.).

Un premier groupe de datations se distingue entre 5900 et 5600 av. J.-C., essentiellement en Ligurie (Arene Candide c.14 de Tinè et Maggi et c.27g de Bemabo Bréa ; Poliera c.21 et c.24) avec toutefois une mesure isolée dans le Latium (Marmotta P214). C'est dès le début de cette même phase que les premières installations néolithiques sont attestées sur le littoral languedocien avec notamment le site de Pont de Roque Haute dont la céramique, marquée par des influences sud-italiques, présente de fortes affinités avec celle de Giglio dans l'archipel toscan. Par rapport au sud-est de la péninsule italienne le décalage chronologique est donc peu sensible. En Ligurie, les datations de l'Impressa souffrent encore de nombreuses contradictions et l'on peut en dire de même pour ce qui concerne sa périodisation fondée sur l'analyse du style ou ses rapports avec le Cardial classique rhodano-provençal.

Plusieurs datations placent également entre 5900 et 5600 av. J.-C. des établissements rattachés au Cardial « classique » de style franco-ibérique. En Provence comme en Languedoc certaines de ces datations peuvent être mises en doute, soit en raison d'incohérences stratigraphiques comme à Châteauneuf, soit en raison d'incertitudes sur l'association entre le matériel néolithique et les matériaux datés comme à Leucate-Corrège. La mesure la plus fiable, obtenue pour Gazel 1, demanderait confirmation.

La deuxième phase regroupe le lot de datations très homogènes du Cardial tyrrhénien à décor géométrique regroupées entre 5600 et 5300, dans les îles (Uzzo f7-9, Corbeddu 1, Filiestru BIO-1 1) et sur le littoral ligure (Pendimoun SE-nS). Ce style pourrait être éventuellement rapproché de Guadone en Italie du sud-est. Il est vraisemblable qu'une partie des datations des Arene Candide se rapporte à cet horizon distinct de l'Impressa en stratigraphie, à Pendimoun comme aux Arene Candide (comm. or. R. Maggi). Dans le Latium, plusieurs mesures de La Mannotta (P 1 08, P 1 98 et P219) pourraient aussi s'y rapporter. Au cours de cette même phase, les données concernant le Cardial « classique » de Provence et du Languedoc restent malgré tout assez fragiles : sites mal caractérisés fouillés anciennement (Saint-Mitre), datations non confirmées (Fontbrégoua couche 47) voire infirmées (Courthézon st. 1). Les datations d'Oullins 6 et de la Resclauze 12, réalisées à Monaco, sont plausibles mais demandent à être confirmées.

Plusieurs indices témoignent alors de l'existence d'horizons du « Péricardial » dans le bassin du Rhône (Corréardes, Montclus 5) ou dans les Pyrénées (Dourgne 6), caractérisés par une économie prédatrice, l'absence de céramique décorée (Dourgne 6) voire l'absence totale de céramique et un outillage lithique relié clairement au Néolithique ancien méditerranéen.

Entre 5300 et 4900 av. J.-C., on constate, ici comme ailleurs, la diversification des productions et des styles céramiques avec la Scratched Ware de Ligurie (Arene Candide, La Poliera), Sasso-Fiorano dans la partie orientale du bassin du Pô, en Toscane et dans le Latium, Vho à l'ouest et au centre du bassin du Pô, Filiestru en Sardaigne etc. La néolithisation de Malte débute également à la fin du 6ème millénaire av. J.-C., avec des intrusions Stentinello (Ghar Dalam) tandis que le Néolithique ancien est inconnu aux Baléares.

En Provence cette phase regroupe la majorité (18/29) des occurrences du Cardial « classique » à décor structuré en bandes horizontales. Parmi ces datations, celles produites par AMS (n7-6) sont très précises et très resserrées dans le dernier tiers du 6ème millénaire. La distinction Cardial ancien 1 Cardial classique fondée sur le radiocarbone ne peut plus être conservée tandis que la contemporanéité du Cardial à décor zoné horizontalement et de l'Epicardial type Gazel 2 est clairement posée.

Cette période verrait l'achèvement de la « Néolithisation » de la zone considérée, soit avec des formes de Mésolithique tardif en interaction avec le Néolithique dans les Alpes (Grande Rivoire B2) ou dans les Causses « Roucadourien » caussenard type Combe Grèze, soit avec la multiplication, dans les Alpes, de faciès péricardiaux (i.e. Couffin, Balme Rousse).

3 - LA PÉNINSULE IBÉRIQUE

La néolithisation des terres méditerranéennes de la péninsule Ibérique et, sur l'Atlantique, de la moitié sud du Portugal, semble imputable à un processus de diffusion côtier dont le Midi de la France pourrait avoir été, logiquement, le relais le plus proche. Sous l'expression globalisante de « Cardial », on désigne, ici également, les plus anciens horizons du Néolithique, caractérisés par une céramique à décoration à base d'impressions et de motifs plastiques (cordons). En fait les données fournies par quelques bonnes stratigraphies (Cova del Frare en Catalogne, Cova de l'Or et Cova de Les Cendres en Valencia, Cariguela de Pifiar en Andalousie orientale) montrent une assez longue évolution de ce premier Néolithique. Les impressions à base de coquillage constituent un bon marqueur des phases anciennes (bien que n'étant pas exclusives, les proportions variant selon les sites) tandis que les étapes récentes montrent un renversement de tendance. Ainsi en Valencia, à la décoration spécifique de bandes imprimées à la coquille et richement ouvrées, incluant parfois des motifs anthropomorphes (orants) ou zoomorphes, succède une thématique à base de motifs incisés, cannelés ou obtenus par impressions diverses. La séquence se termine, dans la couche VIII de Les Cendres, par une phase à céramiques peignées.

De même assiste-t-on à Cariguela au progressif passage d'un horizon cardial aux récipients ornés de bandes et de panneaux, à des phases évoluées marquées par la montée de poteries à décor de sillons ou d'impressions diverses. En Andalousie notamment se développe un Néolithique ancien secondaire original, caractérisé par des récipients en sac ou en amphore (avec parfois un fond conique), des marmites, des bouteilles, des vases hémisphériques et une décoration exubérante (cannelures margées, incisions en chevrons, grillages, faisceaux de lignes, cordons cupulés, traitement des surfaces à l'ocre). Anses superposées, anses à crête, becs verseurs renforcent ces particularismes ainsi que certaines productions comme les bracelets de marbre (« Culture de las Cuevas »).

Même configuration chrono-culturelle au Portugal où à une étape ancienne avec Cardial (bien que le décor à la coquille puisse être peu abondant : Pointe de Sagres, sites de Figueira da Foz), succède une étape récente caractérisée par des vases en bombe à décor de panneaux incisés ou imprimés avec thématique fréquente de chevrons verticaux (Fuminha, Bocas).

Les problèmes chronologiques rencontrés au cours de ces vingt dernières années et que le radiocarbone a contribué à élucider (ou à entretenir !) sont à peu près identiques à ceux qui ont marqué l'histoire de la recherche en Italie ou en France, à savoir :

- une trop grande confiance parfois accordée à des dates fort « hautes ». Cette démarche pourrait expliquer une certaine crédibilité en une ancienneté tendant à autonomiser l'Occident par rapport au Proche-Orient. Cette solution ne repose malheureusement sur aucune base économique solide, la péninsule Ibérique ne disposant pas de céréales ni d'espèces animales indigènes susceptibles de se prêter à la domestication (hormis le cas, parfois avancé, mais qui demeure à prouver, de Myotragus balearieus des Baléares). Il a donc fallu revoir à la baisse certaines datations obtenues en raison de mélanges culturels (Verdelpino) ou parce que les résultats étaient, pour des raisons à préciser, globalement inacceptables (cas de diverses datations en sites de grotte d'Andalousie : Cueva Chica de Santiago, Cueva de la Dehesilla, etc.).
- l'évolution globale du Néolithique ancien, corroborée par plusieurs stratigraphies (Cardial se transformant en des faciès secondaires caractérisés par des poteries à décor d'impressions) a parfois été contestée au bénéfice d'un buissonnement culturel supputant l'existence de faciès anciens à poterie imprimée, démarqués du Cardial (Cova Fosca).
- surtout le problème de l'insertion des populations mésolithiques indigènes dans le processus de néolithisation a donné lieu, essentiellement en Valencia et au Portugal, à des scénarios divers (exclusion et rupture pour les uns, acculturation progressive pour les autres).

Les questions actuellement en suspens peuvent donc être ainsi cataloguées.

- peut-on quantifier un gradient de diffusion du Néolithique côtier, appréciable par le ^{14}C, depuis les côtes est-pyrénéennes jusqu'au Portugal moyen, voire jusqu'au Nord-Ouest de la péninsule (où le premier Néolithique est, en l'état de la recherche, mal marqué ou absent) ? Les faciès stylistiques du Cardial ibérique variant sensiblement d'une province à l'autre, cette progression peut-elle rendre compte de ces changements (évaluation des caractères transmis par un groupe géographique précédemment néolithisé dans un groupe qui développe par ailleurs ses propres traits identitaires) ?
- selon quelle dynamique chronologique se réalise la « conquête » des terres intérieures (mesetas) qui ne semblent néolithisées qu'à un stade secondaire (*cf.* Epicardial. Cueva de la Vaquera, Cueva de la Nogalera, dans la province de Segovia) ? Comment expliquer, parallèlement, la pénétration de faciès cardiaux sur certains sites « continentaux » (grotte de Chaves, en Haut-Aragon à mi-chemin entre les littoraux catalan et basque, occupations cardiales des montagnes de Haute-Andalousie : Cariguela, Moclin, Majolicas de Alfacar) ?
- comment rendre compte de certaines datations non consensuelles ? Un cadre chronologique situant le Néolithique cardial aux alentours de 5600 av. J.-C. et évoluant, aux alentours de 5300 av. J.-C., vers des styles secondaires, pourrait faire l'objet d'un certain accord (*cf.* stratigraphies de Valencia et d'Andalousie). Mais, dans ce cas, comment expliquer certaines datations, fort basses, du site lacustre cardial de la Draga (autour de 4950 av. J.-C.) ou du Maroc (où le Cardial semble bien être un épiphénomène d'origine ibérique) ? Evoquer des processus de conservatisme culturel et des buissonnements stylistiques ne constitue pas une solution satisfaisante.
- enfin une autre question réside dans l'éclaircissement même du processus de néolithisation en rapport avec la base indigène. Ce problème est grevé, dans un certain nombre de régions, par une faible connaissance du Mésolithique final. Ainsi en Catalogne où certains faciès mésolithiques sont, après calibration, placés sur la transition 8ème-7ème millénaires, donc bien antérieurs au Néolithique ancien (Margineda, Font del Ros). On peut faire la même remarque pour l'Andalousie où le Mésolithique est encore peu consistant.

En Valencia et Haut-Aragon, le modèle « dual », élaboré par J. Juan Cabarfflies, semble plus solide. Il met en parallèle une néolithisation « intrusive » caractéristique du Cardial et de l'économie de production (Sarsa, l'Or) et, parallèlement, une néolithisation par acculturation des populations épipaléolithiques, au contact du Cardial auquel sont empruntés de la vaisselle ou la connaissance de l'élevage. Ainsi dans la région d'Alcoy (La Cocina) ou en Bas-Aragon (Costalena, Botiqueria dels Moros). Toutefois ces contacts devraient être mieux situés dans une séquence temporelle et leur durée évaluée. On pourrait retrouver en France un scénario proche de celui-ci dans les relations mettant en jeu Cardial et Roucadourien.

Le problème de la « cohabitation» entre chasseurs-pêcheurs-collecteurs et agro-pasteurs se pose avec plus d'acuité au Portugal. Certains auteurs considèrent que les mésolithiques implantés dans les zones reculées des anciens estuaires du Tage, du Sado ou du Mira exploitaient de façon saisonnière plusieurs niches écologiques complémentaires incluant aussi le littoral. Le développement sur les zones côtières du Néolithique cardial a dû perturber ce système mais les « résistances » mésolithiques auraient un temps freiné la néolithisation dans les aires de forte implantation autochtone : sur ces terres l'économie productrice n'aurait pris pied qu'au Néolithique ancien évolué (J. Zilhao). J. Soares semble peu favorable à une telle dichotomie. Les grandes dimensions de certains habitats du Néolithique ancien (Vale Pincel : 10 ha), mais constitués en fait de noyaux dispersés, montrent la pratique d'activités agricoles certaines mais aussi d'activités saisonnières spécialisées, par exemple dans la récolte de mollusques (Medo Tojeiro, Castelejo). On aurait donc ici la survivance d'un modèle de camp de base avec exploitations périphériques spécifiques. J. Soares met donc en doute la coexistence d'agriculteurs et de chasseurs-collecteurs exclusifs. Ce serait plutôt les néolithiques qui auraient, dans certains cas, perpétré des comportements périodiques de ramasseurs de coquillages.

Ces divers scénarios ne seront pleinement validés (ou rejetés) que lorsque la dimension temporelle sera mieux étayée.

En effet, pour l'ensemble de la péninsule ibérique les datations radiométriques posent de nombreux problèmes de fiabilité, aussi bien sur le plan archéologique qu'analytique. Pour le Portugal en particulier des incertitudes sont introduites par la multiplication des mesures sur coquilles et par le caractère discutable des corrections réalisées en tenant compte de l'effet réservoir.

En Espagne le Mésolithique à lames et trapèzes occupe la deuxième moitié du 7ème millénaire (Tossai de la Rocca 1, La Falguera 1, El Pontet 2) et pourrait connaître une phase tardive entre 5500 et 4800 av. J.-C. (El Pontet 1, Riols 1) encore mal étayée par le radiocarbone. Les mesures les plus fiables ne placent pas l'horizon le plus ancien du Néolithique (Cardial) avant 5600-5500 (Chaves 2b).

Pour le Portugal, les datations fiables du Néolithique ancien sont très rares (Caldeirao NA2, Casa da Moura) et appartiennent toutes à la deuxième moitié du 6ème millénaire voire au début du 5ème ce qui les place effectivement en synchronie avec plusieurs sites attribués au Mésolithique final (Cabeço de Arruda, Cabeço di Pez sup., Vidigal 2, Samouqueira) ; les premières phases du Mésolithique à lamelles et géométriques occupant la fin du 7ème millénaire (Moita do Sebastiao) et les débuts du 6ème (Cabeço de Arruda, Vidigal 3).

Tout modèle, si séduisant soit-il, doit d'abord être confronté l'épreuve de la précision chronologique.

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Le Néolithique ancien danubien

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Traditionnellement, la formation et la diffusion du Rubané et l'émergence de l'agriculture en Europe du centre et du nord-ouest sont perçus comme deux facettes d'un phénomène unique. Cette vision a cependant été remise en cause ces dernières années par une série de découvertes qui suggèrent que l'économie de production a pu, au moins dans la partie occidentale de l'aire de répartition de cette culture, précéder l'installation du Rubané. Cet aspect, les indices précoces d'agriculture en milieu non-rubané et leur datation, sera abordé dans une seconde partie, après que nous ayons fait le point sur le Néolithique ancien danubien.

1 - LE RUBANÉ

Les deux aspects principaux sont d'une part la datation des débuts du Rubané et, d'autre part, la question du rythme de son expansion à travers l'Europe. Le corpus rassemblé à l'occasion de la préparation du colloque de Lyon comprend environ 280 dates. Leur répartition dans l'espace laisse apparaître un fort déficit pour les zones de peuplement de la moitié est de l'aire de répartition : l'Ukraine, la Roumanie et la Hongrie (pour ce pays il y a 11 dates, mais toutes concernent le Rubané dit « oriental » qui ne joue aucun rôle dans la néolithisation). Pour le reste, Pologne comprise, la situation est assez satisfaisante, et cela d'autant plus que la distribution des dates dans le temps a bénéficié ces dernières années d'un rééquilibrage en faveur de la phase la plus ancienne (Rubané 1) aussi bien en Autriche qu'en Allemagne.

Sur la foi de dates isolées, on avait pris l'habitude ces dernières années de situer très haut les débuts du Rubané, soit aux alentours de 5800 - 5700 av. J.-C. Cette tendance a été quelque peu tempérée par les travaux plus systématiques menés récemment sur des séries plus significatives, par exemple 20 dates dans le complexe d'habitat du Rubané I de Brunn, en Basse Autriche. En s'appuyant sur des corpus en grande partie distincts, H. Stâuble (1995) d'un côté, E. Lenneis et P. Stadier (1995 et 1996) de l'autre ont obtenus des résultats convergents. Ils situent l'émergence du Rubané autour de 5500 av. J.-C., avec une préférence pour le début du 55ème siècle. Dans l'état actuel, les datations radiacarbones ne contribuent en rien au débat sur la localisation de la zone nucléaire du Rubané. Il n'existe en effet pas de variations significatives dans les dates des sites de l'étape la plus ancienne (Rubané 1) qui s'étend de la Vistule au Rhin.

E. Lenneis et P. Stadier se sont également attelés à une comparaison systématique avec les corpus des cultures du Néolithique ancien carpato-balkanique qui ont pu, de par leur position géographique, jouer un rôle dans l'émergence du Rubané, à savoir Kôrôs et Starcevo. Dans les deux cas, la plus grande partie des dates se range dans la première moitié du 6ème millénaire. Les indices de chevauchement chronologique avec le Rubané (dates postérieures à 5500 av. J.-C.) demeurent extrêmement rares.

Les mêmes auteurs proposent de placer l'étape «la plus ancienne» (« älteste Linearbandkeramik » de la recherche allemande) (Rubané 1) entre 5480 et 5250 av. J.-C., les quatre étapes stylistiques suivantes (Rubané II à V) se partageant la fourchette 5250 - 4900 av. J.-C. L'étape initiale n'ayant pas encore pu être périodisée par les archéologues, il est donc vain de se poser la question de l'adéquation entre la chronologie archéologique et la chronologie radiocarbone. La périodisation en quatre étapes de la seconde partie du Rubané repose aujourd'hui sur des bases solides, les sériations statistiques étant régulièrement étayées par des observations stratigraphiques. Pour la fourchette concernée, qui embrasse les 3 derniers siècles du 6ème et le premier siècle du 5ème millénaire, il n'y a pas grand chose à espérer du ^{14}C. Cette fourchette correspond en effet à un plateau de la courbe de calibration (Kind, 1997). L'incohérence des séries locales illustre bien cette impuissance : à Cuiry-lès-Chaudardes, 17 dates qui s'étalent sur un bon millénaire pour un site dont l'occupation n'a guère pu dépasser un siècle et demi, à Oiszanica, 9 dates et à Bylany, 11 dates. On retrouve la même incohérence (absence complète d'adéquation entre les observations archéologiques et les datations ^{14}C) lorsque l'on travaille à l'échelle régionale.

2 - LA PÉRIPHÉRIE

Les recherches menées autour de la question de la céramique de La Hoguette suggèrent fortement que, dans le Bassin du Rhin, le Rubané n'a sans doute pas été le seul acteur de la néolithisation. Au moment où se manifestent les premiers indices de présence rubanée, cette région est en effet occupée par des populations autochtones qui sont ancrées dans la tradition mésolithique de l'Europe du Nord-Ouest, mais qui se distinguent des groupes contemporains par leur maîtrise de la technique céramique et, comme on le sait depuis peu grâce à la fouille d'un premier site purement Hoguette dans le Wurtemberg, probablement aussi par la pratique de l'élevage. L'existence de plantes domestiquées n'est pas démontrée, mais ne peut être exclue. L'idée la plus répandue aujourd'hui est que l'on se trouve en présence de populations qui, suivant des modalités restant à préciser, ont acquis la technique céramique et des rudiments d'agriculture au contact des cultures du Néolithique ancien de la Méditerranée occidentale. La céramique de La Hoguette est datée indirectement grâce aux nombreux ensembles où elle apparaît en association avec du mobilier de l'étape 1 du Rubané. Parmi les rares sites Hoguette «purs», seul celui de Bavans (Fr., Doubs) a fait l'objet de datations radiocarbones. Une de ces mesures laisse supposer, avec toute la prudence qu'il convient de manifester face à une date unique, une présence Hoguette dans le nord du Jura français dès la première moitié du 6ème millénaire (Jacattey, 1997).

La découverte récente d'indices précoces d'anthropisation des paysages dans les domaines alpins et jurassiens vient donner du corps à cette hypothèse d'une agriculture pré-rubanée dans le sud de l'Europe centrale. Dans le Jura français, un site daté aux alentours de 5800 av. J.-C. a livré, entre autres traces d'anthropisation, des pollens de céréales ; deux découvertes comparables se situent autour de 5500 av. J.-C. (Richard, 1944 et 1997). Sur le plateau suisse et dans le Tyrol, les premiers indices d'activité agricole remontent au milieu du 7ème millénaire. Ils sont suivis d'un second épisode qui se situe dans le second quart du 6ème millénaire (Erny-Rodman *et al.*, 1997). Les niveaux concernés n'ont malheureusement pas livré de documents susceptibles de nous éclairer sur le contexte culturel de ces indices précoces d'agriculture. Pour l'ouest du domaine concerné (Jura et, éventuellement, Plateau suisse) les porteurs de la céramique de La Hoguette figurent bien sûr au premier rang des prétendants.

Des travaux récents montrent d'autre part qu'il convient de réévaluer le rôle de la composante autochtone dans la formation du Rubané et la mise en place de ses sous-ensembles régionaux (Gronebom, 1997 ; Jeunesse, 1997 ; Tilmann, 1993). Si l'on se fie aux conclusions de ces recherches, le Néolithique ancien danubien serait, à des degrés divers suivant les régions, le produit de phénomènes d'acculturation entre les colons rubanés et les autochtones. Si, comme le suggère les éléments développés dans les deux paragraphes qui précèdent, certains de ces autochtones maîtrisent déjà l'agriculture et/ou l'élevage, notre perception de la néolithisation de l'Europe centrale s'en trouvera sensiblement modifiée, en commençant, bien sûr, par le problème de la datation des premiers indices d'activité agricole. Un témoignage de l'existence d'un substrat « agricole » pré-danubien dans la future aire de répartition du Rubané pourrait être la pratique de la culture du pavot (Bakels, 1982) par les communautés rubanées de la région Rhin-Meuse.

La réflexion sur le rôle des phénomènes d'acculturation dans la mise en place des cultures du Néolithique danubien ancien et moyen s'inscrit en faux contre l'idée d'une assimilation rapide par une colonisation « rouleau compresseur ». Il convient de restituer toute sa profondeur à ce phénomène, et, pour commencer, d'éviter le rejet systématique et a priori des dates ^{14}C postérieures à 5000 av. J.-C. pour des contextes mésolithiques. Parmi les processus étudiés ces dernières années, il en est en effet certains qui supposent un dialogue durable entre la composante danubienne et une composante autochtone bien vivante. Il n'est plus envisageable aujourd'hui d'assimiler la néolithisation de l'Europe centrale à un phénomène massif et quasi instantané qui coïnciderait avec l'arrivée du Rubané. Celle-ci ne serait en fait qu'un épisode parmi d'autres d'un processus qui s'amorce au plus tard dans le courant de la première moitié du 6ème millénaire avec les premiers indices d'agriculture pour se poursuivre jusque bien avant dans le millénaire suivant. Il ne s'agit plus simplement de dater un changement brutal, mais de saisir les différentes étapes d'un processus qui s'inscrit dans la longue durée. Pour cela, une révision des datations disponibles et la mise en place de problématiques nouvelles faisant largement appel aux potentialités du radiocarbone vont, bien sûr, s'avérer nécessaires.

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Chronologie de la néolithisation dans le haut-bassin rhodanien

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Au centre de *la tenaille cardialo-rubanée*, le Haut Bassin rhodanien, qui réunit la Suisse romande, la Franche-Comté et la région Rhône-Alpes, a fait l'objet de nombreuses recherches récentes qui permettent d'appréhender de manière tout à fait nouvelle la mise en place de l'économie agro-pastorale.

En effet, on dispose à présent pour cette région d'un bon corpus de 105 datations radiocarbones, retenues après un tri très sévère en fonction de leur lien archéologique, et qui assurent de manière quasi continue la chronologie des 7^{e}, 6^{e} et 5^{e} millénaires. On peut les répartir en trois groupes, 9 dates indiquant la fin du Mésolithique récent entre 7000 et 5700, 36 autres permettant d'appréhender le Néolithique ancien, cette complexe période formative d'échanges, d'acculturations, d'emprunts et de colonisations, tandis que les 60 dates restantes concernent la mise en place des terroirs agro-pastoraux et la formation des grandes cultures de la première moitié du Néolithique moyen, le Chasséen ancien et le Saint-Uze.

Le Mésolithique récent, caractérisé par le débitage micro-laminaire, les trapèzes, le Montbani, les harpons et les affinités castelnoviennes, est daté dans le Vercors entre 7000 et 6500 (Pas de la Charmatte et Coufin 2), puis entre 6200 et 5700 en Suisse avec les sites de Vionnaz, de l'abri Freymond, de Château-d'Oex et de Schötz 7 (les dates plus récentes des Gripons, de Liesbergmühle VI et de Tschäpperfels étant éliminées par la critique rigoureuse du contexte archéologique). Soulignons ici l'importance du site de Schötz 7, qui apparaît vers 5800 - 5700 comme le site le plus récent et le mieux documenté du Mésolithique suisse.

J'ai réuni ensuite quinze datations importantes, comprises entre 5600 et 4800, provenant de ce que l'on a qualifié récemment *d'ensembles mixtes*, c'est-à-dire d'ensembles stratigraphiques dans lesquels ont été découverts, associés à un fonds industriel de type Mésolithique récent, donc résultant d'une longue tradition locale autochtone, une ou plusieurs composantes allochtones de type néolithique :

- restes d'ovins ou de boeufs domestiques de petite taille, donc sans doute importés,
- céramiques de la Hoguette à décor peigné de bandeaux margés, sans doute diffusées rapidement dans un très large réseau (de Barcelone à Stuttgart), réseau qui aurait pu être formé dès le Mésolithique, d'où la notion de « céramisation des chasseurs »,
- céramiques ovoïdes lisses ou décorées sobrement de petites cannelures, de cordons incisés ou d'impressions circulaires,
- armatures géométriques tranchantes à bitroncatures inverses (« flèches de Montclus », « trapèzes de Beuron »), et autres artefacts de facture technologique néolithique,
- armatures perçantes asymétriques à base concave (« pointes de Bavans »), « fléchettes » trapues.
- indices d'impacts de l'homme sur le couvert végétal ou d'agriculture mis en évidence par la palynologie (baisse du rapport AP/T traduisant une ouverture dans l'espace forestier, augmentation des arbustes pionniers, concurrence entre les arbres, plantes rudérales, prairiales et messicoles, céréales, ...),

Les ensembles mixtes les mieux datés se trouvent dans les Alpes du Nord (Vieille-Eglise, Coufin 1, Grande Rivoire, Balme-Rousse), mais aussi dans le Jura (Roseau, Montandon et Bavans, si l'on excepte sa plus vieille date Lv 1415 qui me paraît être trop haute). Les sites bugistes d'Arbignieu et de Culoz pourraient également en faire partie, mais les dates Ly 619 et Ly 289 ont des écarts-types trop élevés, pour des fouilles déjà anciennes. L'histogramme réunissant ces quinze datations présente une forte pente entre 5600 et 5300. C'est donc à ce moment-là que démarrent les processus d'acculturation des populations mésolithiques locales, et donc que se met en place la néolithisation rhodanienne.

Le Néolithique ancien stricto sensu, avec des sites livrant toutes les composantes bien développées de la néolithisation, économie pastorale ou agricole, céramique décorée ou lisse, industries lithiques d'affinités cardiales, reçoit 21 datations fiables comprises entre 5400 et 4600, cette fourchette pouvant même se réduire à 5300 - 4700 après critique des liens.

Soulignons que c'est justement dans la première moitié de cette fourchette, c'est-à-dire entre 5350 et 5000, que se trouvent les premiers indices d'agriculture et d'anthropisation du paysage révélés par la palynologie à Chalain dans le Jura, au lac Cerin dans le Bugey et au lac du Montorge près de Sion. Le synchronisme des données palynologiques et archéologiques de la néolithisation, et non l'antériorité des premières comme le suggèrent les botanistes zurichois, renforce la brièveté de la période - moins de 400 ans - pendant laquelle se diffusent toutes ou certaines composantes socio-économiques de la néolithisation, et renforce aussi l'ampleur géographique de cette diffusion, puisque dès 5500-5400, plus aucun groupe humain ne peut ignorer les innovations néolithisantes. Cela semble vrai quel que soit le facteur porteur du changement : circulation d'objets à statut particulier dans des réseaux préexistants (Hoguette, Montclus...), acculturations techno-économiques par emprunts de voisinage (animaux domestiques, agriculture, céramiques lisses...), ou colonisation de paysans céréaliers ou d'éleveurs migrants ou transhumants.

Les deux sites du Néolithique ancien rhodanien qui montrent le plus d'affinités avec le Cardial final du Midi, les Corréardes au sud de la Drôme et le Gardon dans l'axe rhodanien, et dans lesquels - ce n'est sans doute pas un hasard - le Mésolithique est absent, recoivent les dates les plus hautes vers 5400 - 5100, tandis que le Néolithique ancien du Valais paraît être légérement plus tardif, avec un très bon tir groupé de 8 datations entre 5100 et 4800. Signalons cependant qu'à Sion, plusieurs sites ont livré des vestiges d'occupations bien datées et plus anciennes (Planta couche 8 par exemple), mais l'absence totale de mobilier interdit hélas toute attribution culturelle.

Dans les tout premiers siècles du cinquième millénaire se placent des sites nettement plus nombreux dont les céramiques décorées semblent s'apparenter plutôt aux dernières phases du Néolithique ancien, ces influences provenant soit du monde danubien pour les sites jurassiens (abri Freymond, Gonvillars, Gondenans), soit du monde méditerranéen (« Tardi-cardial » ou « Epicardial »), pour les sites de la Drôme, des Alpes du Nord ou du Bugey. C'est à ce moment que l'on assiste à la consolidation de l'emprise territoriale des paysans, dans toutes les directions, jusqu'aux plateaux du Massif central (Les Estables) ou jusqu'au coeur de la Suisse centrale (Zurich, Egolzwil).

Enfin, la compilation des dates à l'aide d'histogrammes fait apparaître vers 4800 - 4600 un bon repère chronologique, l'abandon des décors cannelés ou imprimés, qui marque le passage du Néolithique ancien au Néolithique moyen. C'est en effet dans cette fourchette que se terminent toutes les dates du Néolithique ancien, aussi bien dans les Alpes que dans le Jura, et que se trouvent les toutes premières datations du Chasséen ancien à décors géométriques de Bourgogne ou de la Drôme (Chassey, Antonnaire), ainsi que celles du Saint-Uze. Ces deux cultures sont maintenant très bien documentées par une soixantaine de dates, et semblent se développer en synchronie durant toute la seconde moitié du cinquième millénaire.

Ce trop bref panorama des données chronologiques de la néolithisation rhodanienne en laisse à peine entrevoir toute la complexité.

Un résultat probant me paraît être l'impossibilité à présent d'imaginer une coexistence de longue durée entre des groupes de chasseurs du Mésolithique récent et les premiers Néolithiques - que ceux-ci soient des chasseurs acculturés ou des colons paysans - puisque dès 5500, ou même un ou deux siècles avant, plus aucun groupe mésolithique ne reste à l'écart de la diffusion des éléments néolithisants, même si ces derniers se développent en ordre dispersé.

Une deuxième conclusion à retenir est la précocité de cet engagement, précocité donnée à la fois par les datations des ensembles mixtes entre 5600 et 4800, par celles du Néolithique ancien *stricto sensu* entre 5300 et 4700, et par celles des indices palynologiques entre 5400 et 5000. L'antériorité des premiers ensembles mixtes sur le début du Néolithique ancien (de 5600 à 5300) montrerait que les phénomènes d'acculturation des populations locales précèdent de quelques siècles l'installation des premiers colons éleveurs ou paysans. Ces fourchettes de datations étant parallèles au Cardial moyen et final de Provence, et les plus anciennes dates étant légérement antérieures au développement du Rubané en Alsace, il paraît légitime de se tourner d'abord vers le sud pour rechercher les prémices de la néolithisation haut-rhodanienne.

La vitesse de diffusion du Néolithique ancien du sud au nord dans l'axe rhodanien peut grossièrement être estimée à moins d'un km par année, puisqu'il a fallu plus de 500 ans (de 5800 à 5300 environ) pour qu'elle couvre les 400 km séparant Ambérieu de Marseille, que cette vitesse soit constante ou non. Cette relative lenteur ne doit pas surprendre, car elle semble générale à toute l'Europe occidentale.

Enfin, un dernier résultat à discuter résulte de la variabilité géographique des sites ayant livré des indices de néolithisation. La diffusion des caractères néolithiques, que ceux-ci soient d'ordre techniques, économiques ou culturels, semble s'être effectuée selon une pluralité de vecteurs géographiques, elle a emprunté plusieurs voies bien distinctes, et non seulement les deux voies de la classique et maintenant bien dépassée image de la tenaille cardialo-rubanée.

A l'image de la carte de répartition des céramiques Hoguette qui révèle un axe de diffusion Barcelone - Stuttgart, ou encore à l'image de la carte de diffusion des « flèches de Montclus » qu'il faudrait reprendre en détail, il conviendrait à présent de réétudier séparément chacun de ces vecteurs néolithisants, avant que de pouvoir commenter leur degré d'indépendance ou d'interdépendance par rapport à l'ensemble de la néolithisation de l'Europe occidentale.

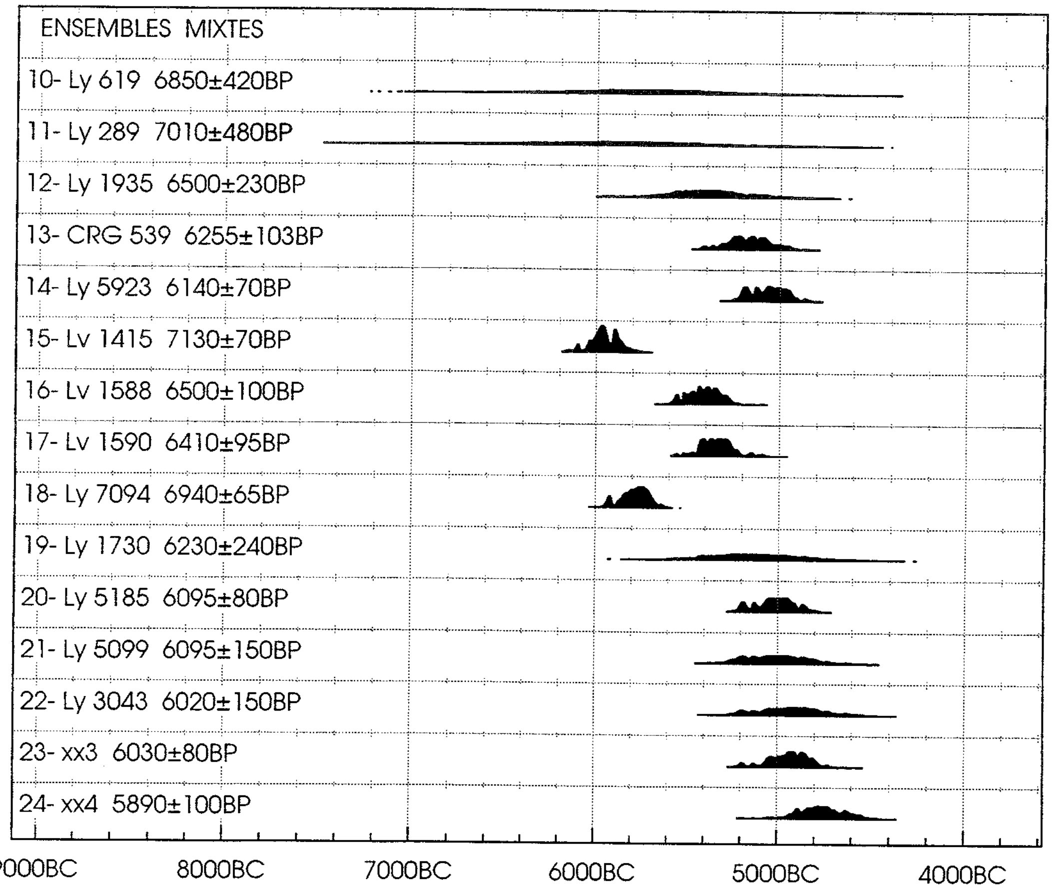

Fig. 1 : Datations radiocarbones calibrées (Oxcal 1995) des « ensembles mixtes » du Haut Bassin Rhodanien, sites avec industries de type mésolithique associées à un ou plusieurs traits néolithisants (témoignages probables de l'acculturation des populations autochtones).

10 : Thoys I, Arbignieu (Ain, France), fouille Robert Vilain et Sabine Morelon.
11 : Sous-Balme, Culoz (Ain, France), fouille Robert Vilain.
12 et 13 : abri de la Vieille Eglise, Balme-de-Thuy, (Haute-Savoie, France), fouille Jean-Pierre Ginestet.
14 : abri du Roseau, Neuville-sur-Ain (Ain, France), fouille Jean-Pierre Guillet.
15 à 17 : abris de Bavans (Doubs, France), fouille Gérard Aimé. La date 15 semble trop haute.
18 : Pas de l'Echelle, Rovon (Isère, France), fouille Pierre Bintz.
19 : Coufin I, Choranche (Isère, France), fouille Pierre Bintz.
20 et 21 : abri de la Grande Rivoire, Sassenage (Isère, France), fouille Régis Picavet.
22 : grotte de Balme Rousse Choranche (Isère, France), fouille Pierre Bintz.
23 et 24 : abri de Montandon (Doubs, France), fouille Christophe Cupillard.

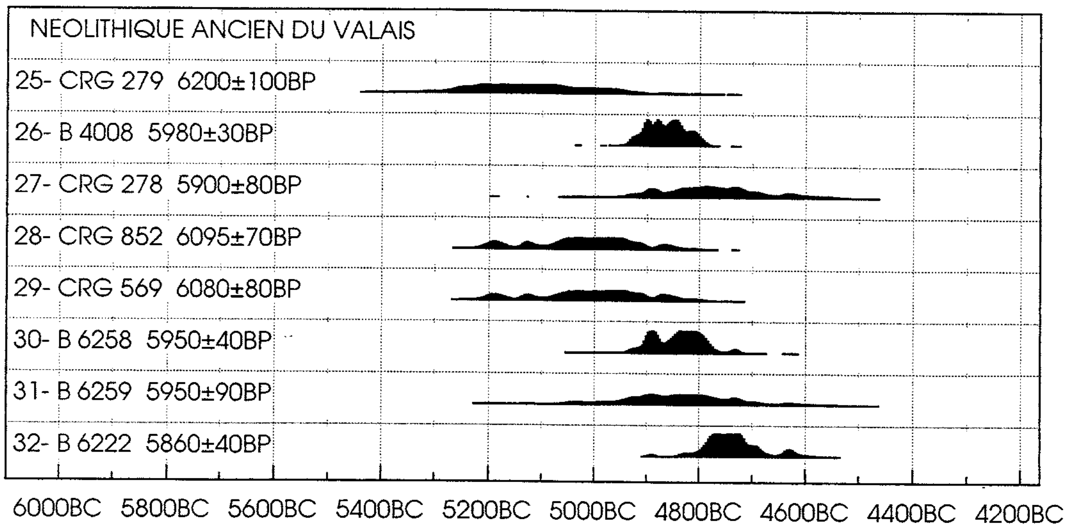

Fig. 2 : Datations radiocarbones calibrées (Oxcal 1995) du Néolithique ancien du Valais (Suisse).

25 à 27 : place de la Planta couche 6C2, Sion, fouille Ricardo Carazzetti, Cynthia Dunning et Alain Gallay.
28 et 29 : abri de Sous-le-Scex, Sion, fouille Alain Gallay.
30 et 31 : Château de Tourbillon, Sion, fouille Dominique Baudais et Caroline Muller.
32 : La Muraz, Ormône, fouille Dominique Baudais.

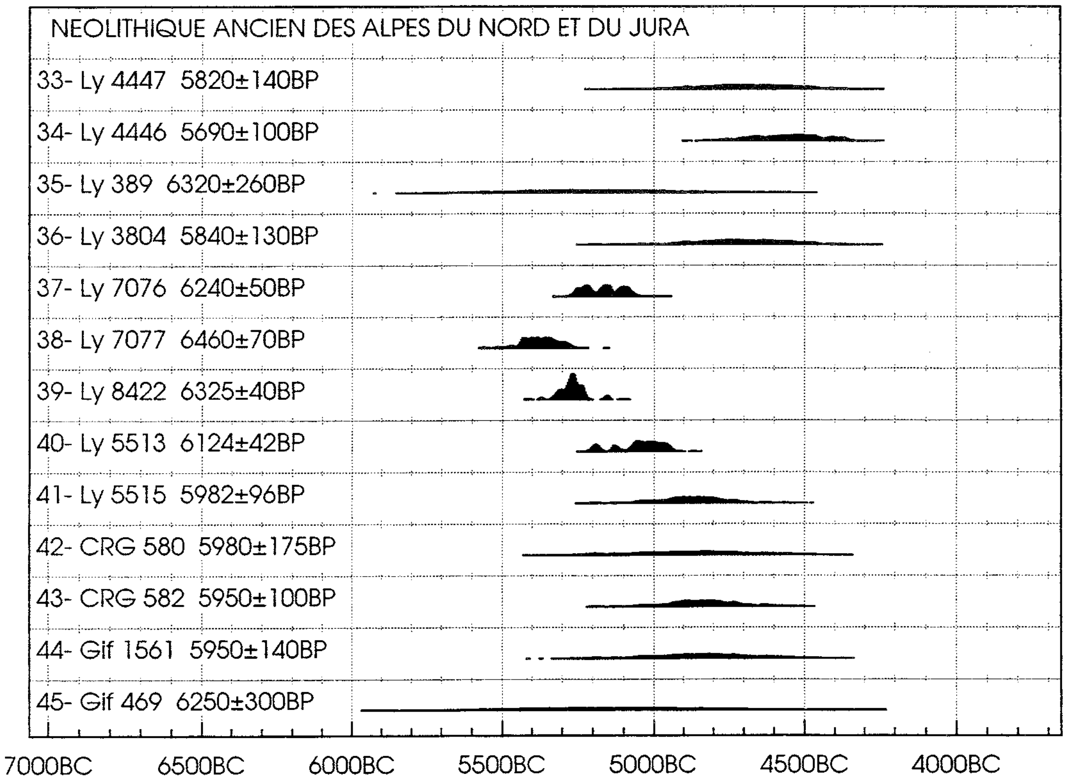

Fig. 3 : Datations radiocarbones calibrées (Oxcal 1995) du Néolithique ancien *stricto sensu* des Alpes du Nord et du Jura, sites présentant toutes les composantes techno-économiques du Néolithique.

33 et 34 : La Grande Rivoire, Sassenage (Isère, France), fouille Régis Picavet.
35 : grotte du Seuil des Chèvres, La Balme (Savoie, France), fouilles Raymond Vanbrugghe et Pierre-Yves Nicod, date très critiquable.
36 : Le Moulin, Barret-de-Lioure (Drôme, France), fouille Alain Beeching.
37 et 38 : abri des Corréardes, Lus-la-Croix-Haute (Drôme, France), fouille Alain Beeching.
39 à 41 : grotte du Gardon couche 58, Ambérieu-en-Bugey (Ain, France), fouille Juliette Bois-Gerets et Jean-Louis Voruz.
42 et 43 : abri Freymond, Mont-la-Ville (Vaud, Suisse), fouille Gervaise Pignat et Pierre Crotti.
44 : grotte de la Tuilerie, Gondenans-les-Montby (Doubs, France), fouille Pierre Pétrequin.
45 : grotte de la Baume, Gonvillars (Doubs, France), fouille Pierre Pétrequin.

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RAPPORT DU GROUPE DE TRAVAIL «AFRIQUE»

Les datations radiocarbone en Afrique du nord et Afrique centrale

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En 1985, à l'occasion d'une table-ronde consacrée au thème «Quaternaire et Préhistoire du Maroc» Jacques Evin et Didier Miallier avaient procédé à un bilan des datations numériques alors disponibles dans ce pays. Issues de quatorze laboratoires différents, 161 dates (dont 102 en contexte strictement archéologique) permettaient aux auteurs de dresser un bilan de carence pour les périodes antérieures au Néolithique et de souligner l'inégale répartition géographique des sites concernés en faveur des provinces méridionales, aux confins de la Mauritanie et du Mali. Presqu'aucune datation pour le terme bas du Paléolithique moyen, aucune sériation possible pour le Paléolithique supérieur et l'Epipaléolithique, pas de calage pour la genèse puis l'évolution du Néolithique et pas de repères pour l'apparition du métal... L'attention des archéologues était en outre appelée sur les précautions méthodologiques relatives à la mise en oeuvre des datations sur les coquilles terrestres et sur les ossements en milieu aride : la céramique et ses inclusions organiques apparaissait en revanche comme un support intéressant susceptible, en outre, de permettre des croisements avec la thermoluminescence (Evin et Miallier, 1985).

Moins de quinze ans après il a paru utile de procéder à un bilan comparable à l'occasion du 3° Congrès international «^{14}C et archéologie» en élargissant le cadre à l'ensemble du Maghreb, mais aussi du Sahel, afin d'apprécier si, comme au Maroc, le développement des travaux de terrain et la multiplication des échantillonnages interdisciplinaires ont, ou non, permis de combler tout ou partie de ces lacunes et de surmonter certaines difficultés méthodologiques. L'abondance même des publications récemment intervenues dans l'ensemble de la zone et plus particulièrement en Mauritanie, au Mali et au Niger, laissaient augurer au mieux d'une entreprise dont les promoteurs étaient particulièrement confiants, forts de la participation des chercheurs les plus actifs.

Dans les faits, le succès a dépassé toutes les espérances puisque les datations concernées atteignent maintenant un millier et demi... Rien que pour le Maroc les bases de données de quinze laboratoires livrent plus de 300 résultats dont près de 200 en milieu archéologique, soit un doublement quantitatif des données. Au total, dans les six pays considérés, ce sont 1374 mesures dont l'on dispose à ce jour, le seul centre de datation de Gif-sur-Yvette en ayant produit environ 900.

	TUNISIE		**ALGERIE**		**MAROC**		**MAURITANIE**		**MALI**		**NIGER**		
	Archéo.	Géol.	Archéo.	Géol.	Archéo.	Géol.	Archéo.	Géol.	Archéo.	Géol.	Archéo.	Géol.	
Ly	4		4		22	5	54		11		31		
Lyon									5				136
Mc	16		105		10		6				13		150
Gif	31	33	169	55	144	81	164	23	49	10	102	17	878
Pa			11		2		5		68		45		131
CRG						2							2
IEN			2										2
Auck					1								1
Anu						18							1
SUA						1							18
GrN					1								1
IRPA						10							10
Kn					1								1
L					2								2
Ny					1						2		3
UCLA					3								3
UQ					4								4
Dak							2				2		4
LGQ							12						12
NIA							11						11
Alg											4		4
	51	33	291	55	191	117	254	23	133	10	199	17	
TOTAL	84		346		308		277		143		216		1374

Les animateurs du groupe de travail ont été pris de court par l'importance de cette matière mais, aussi, par son hétérogénéité formelle : la nomenclature des laboratoires est changeante et doit faire l'objet d'une uniformisation ainsi que la formulation des supports et des attributions culturelles. Plus contraignantes encore sont les règles de calibration : les mesures obtenues antérieurement à 1993 avaient été calibrées (lorsqu'elles l'étaient....) en référence au tableau de Klein *et al.,* (1982) et aux courbes de Stuiver (1982) ; comme pour les dates plus récemment obtenues il convient de les retraiter à l'aide des logiciels proposés par M.-F. Pazdur (Laboratoire du radiocarbone de l'université de Gliwice, Pologne) et par M. Stuiver et P.-J. Reimer (Laboratoire du radiocarbone de l'université de Washington Seattle, Etats Unis) ce qui constitue une tâche considérable. Enfin, en zone tropicale il serait important d'accompagner chaque résultat de celui du dosage du ^{13}C afin de pouvoir pondérer les dates obtenues sur les coquilles marines et sur la matière organique végétale. Le plus souvent cette donnée fait défaut, soit que le dosage n'ait pas été réalisé, soit que son énoncé ne figure pas dans les bases de données. Faute de règle générale, il a été décidé de surseoir provisoirement et d'évoquer cette question en séance.

Devant tant de contraintes, il a fallu renoncer à l'objectif visant à publier l'ensemble des dates.

EVIN, J. et MIALLIER, D., 1985 - Les datations radiocarbone et T.L. au Maroc : bilan et perspectives. *Première table-ronde franco-marocaine «Quaternaire et Préhistoire du Maroc»,* Université de Bordeaux I, Institut du Quaternaire, 11-13 février, 13 pages dactylographiées, 14 tableaux.

Actes du colloque «C14 Archéologie», 1998, p. 467-469.

RAPPORT DU GROUPE DE TRAVAIL «ASIE»

Du nouveau dans la chronologie de l'Asie Centrale du Chalcolithique à l'Age du Fer

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N. B. Le groupe de travail sur l'Asie centrale comprenait R. Besenval, C. Debaine-Francfort, M. Fontugne, H.-P. Francfort, E. E. Kuz'mina, Ch. Oberlin ; la synthèse a été faite par E. Kuz'mina et H.-P. Francfort, ce dernier, responsable de la mise en forme finale, est responsable des imperfections et défauts qu'il peut comporter. Il sera utile de consulter également sur la question la revue *Radiouglerod i Arkheologija, fasc.* 2, Saint-Pétersbourg, 1997.

Dans l'immense territoire qui s'étend de la mer Noire et de l'Oural à l'Extrême-Orient, l'absence de civilisation à textes entre le Moyen-Orient et la Chine a conduit à construire la chronologie en composant des chaînes de comparaisons de matériels et d'objets ancrées dans le terrain plus solide des régions méditerranéennes, proche-orientales ou chinoises.

Dans le cas de la civilisation de l'Indus, du plateau Iranien et de l'Asie centrale des oasis, ce sont les liens avec le monde mésopotamien qui ont fourni l'ancrage chronologique recherché. Dans le cas d'une partie de l'Asie centrale des steppes de Mongolie et de Sibérie du Sud, les parallèles chinois ont apporté les calages désirés, et dans le cas des steppes eurasiatiques, de l'Oural aux Tianshan, ce sont des rapprochements avec le monde méditerranéen oriental qui ont été utilisés. Naturellement, des incertitudes subsistaient localement, mais là n'était pas le plus grave.

Le plus grand problème résidait dans le hiatus chronologique que l'on constatait à la jonction des deux chaînes chronologiques, entre la steppe et les oasis, sur une ligne s'étendant du Caucase au Pamir (mais nous n'en parlerons pas ici, voir les contributions de Trifonov ; Shishlina, Aleksnadrovsky, Chigashova dans le présent volume). La chronologie obtenue par le nord (les steppes) était de 500 à 1000 ans plus basse que celle obtenue par le sud (les empires) ! La gravité du phénomène était extrême car on constatait par exemple la présence, dans des couches bien datées des environs de 2000 (par le sud), de poteries bien datées des environs de 1200 (par le nord).

L'enjeu était loin d'être négligeable, puisqu'il s'agissait de placer dans l'échelle du temps, dans le cours des 4e-2e millénaires, des macro-phénomènes comme d'éventuelles migrations transcontinentales d'Indo-Européens de l'ouest vers l'est, d'Indo-Aryens ou Aryas védiques d'Asie centrale vers l'Inde, d'Iraniens anciens vers les oasis et de replacer dans leurs cadres temporels des colonisations comme celles des civilisations Indus-Baloutchistan vers l'Asie centrale, du développement de la civilisation de l'Oxus (Bactriane-Margiane) par rapport à celle de l'Indus, aux steppes ou à l'Elam. Il s'agissait également, pour le tournant des 2e-1er millénaires avant notre ère, de trancher des questions comme celle de l'origine du style animalier scytho-sibérien, appelé également art des steppes, et de ses rapports avec les arts et les croyances du Moyen-Orient et du Caucase d'une part et de la Chine de l'autre.

Longtemps, dans le Nord, on a douté que le C14 puisse fournir une réponse satisfaisant à ces anomalies, d'autant plus que les calibrations accentuaient le hiatus au lieu de le réduire.

Cependant, aujourd'hui, prenant appui sur des méthodes affinées et surtout de meilleures séries, aidés par un calage sur la dendrochronologie quand cela est possible (Altaï) (Seifert et Sljusarenko, 1996), nous pensons que le moment est venu de poser le problème de la cohérence des évolutions culturelles et des relations inter-culturelles en Asie centrale.

Nous n'évoquerons pas ici les problèmes posés par la chronologie de l'âge du bronze de l'Ukraine dans ses rapports avec celles de l'Europe et de Mycènes (voir Kuznetsov), ni les questions concernant la région Oural-Volga (on tend à penser maintenant que les prototypes des ailes de mors circulaires présents dans les steppes sont dans l'Oural, et que de là elles sont passées à Mycènes), d'autres communications le feront.

Après avoir collecté environ 400 datations calibrées, la situation se présente aujourd'hui comme suit.

Dans les oasis tout d'abord, à l'âge du bronze. La civilisation de l'Oxus, ou complexe archéologique de Bactriane-Margiane, qui s'est étendue du Kopet-Dagh au Pamir, après avoir tout d'abord été datée de la seconde moitié, puis de la première moitié du 2e millénaire, est maintenant bien replacée entre 2400 et 1600 BC (Francfort, 1984 ; Francfort *et al.*, 1989 ; Hiebert, 1993 ; Hiebert, 1994, p. 75 s. ; Salvatori, 1995a ; Salvatori, 1995b ; Salvatori, 1998). Cette mise en place résulte de la conjonction de plusieurs facteurs. D'abord la datation de la période précédente de la séquence dans la vallée du Zeravshan au Tadjikistan : sur le site chalcolithique de Sarazm, la fouille de R. Besenval est datée par une bonne série inédite de C14 entre 3000 et 2300 de Gif) ; ensuite de la nouvelle datation des phases des débuts de la civilisation de l'Oxus, par la calibration de dates anciennes et l'obtention de nouvelles dates (Dashly-3 Palais en Afghanistan vers 2300BC, en tenant compte aussi des dates LE 1253 et 1254 qui sont les plus anciennes et toujours écartées a priori, Gonur en Margiane vers 2200) (Sarianidi, 1977, p. 169) ; et enfin d'une série inédite de nouvelles dates de la phase finale de cette civilisation, au cimetière de Bostan-VI à Dzharkutan, contemporain de Shortughaï-IV entre 1530 et 1670 (Gif) (Avanessova, 1995). Notre séquence de Shortughaï, en Afghanistan du NE (ca. 2200-1700), relie l'Indus mûr, entre 2500 et 2000, à cette fin de Namazga-VI appelée Mollali-Bostan-Bishkent dans la séquence bactrienne de Sapallitépa en Ouzbékistan et dans celle du Tadjikistan méridional (Francfort, 1981 ; Francfort, 1984 ; Francfort *et al.*, 1989, p. 241-242).

Ces datations s'accordent avec la chronologie de l'Indus, avec celle du NE de l'Iran (Tépé-Hissar, Tureng-Tépé) comme avec la séquence du Turkménistan des piémonts de Namazga IV-V-VI, malgré des dates au radiocarbone très éparpillées qui ne forment pas un faisceau serré dans le cas de Namazga (Götzelt, 1996, p. 157-158 ; Hiebert, 1994). Deux autres cultures de l'Asie centrale de l'âge du bronze des oasis, à la chronologie mal assurée, nécessitent encore un effort de datation, celles de Chust au Ferghana et celle de Vakhsh au Tadjikistan méridional (celle de Bishkent étant maintenant bien en place vers 1700-1500 grâce à Shortughaï-IV et Mollali).

Dans les oasis toujours, pour l'âge du fer ancien, les conséquences de la remise en place générale à une date plus haute du Bronze de l'Asie centrale des oasis, et en particulier de sa phase finale, sont doubles.

D'abord, le début de l'âge du fer, de la culture appelée Jaz-I/Kuchuk/Tillja doit être situé vers 1500 et non plus après 1000BC, ce que certaines dates récentes semblent confirmer (Erdosy, 1998, p. 145, n. 11 ; Lyonnet, 1997, p. 105-119 ; Vinogradova, 1996, p. 172). En cause sont aussi la date du début de la poterie "valikovaja", ainsi que le début du Bronze final de type Karasuk et apparenté, nous y reviendrons plus bas (voir Gösdorf, Parzinger, Nagler, Leont'ev).

Ensuite, comme on trouve des tessons de céramique des steppes de type Andronovo dans les couches des établissements de la civilisation de l'Oxus depuis le début du 2e millénaire, (après la remise en place opérée), il est nécessaire d'obtenir une cohérence avec les datations "du Nord", celles de la zone steppique.

Dans les steppes, les datations sont nombreuses (Mallory, 1989 ; Mallory, 1997 ; Kuz'mina, 1994). La culture de Jamnaja-Katakombnaja (dans la région de la Volga, voir Kuznetsov) prend bien place au cours de la première moitié du 3e millénaire ; la seconde de ces cultures se poursuit également au cours de la seconde moitié du millénaire, suivie par Poltavka (seconde motié du 3e millénaire) et Potapovka, puis Srubnaja, en gros contemporaines de Fedorovo-Alakul' plus à l'Est.

Ainsi, l'ensemble andronovien de Sintashta-Petrovka (Kazakhstan), considéré par certains auteurs comme étant à l'origine des Indo-Aryens, traditionnellement daté du milieu du 2e millénaire, est maintenant, grâce au radiocarbone et aux calibrations, situé peu après 2000. Et la séquence de l'ensemble andronovien, de l'Oural au Kazakhstan, s'ensuit normalement tout au long de ce millénaire. En particulier, les variantes Fedorovo et Alakul', très importantes au Kazakhstan, remontent largement vers le début du 2e millénaire (Matveev, 1995).

Dans les régions de l'Est du monde des steppes, du Kazakhstan oriental, de la Sibérie du Sud (bassin de Minusinsk) et de l'Altaï, la culture chalcolithique d'Afanasevo occupe apparemment tout le 3e millénaire (avec elle d'Okunevo dans le bassin de Minusinsk après 2500) (Gösdorf *et al.*, 1998 ; Lazaretov, 1995). Elle est suivie de celle d'Andronovo (et Elunino dans l'Altaï) au 2e millénaire, parfois jusqu'à la fin. Puis vient celle de Karasuk et Lugav, dont les plus anciens exemples remontent au milieu du 2e millénaire, avec le faciès apparenté, dans la taïga, de la culture d'Irmen, qui, comme celle de Begazy-Dandibaj au Kazakhstan, se prolongent jusqu'au début du 1er millénaire.

Toujours dans les régions orientales du monde des steppes, une période cruciale est celle de la première moitié du 1er millénaire, dans la mesure où la datation des importants kourganes de Sibérie du Sud, de l'Altaï, des Sajan et de la Touva, et donc du matériel associé (objets mobiliers et représentations artistiques) déterminent le sens de la flèche des influences, et donc des mouvements éventuels de population, ainsi que les régions d'origine de l'art scythe. Dans la Scythie d'Europe, les résultats du radiocarbone ont confirmé les datations traditionnelles du 7e au 4e siècle (voir Zaitseva, Possnert, Alekseev, Drgachev, Sementsov). En revanche, en Asie, (voir Zaitseva, Bokovenko, Sementsov, Chugunov ; Zaitseva, Vasiliev, van der Plicht, Marsadolov, Sementsov, Dergachev, Lebedeva) les résultats du radiocarbone ont modifié la conception ancienne, notamment avec l'aide de la dendrochronologie (Marsadolov, 1984 ; Marsadolov, 1996 ; Marsadolov, Zajceva, et Lebedeva, 1994). On obtient ainsi (voir Marsadolov) : Arzhan (808), Tuekta-1 (583), Pazyryk-2 (455), Pazyryk-1 (454), Pazyryk-5 (406). Les autres kourganes des Sajano-Altaï prennent place dans cette série, mais avec moins de précision, comme Bashadar, Katanda, Shibe, Ustyd, (Hall, 1997) et Ukok ; pour ce dernier ensemble, la dendrochronologie, inédite, a montré, comme à Pazyryk, une brève période de temps, entre 430 et 350BC : (Seifert et Sljusarenko, 1996)). Ces résultats montrent une fois de plus, et on peut penser maintenant une fois pour toutes, avec la certitude de la date haute d'Arzhan, l'antériorité de la phase dite Arzhan-Maiemir de l'art des steppes sur les formes Proche-orientales, et par conséquent ses rapports avec la fin de Karasuk d'une part, la Chine des Zhou occidentaux et de la fin des Shang de l'autre. Ensuite, on confirme les rapports de Pazyryk (ainsi que Ukok, Ustyd, Ulandryk, Sajlugema) avec la Perse achéménide et la Chine des Royaumes combattants.

En Chine, au Xinjiang, la série des dates au radiocarbone est publiée jusqu'en 1990 et doit être complétée à l'aide d'articles plus récents.

Pour les points soulignés ici, dans un contexte de cultures à céramiques peintes à l'est et grises à l'ouest, la culture d'Andronovo est représentée sur un site au moins, Xintala, au sud des Tianshan, daté de 1690-1425 +- 150.

Au Xinjiang toujours, trois nécropoles présentent traditionnellement des tombes et du matériel datés au radiocarbone de cette période cruciale de la fin du 2e millénaire et du début du 1er. Mais seules une analyse serrée des datations au radiocarbone et une étude précise du matériel tombe à tombe permettront de ne pas s'égarer dans des hypothèses hasardeuses sur des rapports avec la culture de Jaz-I ou dans de vastes théories sur une migration hallstattienne, comme on a pu le faire en ne prenant en compte que des dates théoriques globales comme 1000 BC pour Zhaghunluk ou Yanbulak et 1200 pour Wupu. En fait, Wupu (Hami) est daté par une série entre 1400 et 800. Yanbulak comprend trois phases successives : phase haute 1500-1300, phase moyenne vers 1000-700 et phase finale autour du début de notre ère. Zhaghunluk (Qiemo) jusqu'ici daté de ca. 1000, a été tout récemment attribué aux environs du milieu du 1er millénaire BC à l'époque des Royaumes Combattants, des Han et Nan Bei Chao, ce qui correspond aux découvertes à Djoumboulak Koum de la Mission Archéologique Franco-Chinoise de la Keriya. La raison pour laquelle des dates plus hautes avaient été proposées pour Zhaghunluk tient très probablement au remploi dans les constructions funéraires de poutres et rondins en bois anciens, usage très fréquent également dans l'Altaï.

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RAPPORT DU GROUPE DE TRAVAIL «AMÉRIQUE»

Le premier peuplement humain de l'Amérique : apport et limite des datations radiocarbone

Danièle LAVALLÉE

Peu de thèmes archéologiques ont engendré et continuent à engendrer autant de discussions et de polémiques que celui du premier peuplement humain de l'Amérique.

La question qui divise la communauté scientifique américaniste en deux camps opposés est celle-ci : l'Amérique a-t-elle été peuplée au cours du Pléistocène, ou son premier peuplement ne remonte-il qu'à l'extrême-fin de celui-ci, soit à partir de 11 500/12 000 BP, cette dernière date étant considérée comme butoir. Rappelons qu'elle correspond, aux Etats-Unis, au début de la période dite «Paléoindienne» (12 000 à 8000 BP) divisée en trois phases dont la première, «Llano» (12 000 à 11 000 BP), est caractérisée par un mode de vie fondé sur une chasse spécialisée au mammouth, mastodonte ou caribou (selon les biotopes), et par l'utilisation de pointes de jet bifaciales à cannelure proximale, dites «pointes de Clovis». Or, cette période Paléoindienne a longtemps été considérée comme représentant le premier peuplement du continent américain, et continue d'être ainsi interprétée pour les tenants d'un peuplement américain «jeune», qui constituent l'école «conservatrice». Selon leur théorie, les chasseurs «Clovis», venus de Sibérie, auraient pénétré en Amérique à la fin de la dernière crue glaciaire quaternaire, vers 12 000 BP, en traversant le pont terrestre alors émergé de Béringie, puis gagné les Grandes Plaines du sud des Etats-Unis en empruntant un couloir libre de glaces (ice-free corridor) séparant les deux masses glaciaires des Rocheuses et des Laurentides.

Cependant, en face des «conservateurs» s'est peu à peu - à partir des années 40 - constituée une école qui se qualifie elle-même de «radicale» et qui, se fondant sur la découverte de gisements apparemment plus anciens, défendent la théorie d'un peuplement remontant au moins à une quinzaine de milliers d'années sinon davantage, en tout cas antérieur au dernier maximum glaciaire. Les premiers occupants auraient apporté avec eux une culture «pré-Clovis» et moins spécialisée, et l'usage des pointes à cannelure «Clovis» ne se serait diffusé que plus tard. R. Morlan, en 1988, mentionne 58 sites «Pré-Clovis» répartis de l'Alaska au sud de l'Argentine, dont il ne retient cependant qu'une quarantaine (Morlan, 1988, 31). Ces nombres ont bien sûr largement augmenté depuis. Toutefois, pour la présente discussion, qui porte sur l'utilisation des datations radiocarbone, nous n'avons retenu que 8 gisements (objets des fiches ci-jointes), la majorité d'entre eux fouillés depuis la fin des années 70 et qui nous paraissent exemplaires des différents problèmes qu'ont soulevés ou soulèvent encore leur interprétation et leur assignation chronologique. Ces gisements sont, du nord au sud et indépendamment de l'âge qui leur est attribué :

- Old Crow (Canada) : fiche 1
- Bluefish (Canada) : fiche 2
- Meadoweroft (USA) : fiche 3
- El Cedral (Mexique) : fiche 4
- Tlapacoya (Mexique) : fiche 5
- Taima-Taima (Venezuela) : fiche 6
- Pedra Furada (Brésil) : fiche 7
- Monte Verde (Chili) : fiche 8

Le principal argument utilisé par les conservateurs pour rejeter les gisements pré-Clovis est qu'il ne s'agirait dans la plupart des cas que de dépôts perturbés, contenant un mélange d'artefacts et de matériel archéologique. Par ailleurs, lorsque la nature anthropique des vestiges est indiscutable, c'est la validité des dates ^{14}C qui est mise en cause. S'appuyant sur le fait que nombre de gisements supposés Pré-Clovis se sont effectivement révélés perturbés et leurs datations de ce fait invalidées - ces gisements, les premiers «découverts» dans les années 40-50, ne sont même plus reconnus comme tels par les radicaux eux-mêmes et ne seront pas évoqués ici - le scepticisme exacerbé des conservateurs les amènent à rejeter en bloc tous les sites pré-Clovis.

Dans ce débat, l'apport du ^{14}C est évidemment essentiel, les âges radiocarbone étant considérés comme déterminants pour assigner les gisements à un stade chrono-culturel «Clovis» ou «Pré-Clovis». On notera que certains progrès récents de la méthode, en particulier l'affinement des appréciations concernant la variation, au cours du temps, de la teneur en ^{14}C de l'atmosphère, qui ont abouti à l'obtention de courbes de calibration de plus en plus fiables, ont peu d'importance à l'échelle de temps où travaillent et discutent les préhistoriens américanistes mais ils recouvrent cependant toute leur importance, concernant les périodes plus récentes, notamment à partir du 8e millénaire. En revanche, l'utilisation, pour l'analyse isotopique, de la spectrométrie de masse avec accélération, a représenté un apport considérable dans la mesure où ce procédé permet de dater des échantillons extrêmement réduits, ce qui est souvent le cas dans cette catégorie de gisements.

En ce qui concerne la nature des matériaux datés, on notera que plusieurs des datations les plus anciennement obtenues l'ont été sur os, à partir de leur fraction inorganique. Celles-ci se sont révélées le plus souvent inopérantes (i.e. le queursoir sur tibia de caribou de Old Crow, d'abord daté - sur la fraction inorganique - de 27000 +3000-2000 BP puis - sur le collagène par AMS - de 1350 +/- 150 BP) (Taylor in Dillehay et Meltzer, 1991, 83). Depuis, si le problème de l'origine anthropique des matériaux datés de Old Crow (os fossilisés travaillés ou non par l'homme) demeure entier, cet objet particulier, reconnu comme intrusif, n'est plus pris en compte pour la validation du gisement et de son ancienneté. Il en est de même d'un certain nombre de restes osseux humains mis au jour en Californie (10), au Canada (1) et en Equateur (1), qui avaient été datés, par des méthodes diverses mais, pour la plupart, par racémisation des acides aminés, d'entre 17 000 et 70 000 BP, et dont les âges ont été récemment ramenés, par l'analyse de la fraction organique de l'os au moyen du spectromètre de masse, à des dates variant entre 6 300 et 15 000 BP (Taylor *et al.*, 1985). Un gisement n'a pas été pris en compte dans notre corpus, bien que les datations obtenues sur os, l'aient été apparemment à partir de la fraction organique, c'est le site de Pikimachay (Pérou). En l'absence de tout vestige de combustion dans le niveau profond j, c'est un fragment osseux de megatherium qui a été daté de 20200 +/- 1050 BP (I-5851) et 19600 +/- 3000 BP (UCLA- 1653A), sur collagène semble-t-il (MacNeish *et al.*, 1981, 204-211, MacNeish, Berger & Protch, 1970, 976-77, Buckley & Willis, 1970, 87). Il est cependant prudent de laisser ces dates de côté car les niveaux profonds k et j du gisement présentent d'autres problèmes d'ordre stratigraphique et typologique qui rendent douteuse, aux yeux de la plupart des spécialistes, la nature anthropique de leur remplissage. En fait, à Pikimachay, ce n'est tant la validité des datations qui est mise en cause, que la réalité d'une association entre le matériau daté et une présence humaine.

Si nous examinons maintenant les 8 gisements supposés pléistocènes que nous avons retenus (fiches 1 à 8) et qui ont livré, à la fois, des vestiges considérés comme anthropiques et des matériaux organiques datables (et datés), ils peuvent être répartis, selon la nature des problèmes qu'ils posent, en quatre catégories :

- a/ L'origine anthropique des matériaux datés est indiscutable mais la validité des datations est contestée : cas de Meadowcroft (Etats-Unis), de El Cedral (Mexique).
- b/ Les datations ne sont pas contestées, mais l'origine anthropique des matériaux datés est discutée : cas de Tlapacoya (Mexique), Boqueirao da Pedra Furada (Brésil) et, jusqu'à une date très récente, de Monte Verde (Chili).
- c/ Les datations ne sont pas contestées, ni la nature anthropique des vestiges non plus, mais l'association des deux est discutée - cas de Taima-Taitna (Venezuela).
- d/ Les datations et la nature anthropique du matériel sont toutes contestées : cas de Ol Crow (Canada) et de Bluefish (Canada).

CONCLUSION

L'apport représenté par la datation radiocarbone, s'il est essentiel dans tous les cas discutés ici, n'a finalement apporté la preuve de l'ancienneté que dans un cas : celui de Monte Verde au Chili, mais après que la nature anthropique des vestiges et leur association avec les matériaux datés aient été enfin acceptées par les plus obstinés des "conservateurs".

Les datations par elles-mêmes ne permettent jamais de valider une telle association, qui ne peut être prouvée que par la rigueur des fouilles et des analyses.

Heureusement (?) pour l'avenir de cette interminable querelle, l'archéologie n'est maintenant plus la seule discipline à apporter sa contribution : la linguistique, l'hémotypologie, l'étude des caractères dentaires, la génétique (étude de l'ADN), ont fourni des éléments nouveaux, bien que parfois ambigus ou contradictoires. Dans l'état actuel des connaissances, il semblerait que l'Amérique ait connu plusieurs vagues de migration (2 à 4 selon les différentes équipes de recherche, mais une seule pour l'équipe de l'université du Michigan), dont la plus ancienne pourrait avoir eu lieu vers 40000 BP pour les uns, 20000 BP pour les autres.

Quant aux gisements pré-Clovis, leur rejet jusqu'alors catégorique de la part des conservateurs est en train de se nuancer, sans toutefois que leur indulgence s'exerce, pour le moment, au-delà de 15000 BP environ.

En faveur de l'hypothèse d'un peuplement pré-Clovis, on notera enfin que la dispersion et la distribution chronologique des sites sud-américains, remontant au Pléistocène final et très généralement acceptés par les conservateurs, cadrent fort mal avec le modèle d'une très rapide diffusion des chasseurs «Clovis». Ces sites, en Patagonie, les grottes de Los Toldos et de Fell et, dans la Terre de Feu, le gisement de Tres Arroyos, sont occupés dès 11 000 BP sans que personne n'en ait jamais contesté l'âge ni l'authenticité.

Il reste que, entre les spécialistes disposés à accepter un peuplement américain initial ayant débuté dès le Pleistocène, à partir de 15 000, voire 20 000 BP, et ceux qui défendent avec véhémence la thèse d'une arrivée beaucoup plus ancienne, dès 60000 BP pour certains, un large fossé reste à combler, ce à quoi ne pourrait suffire, à elle seule, la multiplication de datations isotopiques de plus en plus fiables.

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La bibliographie relative au premier peuplement de l'Amérique compte des centaines de titres. On se bornera ici à indiquer quelques ouvrages ou articles de synthèses parmi les plus récents.

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TAYLOR, R.E. *& al.*, 1985 - Major revisions in the Pleistowne age assignments for north american human skeletons by C- 14 accelerator mass spectrometry : none older than 11,000 c-14 years B. P. *American Antiquity*, 50 (1), 136-140.

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Curretu Research in Pleistocene, A Peopling of the Americas Publication, Center for the Study of the First Americans, Oregon State University, CorvaHis, Oregon (parution annuelle).
Mammoth Trumpet, Center for the Study of the First Americans, Oregon State University, Corvallis (4 numéros par an).
Revista de Arqueologia Americana, Instituto Panamericano de Geografia e Historia, Mexico (2 numéros par an).

Fiche 1 : OLD CROW

Site : aujourd'hui bassin de la rivière Old Crow (Yukon, Canada). Dépôts sédimentaires le long des rives d'un ancien lac périglaciaire.
Découverte et étude : site fossilifère connu (signalé) depuis 1873 mais os «travaillés» détectés en 1966 par C.R. Harington (National Museum of Canada). Depuis, plus de 200,000 spécimens récoltés. Etude intensive (expérimentale sur os d'éléphant actuel, et comparative) des pièces osseuses ensuite menée par R. Bonnichsen, afin de déterminer, a/ l'origine, humaine ou non, des traces (enlèvements et fractures) observées, et b/ à quel moment - avant ou après fossilisation - les os avaient-ils été ainsi altérés. Conclusion des expérimentations : les fractures ont été faites avant minéralisation de l'os. Les chercheurs/inventeurs ont donc conclu à une intervention humaine.
Vestiges : nombreux fragments osseux de mammouth «travaillés» et un queursoir sur tibia de caribou, vestiges non en place, trouvés dans sédiment sableux.
Datations :
- le queursoir : 27000 +3000-2000 B.P. (GX-1640) (sur apatite)
- 2 fragments d'os de mammouth : 25750 +1800-1500 (GX-1568) (sur apatite)
  29100 +3000-2000 (GX-1567) (sur apatite)
- 1 éclat d'os de mammouth : 29300±1200 (I-1105) (sur collagène, en 1980)
- 5 éclats d'os : entre 22000 et 43000 (NMC) (par S.M.A., sur collagène, 1985)
- le queursoir (à nouveau) : 1350±150 (RIDDL-145) (par S.M.A. sur collagène)

Conclusion : le problème reste entier et des doutes subsistent chez de nombreux chercheurs. Tout repose sur le diagnostic de «travail humain», lui-même basé sur la systématisation observée des types et emplacements de fractures sur les os, et sur les datations effectuées sur la fraction apatite de l'os. Quant au queursoir (d'ailleurs non fossilisé), il est à l'évidence intrusif. D'où 4 possibilités :
- les os ont bien été travaillés avant fossilisation, et les dates sont bonnes (opinion des inventeurs),
- les os ont bien été travaillés mais les dates sont fausses,
- les os ont été naturellement fracturés et les dates sont bonnes,
- les os ont été naturellement fracturés et les dates sont fausses,

Remarque : tous les restes de faune pléistocène datés provenant des bassins du Yukon sont plus jeunes.

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Fiche 2 : BLUEFISH CAVE (Grotte du Poisson-Bleu)

Site : le long du cours moyen de la rivière Bluefish (nord du Yukon, Canada). Il s'agit en fait d'un ensemble de trois petites grottes creusées au pied d'affleurements calcaires (vestiges d'un ancien réseau karstique mis au jour par l'érosion ?).
Découverte et étude : découvertes en 1975 et étudiées entre 1977 et 1987 par J. Cinq-Mars et R.E. Morlan.
Vestiges de faune : milliers de vestiges osseux dans le niveau de loess et dans celui, au-dessus, d'«humus à cailloutis». Faune typique du Pléistocène supérieur béringien (cheval, renne, mouflon, bison, élan, cerf élaphe, mammouth, saiga, boeuf musqué, ours, loup) dans le loess, appauvrie dans l'humus.

Vestiges culturels : mis au jour dans niveau de loess des grottes I et II :
- industrie à nucléi, micro-lames et burins d'angle sur troncature, façonnés en chert allochtone et petits déchets de taille en chert,
- traces de découpe et décarnisation sur os (dans le fond du niveau).

Datations : 12 dates (par compteurs et S.M.A., dans 3 labos différents) :
- fémur de cheval du sommet du loess (grotte 1) : 12 950±100 BP (sur collagène, par compteur : GSC-2881),
- omoplate de mammouth du fond du loess (grotte H) : 15 500±130 BP (sur collagène, par compteur : GSC-3053),
- tibia de caribou (travaillé ?) dans fond du loess (grotte 11) : 24 820 BP (sur fraction collagène, S.M.A.),
- os long de mammouth taillé par percussion : environ 23 500 BP.

Conclusion : il n'y a pas de foyer, donc pas de datation «directe» de vestiges culturels. Seulement corrélation entre vestiges osseux datés et industrie lithique qui remonterait au plus tard, selon les inventeurs, à 15 000 à 12 000 BP. Les os «travaillés» sont plus anciens (environ 25 000 BP) mais le sont-ils ? Pour les inventeurs, ils sont semblables à ceux de Old Crow, alors que le contexte environnemental est différent, donc, ils résulteraient bien d'un travail humain.

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Fiche 3 : MEADOWCROFT

Site : sur rive nord de la rivière Cross Creek (Pennsylvanie), abri creusé dans des schistes, où 11 couches naturelles ont été identifiées. L'intérêt du site réside dans le contenu et l'âge de la couche inférieure II, niveau profond IIa.

Découverte et étude : début des fouilles en 1973, par J. Adovasio.

Vestiges : les seuls objets discutés proviennent du niveau IIa, moyen et inférieur : outils et éclats, lames, nuclei majoritairement en chert. Environ 400 objets directement associés aux restes de combustion datés, et sans possibilité que ce matériel soit intrusif puisque le niveau est scellé par un éboulement du toit de l'abri.

Par ailleurs, la faune du niveau IIa est moderne (rare dans le IIa inférieur, seulement 11 fragments identifiables, Odocoiteus Wrginianus).

Datations : 52 dates au total, dont 13 pour le niveau IIa.

Les premières effectuées dès 1973-74 par la Smithsonian :
- charbons de bois, niveau IIa (milieu) : 11 300 ± 700 BP,
  niveau IIa (fond) : 19 600 ± 2 400 BP.

Par la suite, nombreuses datations, toutes sur charbon sauf 2 (sur vannerie).

En somme, le fond du niveau IIa est daté d'entre 19 600 ± 2 400 et 12 800 ± 870 BP, en association avec d'indiscutables vestiges anthropiques. Toutes les datations ont été effectuées par R. Stuckenrath, Lab. de Biologie et des Radiations, Smithsonian.

Après 1983, une datation issue d'un autre laboratoire : Dicarb Radioisotope Company (Gainesville), sur un échantillon de charbon du niveau le plus profond (sans vestiges culturels), et effectuée avec une préparation et une technique de comptage différentes de celles de la Smithsonian. La date (21070 ± 475 BP) correspond parfaitement à celle obtenue à la Smithsonian pour ce même niveau (21 380 ± 800 BP).

Plus récemment encore, 2 datations SMA à Oxford du niveau pré-culturel, sur un échantillon totalement exempt de contamination, particules ou micro-flore) :
- fraction solide : 31400 ± 1 200 BP (OxA-363),
- fraction soluble: 30 900 ± 1 100 BP (OxA-364).

Ces deux datations sont très équivalentes d'une date faite à la Smithsnian pour le même niveau :
30 710 +/- 1 140 BP

Problèmes : dès les premières dates obtenues, la contamination a été évoquée- des gisements houillers (300 MA) se trouvent à environ 1 km du site et des particules auraient pu contaminer le gisement ; les eaux souterraines pouvaient aussi être riches en «carbone ancien» dissous (Haynes, Dincauze). Les inventeurs excluent les deux possibilités. D'après eux, aucune autre cause de «mauvaise datation» (perturbation de la stratigraphie, bioturbation) ne peut être invoquée.

Réponse de Adovasio *et al.* (1990) :
- Concernant la contamination par des particules : les échantillons pour datation examinés au microscope électronique n'ont révélé aucune particule de charbon minéral (houille), pas plus que de restes de micro-flore généralement associée à la houille (vérification par 4 labos).
- Concernant la contamination par l'eau : la nappe souterraine actuelle se trouve à 5 m en dessous du niveau d'occupation le plus profond et n'a jamais été plus haut. Par ailleurs, si infiltrations il y eut, elles auraient dû alors contaminer aussi les datations les plus récentes (niveaux paléo-indiens et plus récentes encore).

Les opposants (Tankersley *et al.*, Haynes) restent convaincus pourtant d'une contamination par du charbon minéral. Leurs arguments sont les suivants :
- Adovasio a reconnu qu'il y avait des fragments de *vitrinized pennsylvanian-age wood* et c'est du charbon minéral, impossible à distinguer (au microscope électronique) du charbon végétal si les particules sont très petites. Conséquence, les échantillons datés pourraient être tout simplement du fusain fossile :

- les «préhistoriques» ont pu utiliser du charbon minéral comme combustible ;
- le charbon minéral ne peut être dissous dans l'eau, mais les hydrocarbones solubles qui s'en dégagent (suite aux actions physiques et chimiques) le peuvent. Carbone soluble = humates, qui ne seront pas forcément éliminés lors du traitement chimique préalable à la datation. - Suggestion : dater des graines (carbonisées et non-carbonisées) et des fragments osseux humains «parmi les plus anciens d'Amérique» (dixit Adovasio).

Conclusion : Meadowcroft a livré la plus longue séquence d'occupation du nord-ouest des Etats-Unis. Aucun site de la même région n'a fait l'objet d'une telle quantité de datations. Pour Adovasio, Meadowcroft représente la meilleure évidence d'une occupation pré-Clovis dans tout l'hémisphère car les 6 datations associées de manière indubitable à du matériel culturel prouvent la présence humaine entre 14 555 et 13 955 BP, et peut-être dès 16 770 BP (d'après la date, +-2400). Mais tout repose sur les datations et l'article de Tankersley laisse persister un doute.

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Fiche 4 : EL CEDRAL (Rancho La Amapola)

Site : ancien lac fossile dans un bassin endoréique, zone aujourd'hui semi désertique (nord de San Luis Potosi, Mexique). 23°49' Lat. N. et 100°43' Long O., altitude 1700 m.

Découverte et étude : zone fossilifère connue depuis longtemps. Etudié à partir de 1977 par J.L. Lorenzo et L. Nlirambell et une équipe pluridisciplinaire (R. Casamiquela) jusqu'en 1985 environ.

Vestiges : stratigraphie de 15 m. Le niveau inférieur d'argile chargée en restes végétaux, stérile, correspond au fond du lac. Faune : *Mammuthus, Mastodon, Equus, Camelops* (principales espèces).
L'intérêt du gisement réside en la présence supposée de l'homme dans les niveaux profonds (foyers et outillage lithique fruste, sauf une pièce (grattoir discoïde de calcédoine), comprenant nucleus, choppers, chopping-tools, éclats et lames.

Datations : foyer 1 : 37 694 ± 1 963 (INAH-305) (sujette à caution)
niveau du grattoir de calcédoine = 33300±2700 BP (GX-7684)
foyer (galette discoïde de charbon de 30 cm de diamètre et 2 cm d'épaisseur entouré d'un cercle de tarses de proboscidiens) : 31 850 ± 1 600 BP (1-10438) (première datation effectuée, mais sur quel foyer ?)
foyer 6 : 28 709 ± 828 BP (INAH-389)
foyer 7 : 27 459 ± 812 BP (INAH-390).
foyer 4 : 33 630 ± 2066 BP (INAH-302A),
28 841 ± 831 BP (INAH-302B),
26 984 ± 850 BP (INAH-391),
25 682 ± 1418 BP (INAH 303) Moyenne : 26 300 BP.
niveau du tibia de cheval brisé et utilisé : 21 960 ± 540 BP (I-10436)
foyer 5= 21468 ± 458 BP (INAH-388).
niveau du percuteur-nucléus de calcaire et lame de silex = > 15 000 BP
(Les datations non-INAH ont été effectuées entre 1977 et 1980)

Problèmes : les datations sont-elles fiables ? Les foyers semblent bien des foyers d'origine anthropique. En revanche, le grattoir de calcédoine a une apparence beaucoup trop «jeune» pour son âge supposé (en place ?). Les autres outils lithiques sont frustres mais indiscutablement d'origine humaine. Les inventeurs eux-mêmes doutent de la datation la plus ancienne et situent la première occupation du site autour de 30 000 BP.

Conclusion : si les datations sont bonnes, F-1 Cedral représente la plus ancienne occupation connue du Mexique, et une des plus anciennes d'Amérique (avec Pedra Furada).

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Fiche 5 : TLAPACOYA

Site : plage pléistocène sur la rive nord du lac fossile de Chalco, au pied du Cone volcanique Tlapacoya, plateau central mexicain (Etat de Mexico, Mexique). Interprété comme campement de plein air installé sur la plage du lac.

Découverte et étude : découvert en 1965 (à l'occasion du percement de la route Mexico-Puebla) puis étudié entre 1965 et 1973 sous la direction de J.L. Lorenzo.

Vestiges et datations : lors de la lère fouille dite «Tlapacoya-tranchée Alpha» :

Dans le Foyer 1 entouré de blocs de pierres et d'amas osseux (Odocoileus) :
24 000 ± 4 000 BP (Arizona-794b)
24 200 ± 500 BP (A-793) sur charbon
22 200 ± 2600 BP sur bois brûlé contenu dans le niveau limoneux scellant le foyer (A-790a).
Dans la même tranchée de fouille, Foyer 3 (aire circulaire de cendres et charbons) associé à amas osseux : 21700 ± 500 BP. (1-4449).
Les trois foyers de Tlapacoya sont proches les uns des autres.
Lame prismatique d'obsidienne (obtenue par percussion bipolaire) à Tlapacoya II, sous un tronc d'arbre (*Taxodium*) daté de 23 150 + 950 BP (GX 0959) selon la monographie ou de 23 950 BP selon le Bulletin de la Société préhistorique française (?).
Au total, 20 dates sont antérieures à 12 000 BP, dont 13 antérieures à 20 000 BP (pour détail des matériaux datés, voir p. 223 de la monographie). 3 laboratoires : Arizona, Geochron et Teledyne-Isotopes. Mais pas une des publications ne précise systématiquement le matériel daté et la méthode. A noter cependant que les datations ^{14}C de Tlapacoya ont fait l'objet d'un article de V. Haynes, un des plus ardents conservateurs, qui ne conteste pas les dates anciennes (voir monographie p. 220). Considérant les intervalles de confiance et leur recouvrement, Tlapacoya 1 et H seraient contemporains et remonteraient à environ 22 000 BP.
Problèmes : apparemment pas de problème. Le foyer 1 de Tlapacoya 1 Alpha semble en tout cas indiscutable. Les autres ne sont pas illustrés dans les publications. Toutefois, nombreuses contradictions entre les diverses publications (dates différentes et attributions aux niveaux différentes, identifications des foyers 1 ou 3 inversée dans monographie et Bryan (éd.) 1978. La monographie est ici prise comme référence.
Conclusion : bien que toujours rejeté par les conservateurs (pourquoi ?), Tlapacoya reste un des plus sûrs témoignages d'une présence humaine en Amérique depuis environ 20 000 ans.

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Fiche 6 : TAIMA-TAIMA

Site : région de Coro (Falcôn, Venezuela). A l'origine, mare ou bourbier dû à la présence d'une source artésienne.
Découverte et étude : découvert en 1961 (ou 1962 ?) par J.M. Cruxent et A. Kirieger. D'abord fouillé de 1962 à 1967 par Cruxent (avec des résultats douteux) puis repris en 1976 par A. Bryan, R. Gruhn et C. Ochsenius.
Stratigraphie, vestiges et datations :
Unit IV : sable colluvial brun. Stérile.
Unit III : sable limoneux organique noir, très chargé en restes végétaux (datés)
: 3 dates, entre 9650+80 BP (IVIC-657) et 10290+90 BP(IVIC-659)
Unit II : sable jaune-orangé. Contient des fragments osseux dispersés (cheval et glyptadonte). Aucun vestige culturel.
Phase d'érosion
Unit 1 : sable argileux gris = niveau à faune fossile (mastodonte, glyptodonde, Megatherium, cheval) avec du matériel lithique «associé». Un éclat de chert utilisé et une portion mésiale de pointe lancéolée type «El Jobo», dans la cavité pelvienne d'un jeune mastodonte découvert à la base de ce niveau. Des restes de branchages cisaillés découverts à proximité du squelette ont été interprétés comme les restes du contenu stomacal ou intestinal de l'animal, et datées.
Deux séries de datations ont été effectuées sur ce niveau :
a/ datations du contenu organique du niveau : 11 580 ± 150 BP (IVIC-627)
12 620 ± 120 BP (XVIC-661)
12 660 ± 120 BP (IVIC-660)
12 730 ± 120 BP (IVIC-664)
12 770 ± 120 BP (IVIC-669)
12 990 + 260 BP (IVIC-670)
13 130 ± 130 BP (IVIC-663)
13 180 ± 130 BP (IVIC-671)
13 390 ± 130 BP (IVIC-662 et 668)
14 010 ± 140 BP (IVIC-672) (inc.)
b/ datations du contenu stomacal supposé : 12 980 ± 85 BP (SI-3316)
13 000 ± 200 BP (Birm-802)
13 880 ± 120 (USGS-247) (inconsistante)
14 200 + 300 (UCLA-2133) (inconsistante)
«Cobble pavanent», recouvrant irrégulièrement un niveau de sable miocène de base. Stérile.
Problèmes : lors des fouilles 1962-67, le seul matériel lithique découvert consistait en «outils de fortune» sur galets (tools of empediency) et dont plusieurs, comme l'admet Bryan, pourraient n'être que des éléments du «cobble pavement».
Les résultats des fouilles de Cruxent avaient été sévèrement critiqués en 1974 par Haynes et Lynch (association, stratigraphie, dates ^{14}C) : ainsi, les restes osseux et objets lithiques seraient intrusifs dans l'Unit I (venus d'un

niveau supérieur). Pour Haynes, les vestiges auraient aussi pu être remaniés par des remontées d'eaux (source artésienne) et donc venus d'un niveau inférieur (il faudrait choisir...).
En 1976, reprise des fouilles. selon Bryan, l'absence d'os de mastodonte et de matériel lithique au-dessus de l'Unit I prouve que le contenu de celle-ci ne peut être venu d'en haut, la faune de l'Unit H étant en outre différente. Et les remontées de la source artésienne n'ont pas perturbé les niveaux. D'après R. Casamiquela, le jeune mastodonte a été partiellement démembré et découpé sur place.
Concernant les dates ^{14}C, Haynes pense que toutes les dates ont pu connaître une contamination dûe à du charbon minéral, présent dans le sable miocène de base et «remonté» par les eaux (pb. analogue à celui de Meadowcroft). Les 4 laboratoires traitants ont donc été alertés : aucune particule de charbon n'a été détectée dans les échantillons.
D'après Bryan et Gruhn, Taima-Taima serait le kill-site le mieux daté d'Amérique.
Conclusion : les problèmes semblent réglés mais pourtant le doute subsiste, notamment chez Lynch, qui persiste à penser que le matériel lithique est intrusif dans l'Unit 1. Les dates radiocarbone ne sont plus mises en doute, et la seule raison de ce doute semble être la présence, encore considérée comme impossible par les conservateurs, d'une pointe bifaciale dans un niveau daté d'environ 13 000BP. Or, si Monte Verde est maintenant accepté, Taima-Taima doit l'être aussi.

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Fiche 7 : TOCA DO BOQUEIRÂO DA PEDRA FURADA

Site : région de Sâo Raimundo Nonato (Piaui, Brésil), 8°51' S et 42°33' O. Intégré dans le Parc national Serra da Capivara. Grand abri au pied d'une falaise de grès, elle-même surmontée d'une strate de conglomérats (poudingues) de quartz et quartzite de 20 m d'épaisseur. Le sol de l'abri se situe à 19 m au-dessus du fond du varon qui lui fait face.
Découverte et étude : découvert en 1973 par N. Guidon. Fouillé de 1978 à 1980, phase exploratoire, puis de 1982 à 1987 par N. Guidon, enfin en 1987-88, reprise des niveaux les plus anciens par F. Parenti. Surface totale exploitée : 400 m2.
Vestiges : l'intérêt du gisement réside dans l'existence des niveaux inférieurs à partir desquels a été définie la phase d'occupation «Pedra Furada», divisée en trois moments, et séparée de la phase plus récente «Serra Talhada» par un hiatus dans la séquence chronologique et par un changement culturel marqué. Les vestiges de la phase PF consistant essentiellement en matériel lithique taillé sur galets de quartz et quartzite, en «foyers» et en «structures». La faune est absente (sol acide).
Datations : 55 datations au total, dont 32 pour les niveaux «Pedra Furada», effectuées par 5 laboratoires :
Centre des Faibles radioactivités de Gif (24)
Beta Analytic (3)
Gif-Tandétron (5)
Modane LSM (3)
Fortaleza (3)
Les datations ont été effectuées sur des échantillons de charbon végétal provenant de «niveaux», de «foyers» (concentrations de charbon avec ou sans bordure de pierres), ou de «structures» (groupements de galets et blocs non chauffés mais «agencés»).
Chronologie radiocarbone : Pedra Furada 3 : de 21400 + 400 à 14 300± 210 BP
Pedra Furada 2 : de 32 160 ± 1000 à 25 000 BP
Pedra Furada 1 : de > 50000 à ≥ 35 000 BP
(les limites chronologiques assignées aux sous-phases se fondent sur les publications les plus récentes, Parenti *et al.*, qui ne coïncident pas forcément avec les publications plus anciennes, Guidon *et al.*) (la liste complète des datations figure dans la thèse de F. Parenti).
Problème : la nature anthropique des vestiges et structures datés est rejetée par beaucoup de spécialistes. Tous les «conservateurs» bien entendu mais aussi quelques spécialistes pourtant favorables à un peuplement américain antérieur à 12000 BF, et eux-mêmes inventeurs de sites pré-Clovis (J. Adovasio, T. Dillehay).
Arguments des opposants :
- les datations (en elles-mêmes considérées comme acceptables, cohérentes et exemptes de contamination) correspondraient à des incendies naturels spontanés et non à des foyers d'origine anthropique. Les charbons auraient aussi pu être apportés par le vent.
- les pierres des «structures» auraient pu être charriées par l'eau.
- le matériel «taillé» est probablement naturel même si quelques objets «pourraient être» d'origine humaine (mais il y a eu une sélection artificielle de l'échantillon étudié, lui-même trop réduit). De plus, absence surprenante d'évolution technologique durant 50 Ka, et absence de traces d'utilisation).
Réponses des inventeurs :
- l'association charbon + bordure de pierres exclue l'hypothèse d'un transport éolien des particules charbonneuses, comme celui des pierres par l'eau.
- les analyses TL ont révélé, sur les pierres analysées, des températures incompatibles avec l'hypothèse d'incendies naturels (où température au sol < 2501) (85 pierres ont subi un test TL : sur ce total, 50 galets et 3 fragments

de grès, provenant de structures ou foyers, en particulier celui daté de 42 400 ± 2 600 BP, ont été chauffés au moins à 450°). Aucun niveau de charbon diffus n'a été mis en évidence dans d'autres gisements voisins.
- le matériel taillé sur galet est bien d'origine anthropique (caractéristiques techniques récurrentes).
Conclusion : Pedra Furada continue d'être le gisement le plus controversé d'Amérique. La nature anthropique de l'industrie sur galets ne parvient toujours pas à faire l'unanimité (*cf.* la réunion sur place en 1993 et les conclusions de J. Pelegrin, qui n'exclue pas l'hypothèse de geofacts). On ne connaît aucun autre exemple de matériel identique dans d'autre sites (sauf toujours au Piaui).
Pedra Furada est sans doute le meilleur exemple de gisement où les datations par elles-mêmes ne sont pas contestées mais l'origine anthropique des échantillons datés l'est.
Si la réalité de son occupation pléistocène parvient à être établie, tout le schéma actuel du peuplement américain devra être révisé, les inventeurs proposant l'arrivée d'une première vague de peuplement dès le stage isotopique 4 (65 000 BP) ou 6 (> 160 000 BP).

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Fiche 8 : MONTE VERDE

Site : sur la rive droite du rio Chinchihuapi, petit affluent de la rivière Maulhn, à 55 km au sud-ouest de Puerto Montt (province de Llanquihué, Chili). 41°30' Lat S. et 73°13' Long. O. Restes d'un campement de plein air recouvert et protégé par une tourbière. Environnement de forêt humide et froide.
Découverte et étude : découvert en 1977 par T. Dillehay et son équipe d'étudiants. Fouillé de 1978 à 1985.
Statigraphie, vestiges et datations :
- MV-1 à 3 : non datés
- MV-4 : sédiments récents (stériles) : 8 207 ± 130 BP (Tx-4436) (bois)
- MV-5 : tourbière (stérile), sommet : 11 155 ± 130 BP (Tx-3207) (bois et charbon)
12 115 ± 470 BP (Tx-3210) (bois)
fond : 11 950 ± 120 BP (Tx-3472) (bois)
13 965 ± 250 BP (Tx-3208) (charbon)
- MV-6 : graviers et sables fluviatiles, contenant les dépots anthropiques «Monte Verde II». Restes de 13 «constructions» à armature de branches et couverture de peau de mastodonte, foyers à cuvette creusée tapissée d'argile, vestiges végétaux, restes osseux (entre autres, 7 ou 8 mastodontes *Cuvieronius* sp. dont les os portent des traces de découpe), outillage lithique assez fruste (plus de 700 pièces, dont des sphéroïdes, boleadoras, choppers) et deux pointes bifaciales lancéolées proches du type «El Jobo», meules, outils de bois (manches, épieux, mortiers), enfin une empreinte de pied d'enfant près d'un foyer.
- datations MV-6 (Monte Verde II) : 11 990 ± 250 BP (TX-3760) (os)
12 000 ± 250 BP (OxA-105) (SMA, sur collagène d'une gouge en ivoire de mastodonte)
11 990 + 250 BP)(Tx-3760) (os)
12 400 ± 150 BP (OxA-381) (bois, AMS)
12 650 ± 130 BP (TX-4437) (bois)
- MV-7 : sables grossiers et roches, sommet : 12 650 ± 130 BP (Tx-4437) (bois)
fond : 33 370 ± 530 BP (Monte Verde 1)
- MV-8 : stérile, non daté.
Problèmes : malgré les évidences archéologiques indiscutables et la fiabilité des datations ^{14}C, réalisées sur des échantillons exempts de toute contamination (*cf.* Dillehay, éd. ; 1989 : 133 sq.), ce gisement était, jusqu'à très récemment, rejeté par les conservateurs uniquement parce qu'antérieur (de seulement environ un millénaire) à l'occupation «Clovis» des grandes plaines des USA, conventionnellement considérée comme la plus ancienne occupation humaine «connue» (i.e. acceptée par eux) d'Amérique (environ 11 200 BP). Les critiques formulées par T. Lynch (1990), qui n'avait pas vu le site, portaient essentiellement sur le fait que «peut-être, les artefacts n'étaient pas véritablement associés aux matériaux datés», alors que la stratigraphie ne montre aucun indice de perturbation et que, par ailleurs, sept des dates obtenues (entre 12 000 et 13 500 BP) l'ont été à partir d'artefacts indubitables récoltés dans le niveau scellé par la tourbière, laquelle contenait d'ailleurs des taxons disparus (d'après diverses datations réalisées dans d'autres sites) vers 12 000 BP.
Conclusion : le problème était dans les têtes et semble maintenant résolu. Mais il reste le meilleur exemple du «blocage» d'une certaine école nord-américaine. Début 1997, un groupe de 9 archéologues nord-américains financés, entre autres, par la National Geographic Society et le Musée d'Histoire Naturelle de Denver, et qui comptait quelques-uns des plus obstinés conservateurs - Alex Barker, Dennis Stanford, Dena Dincauze, Vance Haynes - s'est rendu sur place, et à l'évidence. (autres participants -. James Adovasio, David Meltzer, Donald Grayson, Robson Bonnichsen, Francisco Mena, Lautaro Nuñez). Même Bryan Fagan (auteur de «The Great

Journey») se déclare maintenant convaincu. L'implication majeure de cette reconnaissance est que une date en tout cas antérieure à 20 000 ans est maintenant considérée comme plausible pour l'entrée de l'homme en Amérique. Concernant le niveau «Monte Verde 1», le doute demeure bien que, selon D. Stanford, les vestiges aient été considérés d'un oeil favorable par les 9 observateurs !

Logiquement l'acceptation de Monte Verde et la disparition de la «barrière pré-Clovis» devrait amener l'ensemble de l'école «conservatrice» à reconsidérer son attitude vis-à-vis de gisements tels que Meadowcroft et Taima-Taima, ainsi que Tlapacoya.

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Voir aussi *Mammoth Trumpet*, New York Times (février 1997).

Cet ouvrage publie 72 communications, conférences et rapports de groupes de travail, présentées lors du 3ème Congrès International "Radiocarbone et Archéologie", tenu à Lyon du 6 au 10 avril 1998.

Ces textes se regroupent suivant cinq thèmes couvrant les principaux aspects de l'application du radiocarbone à l'archéologie depuis le Paléolithique supérieur jusqu'au Moyen-Age :

- les matériaux de datation
- la "calibration", c'est-à-dire l'ajustement des dates ^{14}C au calendrier en années av. ou ap. J.-C.,
- l'apport du radiocarbone à la résolution de questions importantes en archéologie, comme la néolithisation, l'apparition de de l'Homme moderne ou de la métallurgie,
- les synthèses de l'ensemble des datations ^{14}C disponibles pour diverses parties du monde (Europe, Asie, Amérique du sud, Afrique),
- la chronologie précise de certaines phases culturelles néolithiques ou médiévales.

En chacun de ces domaines des contributions des laboratoires de radiocarbone de toutes les régions du monde font état des dernières données acquises tant en méthodologie que par l'accumulation d'un grand nombre de résultats.

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