DU BIG DRY À L'HOLOCÈNE
EN AFRIQUE DE L'EST ET AU-DELÀ

FROM THE BIG DRY TO THE HOLOCENE
IN EASTERN AFRICA AND BEYOND

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ACTES DE LA SÉANCE DE LA SOCIÉTÉ PRÉHISTORIQUE FRANÇAISE

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Textes publiés sous la direction
de Joséphine Lesur, Jessie Cauliez, Lamya Khalidi,
Laurent Bruxelles, Isabelle Crevecoeur, David Pleurdeau,
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Avant-propos

J. Lesur, J. Cauliez, L. Khalidi, L. Bruxelles,
I. Crevecoeur, D. Pleurdeau, C. Tribolo et F. Bon

La présente publication réunit un ensemble de contributions issues de la séance d'automne de la Société préhistorique française, qui s'est tenue à Toulouse au mois de septembre 2019 et qui avait pour intitulé *Dynamiques culturelles et transformation des paysages dans un continent en mutation : du Big Dry à l'Holocène dans l'Est africain.*

En Afrique de l'Est, que l'on s'interroge sur les mécanismes qui sous-tendent les changements technologiques, culturels, sociaux ou économiques des sociétés humaines et des populations qui les composent, ou bien au contraire que l'on constate leur persistance, les conditions environnementales sont souvent mises en avant. Dans le contexte de la Préhistoire récente, on assigne par exemple à l'écologie et au climat un rôle majeur dans le maintien des économies de prédation ou, à l'inverse, dans l'émergence de la domestication animale et végétale et donc l'adoption de nouveaux modes d'alimentation par les sociétés humaines.

Pour mieux comprendre le rôle de l'écologie et du climat dans les trajectoires socioculturelles humaines, nous avons porté notre attention sur les dynamiques culturelles des sociétés et leur relation avec les transformations environnementales et paysagères entre les vallées du Nil et du Rift est-africain, depuis la fin du Pléistocène à l'Holocène récent, en commençant par une phase froide et aride dénommée « Big Dry », ou Dernier Maximum glaciaire (LGM). Cette période, qui s'est déroulée entre environ 29 ka et 19 ka, a entraîné l'extension des zones désertiques, l'abaissement du niveau des mers et des lacs et la réduction du couvert végétal. La vallée du Rift livre peu de sites pour cette période, ce qui suggère des refuges de population dans des écozones plus idéales, comme cela semble être le cas dans la vallée du Nil, ou bien l'effacement des traces à la suite de phénomènes d'érosion contemporains ou postérieurs à cet épisode climatique. Des conditions plus humides s'installent partout pendant la période humide africaine (~ 15 ka-5 ka), accompagnées d'une augmentation de sites de chasseurs-cueilleurs, mais l'on constate là encore des contrastes assez forts dans les enregistrements que fournissent ces deux contextes géographiques. Entre le neuvième et le premier millénaire BP, les premières transitions vers la production alimentaire et la domestication animale commencent à se produire dans ces mêmes vallées, mais selon là encore des rythmes et des enregistrements très différents.

En raison de la mosaïque des écosystèmes disponibles, des géographies et des topographies diverses dans ces régions – des montagnes de haute altitude et leurs forêts arbustives aux plaines désertiques ou encore aux milieux lacustres et marins –, les sociétés ont adopté des stratégies d'adaptabilité polymorphes. Ces transitions se sont produites avec des décalages chronologiques importants selon les régions. De même, de nettes divergences dans les innovations techniques sont observées, mettant en évidence des trajectoires différentes de sociétés qui ont pu être connectées à certaines époques et isolées à d'autres, et dont la subsistance et la mobilité ont été partiellement adaptées à l'évolution des paysages – paysages affectés eux-mêmes par des changements hydro-climatiques d'amplitudes contrastées. Avec le passage progressif à des économies alimentaires plus diversifiées, s'ajoute encore la question de l'accumulation et du stockage des denrées alimentaires, partiellement facilités par les conditions environnementales et les ressources. On peut ainsi voir se mettre en place des pratiques secondaires de l'élevage chez des sociétés semi-sédentaires tournées vers la pêche et dans des sociétés chasseurs-cueilleurs avec différents degrés de mobilité.

Les nouvelles données archéologiques et environnementales des vallées du Rift est-africain et du Nil et au-delà, qui sont rassemblées dans cette session, démontrent, sur fond de biodiversité environnementale, la pluralité des stratégies de subsistance économique et des dynamiques de peuplement qui se produisent de manière arythmique à travers le continent au cours de cette période. À travers les contributions réunies ici, nous assistons au changement sociétal et à la transformation du paysage à travers différents prismes, ceux du climat et de l'environnement comme ceux de l'économie, de la démographie, des traditions techniques et des expressions culturelles humaines. Ce numéro offre une exploration des multiples expressions de ces modifications ainsi qu'une fenêtre sur les changements des anthroposystèmes dynamiques à travers le continent africain.

La première partie de ce volume est consacrée aux dynamiques culturelles et à la transformation paysagère du Big Dry à travers des travaux conduits actuellement dans les vallées du Nil et du Rift est-africain. La seconde porte sur la présentation de grandes synthèses régionales permettant d'élargir la thématique à l'échelle du continent africain.

L'ensemble de la publication est un hommage à notre collègue le professeur X. Gutherz, pour ses contributions majeures à l'archéologie et à la préhistoire de la Corne de l'Afrique.

Nous tenons à remercier la Société préhistorique française pour l'édition et la publication de ce volume. Tous nos remerciements vont également à l'université de Toulouse Jean-Jaurès qui a accueilli cette manifestation, aux UMR 5199 (PACEA), 5608 (TRACES), 6034 (Archéosciences Bordeaux), 7194 (HNHP), 7209 (AASPE), 7264 (CEPAM) ainsi qu'à l'Agence nationale de la recherche (ANR-14-CE31), au projet UCA JEDI (ANR-15-IDEX-0), au LabEx LaScArBx-AAP5-2015 (université de Bordeaux), à la commission des fouilles du ministère de l'Europe et des Affaires étrangères (MEAE), au label Site d'étude en écologie globale (SEEG) de l'INEE CNRS, à l'ambassade de France auprès de la république de Djibouti, à l'Institut des déserts et des steppes, au ministère de l'Enseignement supérieur et de la Recherche djiboutien et à l'Institut de recherches archéologiques et historiques (IRAH) de Djibouti, au Centre français des études éthiopiennes (CFEE), à l'Ethiopian Authority for Research and Conservation of Cultural Heritage (ARCCH), à l'Afar Bureau for Tourism and Culture et à l'IRP ABASC (CNRS-INEE) pour leur soutien financier dans la réalisation de ce volume et dans la conduite des projets archéologiques dans la vallée du Nil et la Corne de l'Afrique dont plusieurs des résultats sont présentés ici.

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Foreword

J. Lesur, J. Cauliez, L. Khalidi, L. Bruxelles,
I. Crevecoeur, D. Pleurdeau, C. Tribolo et F. Bon

This publication brings together a number of contributions from the autumn session of the Société Préhistorique Française conference entitled Cultural dynamics and landscape transformation in a rapidly changing continent: from the Big Dry to the Holocene in Eastern Africa*, that took place in Toulouse in September 2019.*

In Eastern Africa, environmental conditions are often put forward to explain the mechanisms underlying technological, cultural, social or economic changes in human societies and the populations that make them up, or, on the contrary, their persistence. In the context of recent prehistory, ecology and climate are believed to have played a major role in enduring predation-based economies for example, or, conversely, in the emergence of animal and plant domestication and thus the adoption of new foodways by human societies.

To better understand the role of ecology and climate in human socio-cultural trajectories, we focused our attention on the cultural dynamics of societies and their relation to environmental and landscape transformations in the Nile and the East African Rift valleys, from the end of the Pleistocene to the Late Holocene, starting with a major cold and arid period known as the 'Big Dry' or Last Glacial Maximum (LGM). This period occurred between ~ 29 ka and 19 ka and led to the extension of desertic zones, the lowering of sea and lake levels and the reduction of vegetation cover. The Rift valley has yielded few sites for this period, suggesting population refugia into more ideal ecozones, as seems to have been the case in the Nile valley, or the erasure of archaeological evidence as a result of erosive phenomena that occurred contemporary with or subsequent to this climatic episode. Milder and wetter conditions were established everywhere during the African Humid Period (~ 15 ka-5 ka), accompanied by an increase in hunter-gatherer sites, but here again, we find strong contrasts in the records provided by these two geographic contexts. Between the ninth and first millennia BP, the first transitions towards food production and animal domestication began to occur in these same valleys, once again at very different rhythms and in very different ways.

Due to the mosaic of available ecosystems and the diverse geographies and topographies of these regions, from high altitude mountains and scrub forest, to desertic plains and lacustrine and marine environments, societies adopted polymorphic adaptability strategies. These transitions occurred at considerably different periods of time, depending on the region. Similarly, clear divergences in technical innovations are observed, highlighting the different trajectories of societies that may have been connected at certain times and isolated at others and whose subsistence and mobility was partially adapted to changing landscapes affected by hydroclimatic shifts of contrasting amplitude. With the gradual transition to more diversified food production economies, the accumulation and storage of foodstuffs, partially influenced by environmental conditions and resources, becomes a central question. We observe the emergence of secondary husbandry practices in semi-sedentary societies relying on fishing, as well as in hunter-gatherer societies with different degrees of mobility.

New archaeological and environmental data from the East African Rift and Nile valley regions and beyond, which are brought together in this session, demonstrate the plurality of economic subsistence strategies and settlement dynamics that occured arhythmically across the continent during this period, against a backdrop of environmental biodiversity. Through the many contributions presented here, we witness societal change and landscape transformation through different prisms, including those of climate and environment, but also those of economy, demography, technical traditions and human cultural expressions. This issue provides a rare exploration of the multiple expressions of these transformations as well as a window into the changes in dynamic anthroposystems across the African continent.

The first part of this volume focuses on cultural dynamics and landscape transformation from the Big Dry to the Holocene by treating archaeological work currently carried out in the Nile Valley and the East African Rift. The second part focuses on the presentation of regional syntheses to enlarge the theme to the scale of the African continent.

The entire publication is a tribute to our colleague, Professor X. Gutherz for his major contributions to the archaeology and prehistory of the Horn of Africa.

We would like to thank the Société Préhistorique française for editing and publishing this volume and the Université de Toulouse Jean Jaurès for hosting the conference which led to this publication. We also thank a number of institutions and agencies for having funded this volume and supported the archaeological programs in the Nile Valley and the Horn of Africa whose results are presented here, including: UMR 5199 (PACEA), 5608 (TRACES), 6034 (Archéosciences Bordeaux), 7194 (HNHP), 7209 (AASPE), 7264 (CEPAM), l'Agence Nationale de la Recherche (ANR-14-CE31) and the UCA JEDI (ANR-15-IDEX-0) Project, the LabEx LaScArBx-AAP5-2015 (Université de Bordeaux), the Ministère de l'Europe et des Affaires Étrangères (MEAE), the Site d'Étude en Écologie Globale (SEEG) of the INEE CNRS, the French Embassy in the Republic of Djibouti, the Institut des Déserts et des Steppes, the Ministère de l'Enseignement Supérieur et de la Recherche djiboutien, the Institut de Recherches Archéologiques et Historiques (IRAH) of Djibouti, the Centre Français des Études Éthiopiennes (CFEE), the Ethiopian Authority for Research and Conservation of Cultural Heritage (ARCCH), the Afar Bureau for Tourism and Heritage, and the IRP ABASC (CNRS-INEE).

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Human Evolution and Population Dynamics in Northeast Africa at the End of the Pleistocene and the Beginning of the Holocene

Évolution humaine et dynamiques de population dans le nord-est africain à la fin de Pléistocène et au début de l'Holocène

Isabelle Crevecoeur, Marie Matu, Marie-Hélène Dias-Meirinho,
Priscilla Bayle, Osbjorn Pearson

Abstract: Although subjected to growing interest, the debates related to *Homo sapiens'* evolution in Africa during the Late Pleistocene and the beginning of the Holocene are currently mainly tied to the success of palaeogenetic studies of Holocene skeletons from sub-Saharan Africa. These genetic results have opened new perspectives pertaining the origin of present-day African diversity and the nature of such diversity in the past, confirming previous assumptions based on the study of African fossils suggesting deep sub-structuration of human populations.
In Northeast Africa, the end of the Late Pleistocene and the beginning of the Holocene were marked by major climatic changes whose effects on human settlements are still poorly understood. Geological evidence support generally dry conditions during the Last Glacial Maximum followed by the so-called African Humid Period which ends abruptly with the second half of the Holocene and the onset of more arid conditions. In parallel with these climatic fluctuations, this transitional period witnessed the emergence of new subsistence strategies with the introduction of pastoralism.
However, the scarcity of human remains in northeast Africa has limited our understanding of modern human diversity and population processes during this transitional period. Through a review of the key human fossils and assemblages associated to the Late Pleistocene and the Early Holocene period in Egypt, Sudan, Ethiopia, Somalia and the Republic of Djibouti, this contribution aims at discussing phenotypic and cultural diversity, addressing hypotheses of population isolation, replacement and/or continuity.
Keywords: Phenotypic diversity, Late Pleistocene, Early Holocene, Nile Valley, Horn of Africa, populations processes, adaptation, environmental changes.

Résumé : Bien que soumis à un intérêt croissant, les débats concernant l'évolution d'*Homo sapiens* en Afrique durant le Pléistocène supérieur et le début de l'Holocène sont actuellement principalement liés au succès des études paléogénétiques sur des squelettes holocènes d'Afrique sub-saharienne. Ces résultats génétiques ont ouvert de nouvelles perspectives concernant l'origine de la diversité africaine actuelle et la nature de cette diversité dans le passé, confirmant les hypothèses antérieures fondées sur l'étude des fossiles africains, suggérant une sous-structuration profonde des populations humaines sur ce continent depuis le Pléistocène moyen.
En Afrique du nord-est, la fin du Pléistocène supérieur et le début de l'Holocène ont été marqués par des changements climatiques majeurs dont les effets sur populations humaines sont encore mal connus. Les données géologiques indiquent des conditions environnementales plutôt arides pendant le dernier maximum glaciaire, suivies à partir de 15000 ans de la période humide africaine qui se termine abruptement avec la seconde moitié de l'Holocène et le retour de conditions plus arides. Parallèlement à ces fluctuations climatiques, cette période de transition a vu l'émergence de nouvelles stratégies de subsistance avec notamment l'introduction du pastoralisme.

Cependant, la rareté des restes humains en Afrique du nord-est a limité notre compréhension de la diversité phénotypique des populations à l'origine de la diversité actuelle, et des processus démographiques qui ont structuré cette diversité durant cette période de transition. À travers un examen des principaux fossiles et échantillons de populations, associés à la fin du Pléistocène supérieur et au début de l'Holocène en Égypte, au Soudan, en Éthiopie, en Somalie et en République de Djibouti, cette contribution vise à discuter de la diversité phénotypique et culturelle de ces derniers groupes de chasseurs-pêcheurs-cueilleurs, en abordant les hypothèses d'isolement, de remplacement et/ou de continuité populationnelle.

Mots-clés : diversité phénotypique, Pléistocène supérieur, Holocène, vallée du Nil, Corne de l'Afrique, dynamique de peuplement, adaptation, changements environnementaux.

1. NORTHEAST AFRICA PHENOTYPIC DIVERSITY DURING THE LATE PLEISTOCENE

The African Late Pleistocene fossil record is extremely sparse for the period that is supposed to have witnessed modern human diversification in Africa and dispersions outside the African continent (Grine, 2016). Archaeological sites with human remains attributed to the first half of the Late Pleistocene (i.e. MIS 5, 130-71 ka; Lisiecki and Raymo, 2005) are essentially located in North Africa (Dar-es-Soltan II and La Grotte des Contrebandiers in Morocco; e.g. Vallois and Roche, 1958; Debénath, 1976 and 2000; Ferembach, 1976 and 1998), East Africa (Ngaloba and Eyasi in Tanzania, Panga ya Saidi in Kenya and Aduma in Ethiopia; Magori and Day, 1983; Mehlman, 1987; Haile-Selassie et al., 2004; Martinón-Torres et al., 2021), and South Africa (Blind River, Blombos and Sea Harvest; e.g. Grine and Kein, 1993; Henshilwood et al., 2001; Grine and Henshilwood, 2002; Wang et al., 2008). Even if we add to the list the sites with a wider chronological range, for which the associated human remains can be dated from at least the marine oxygen-isotope stages (MIS) 5 to 4 (black and full green dots from figure 1; for discussion about their dating see Grine, 2016), the fossil record from the first half of the Late Pleistocene is mostly documented by fragmentary human remains (incomplete cranial remains, isolated teeth or infra-cranial fragments). Comparative morphometric studies of these fossils have delivered partial information about past modern human diversity during this period. The results suggest a high level of phenotypic diversity with the persistence of plesiomorphic features in some specimens (e.g. Rightmire and Deacon, 1991; McCrossin, 1994; Pearson et al., 1998; Royer et al., 2009; Harvati and Hublin, 2012; Hublin et al., 2012), while others are described as fully modern (e.g. De Villiers, 1973; Grine and Klein, 1985; Bräuer and Mehlman, 1988; Bräuer and Singer, 1996). This situation limits our understanding of past modern human phenotypic diversity during this crucial period of modern human African diversification. In addition, no data exists from West and Central Africa, which together characterize the largest part of the African continent.

The situation is even worse for the second half of the Late Pleistocene until the end of the Last Glacial Maximum (i.e. from MIS 4 to MIS 2). Only four sites with human remains are securely associated with MIS 4 (light green dots in figure 1), and seven for MIS 3 (light red dots in figure 1; for discussion about their dating see Grine, 2016). With the exception of the Nazlet Khater 2 and Hofmeyr specimens (light red stars in figure 1), these sites preserved very fragmentary human remains, some still unpublished, that have nonetheless contributed to palaeoanthropological discussions about the phenotypic diversity of past modern humans in Africa at that time (e.g. Grine, 2000; Hublin et al., 2012; Verna et al., 2013, Pleurdeau et al., 2014; Harvati et al., 2015; Willoughby et al., 2018; Reiner et al., 2017). The Nazlet Khater 2 (NK 2) skeleton from Egypt and the Hofmeyr (HOF) cranium from South Africa are the only two reasonably complete and well-dated African specimens from the MIS 4-MIS 3 interval. During MIS 2 and until the peak of the Last Glacial Maximal (~ 20 ka; Clark et al., 2009), five additional sites can be added to the African fossil record (light blue points and stars in figure 1). After 20 ka, the number of sites with human remains gradually increases until the end of MIS 2, although a large portion of the African continent remains undocumented. During the Holocene, the fossil record increases substantially, and homogenization of cranio-morphological features has been documented, particularly within sub-Saharan African populations, with its peak both during and after the Bantu expansion from 6 ka onwards (Ribot, 2011).

The paucity of human remains found in Africa from the last glacial period (MIS 4-MIS 2) is probably multifactorial. Historical factors involving unequal attention paid to specific African regions could have played a role, as well as taphonomic bias (Surovell et al., 2009). Another hypothesis relates to the intense environmental and climatic changes that occurred in Africa during this period, that may have affected human population adaptation and survival in some areas (Carto et al., 2009). From MIS 6 to the LGM, a growing amount of paleoclimatic evidence indicates increasing aridity that correlates with the onset of the northern hemisphere glaciation (e.g. deMenocal et al., 2000; Moreno et al., 2002; Battarbee et al., 2004; Carto et al., 2009). However, the climatic changes in Africa were not synchronous, and interregional differences are recorded in the timing of alternance between humid and arid conditions (Blome et al., 2012). In North Africa, the density of sites appears to be inversely correlated with the expansion of the Sahara, with the exception of the Nile Valley (Blome et al., 2012; Leplongeon et al., 2020; Leplongeon, 2021). Whatever the cause, the sparse fossil record for the Late Pleistocene is clearly a limitation in discussing modern human evolution in Africa.

In northeast Africa, the only site with well-preserved and securely dated human remains during the MIS 3 is Nazlet Khater 2 (Egypt; Vermeersch et al., 1984; Vermeersch, 2002). It is penecontemporaneous from Hofmeyr (South Africa; Grine et al., 2007), the only other site from this time range with dated and substantial human remains. The NK 2 skeleton has been directly dated by ESR on tooth enamel fragments to 38 ± 6 ka (Crevecoeur, 2008), while the Hofmeyr skull has been dated to 36.2 ± 3.3 ka by a combination of optically stimulated luminescence and uranium-series methods (Grine et al., 2007). Both specimens are anatomically modern, but they also display cranial plesiomorphic features that put them on the brink of extant modern human African phenotypic diversity (Grine et al., 2007; Crevecoeur, 2012a). Regarding the infra-cranial remains of Nazlet Khater 2, the main characteristics express adaptation to high biomechanical strength and specialized activities (Crevecoeur, 2008 and 2012a). Together with the mining archaeological context, these results support the hypotheses of well-organised settlements and planned specialized activities in the Nile Valley during the MIS 3 (Van Peer, 1998).

The Hofmeyr specimen exhibits the greatest overall similarities to Upper Palaeolithic specimens from Europe rather than Holocene San populations from South Africa (Grine et al., 2007; Grine et al., 2010). Similarly, the Nazlet Khater 2 individual presents plesiomorphic features on the cranium and the mandible more comparable to those of Late Middle Pleistocene and early Late Pleistocene fossils than to chronologically closer recent African populations (Crevecoeur, 2008 and 2012a). However, their morphometric characteristics do not particularly draw them together. On the contrary, the two specimens appear to reflect different aspects of Late Pleistocene African phenotypic variation (Crevecoeur et al., 2009). While we can observe a community of robustness related to temporal trends compared to Holocene populations, they exhibit different morphological conformation, as illustrated by the following examples of craniofacial and inner ear morphology comparisons (fig. 2 to fig. 4). The face of NK 2 is particularly robust, with notable height and width dimensions. The projection of the two first principal components of the PCA performed on seven cranio-facial dimensions (fig. 3; for details of the analysis see Crevecoeur, 2012a) shows that the position of NK 2 is closer to Middle Pleistocene hominin and early *Homo sapiens* specimens than chronologically closer specimens. Hofmeyr occupies a transitional position between the earlier specimens and the extant population, lying closer to European Upper Palaeolithic specimens, and North African fossil samples from the end of the Late Pleistocene (LPNEA and LPNWA, < 20-11 ka). This dispersion along the first axis illustrates a temporal trend of a reduction in facial dimensions over time. The result is consistent with studies on the evolution of human craniofacial morphological variation (e.g. Enlow, 1990; Freidline et al., 2012; von Cramon-Taubadel, 2014; Bastir and Rosas, 2016). In

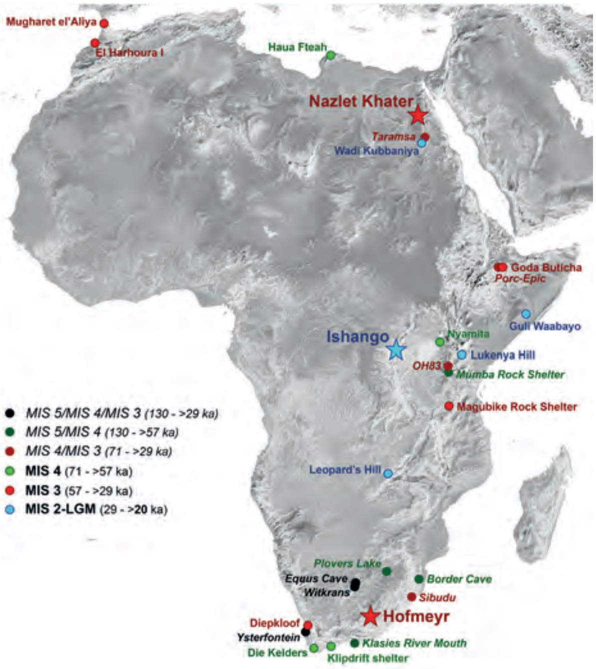

Fig. 1 – African map with the location of human remains dated from the Marine Isotopic Stage 4 (MIS 4) to the Last Glacial Maximum (LGM) peak. The stars identify sites that are detailed in the text.

Fig. 1 – *Carte de l'Afrique avec l'emplacement des restes humains datés depuis le stade isotopique marin 4 (MIS 4) au Dernier Maximum glaciaire (DMG). Les étoiles signalent les sites qui sont décrits dans le texte.*

this regard, the position of Nazlet Khater 2 is somewhat anachronic.

Comparison of the inner ear structures of Pleistocene *Homo* have allowed the reconstruction of the phenetic and phylogenetic relationships between hominin specimens (e.g. Spoor et al., 1994 and 2003; Braga et al., 2013; Wu et al., 2014). While earlier studies have mainly focused on archaic specimens, several studies have since highlighted phenotypic variations on small regional and temporal scales, emphasizing the importance of this structure to discuss genetic distances and population affiliation in *Homo sapiens* (Spoor et al., 2003; Bouchneb and Crevecoeur, 2009; Crevecoeur et al., 2016; Ponce de León et al., 2018). Analysis of the Nazlet Khater 2 inner ear showed that it exhibits a set of labyrinthine characteristics that put it closer to European Upper Paleolithic specimens than to recent modern human populations, notably regarding the width of the anterior semicircular canal (Bouchneb and Crevecoeur, 2009; Crevecoeur et al., 2012a). On the other hand, the more recent MIS 2 specimen from Ishango 37 (ISH 37; fig. 1) showed greater affinity with the bony labyrinth morphology of the Qafzeh and Skhul (Q-S) samples (Crevecoeur et al., 2016). The characteristic that set ISH 37, apart from the recent and chronologically closer modern human samples, is the position of the cochlea together with its morphology. In addition to being more coronally oriented in the transversal plane, Ishango 37 possesses a larger cochlea basal turn (Creve-

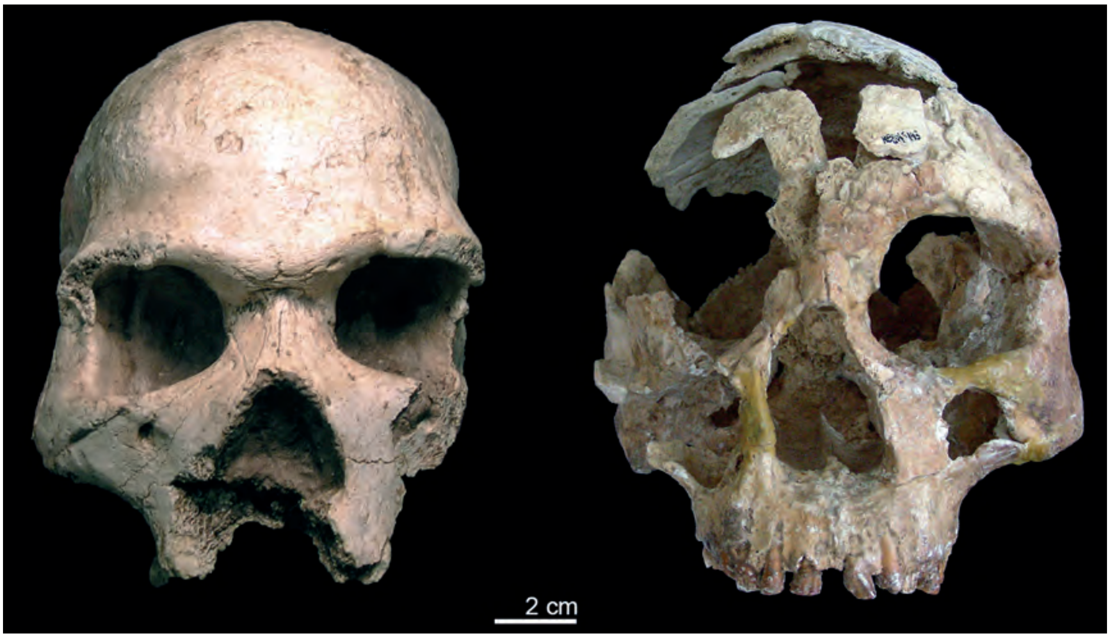

Fig. 2 – Composite picture of Hofmeyr (left) and Nazlet Khater 2 (right) cranium in frontal view.
Fig. 2 – *Image composite des crânes d'Hofmeyr (à gauche) et de Nazlet Khater 2 (à droite), en vue frontale.*

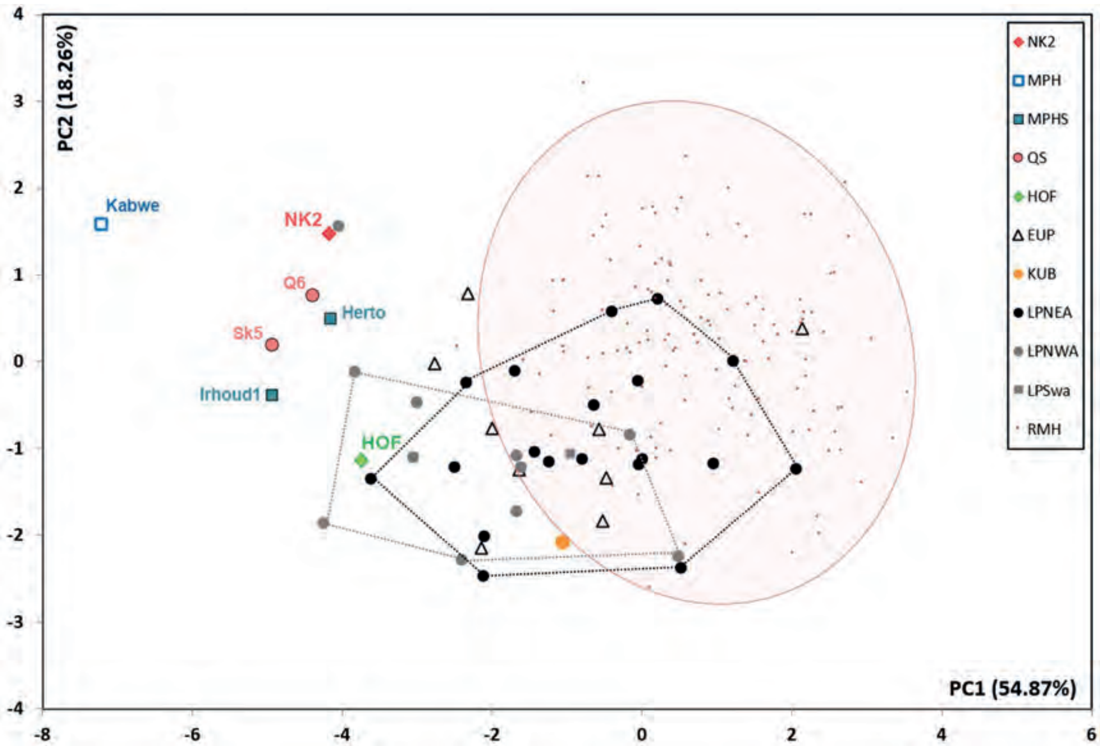

Fig. 3 – Bivariate plot of the projection of the first and second principal component of the PCA on seven cranio-facial dimensions. NK2 = Nazlet Khater 2, MPH = Middle Pleistocene Hominin, MPHS = Middle Pleistocene early *Homo sapiens*, QS = Qafzeh and Skhul, HOF = Hofmeyr, EUP = European Upper Palaeolithic fossils, KUB = Wadi Kubbaniya, LPNEA = Late Pleistocene specimens from north-east Africa (i.e. Jebel Sahaba and Wadi Halfa), LPNWA = Late Pleistocene specimens from north-west Africa (i.e. Taforalt and Afalou), LPSwa = Late Pleistocene from south-west Asia (i.e. Natufian; see Bocquentin, 2003), RMH = Recent modern human (here Egyptian population; see Howells, 1996). The ellipse represents 95% of the RMH variation.
Fig. 3 – *Diagramme bivarié de la projection de la première et de la deuxième composante principale de l'ACP sur sept dimensions cranio-faciales. NK2 = Nazlet Khater 2, MPH = hominines du Pléistocène moyen, MPHS = premiers* Homo sapiens *du Pléistocène moyen, QS = Qafzeh and Skhul, HOF = Hofmeyr, EUP = fossiles* Homo sapiens *du Paléolithique supérieur européen, KUB = Wadi Kubbaniya, LPNEA = spécimens de la fin du Pléistocène supérieur du nord-est de l'Afrique (à savoir Jebel Sahaba et Wadi Halfa), LPNWA = spécimens de la fin du Pléistocène supérieur du nord-ouest de l'Afrique (à savoir Taforalt et Afalou), LPSwa = spécimens de la fin du Pléistocène supérieur d'Asie du sud-ouest (à savoir les Natoufiens ; voir Bocquentin, 2003), RMH =* Homo sapiens *récents (ici population égyptienne ; voir Howells, 1996). L'ellipse représente 95 % de la variation du group RMH.*

coeur et al., 2016). F. Spoor et al. (2003) highlighted this characteristic in a smaller comparative sample consisting of Qafzeh and Skhul specimens. Similar morphologies have been observed in the Hofmeyr specimens (Crevecoeur et al., 2022). An enlarged anterior semi-circular canal, like Nazlet Khater 2, and a wide cochlea that is positioned more inferiorly with respect to the level of the lateral semi-circular canal, like Ishango 37, characterize the Hofmeyr inner ear. As illustrated by their position in the lower left quadrant of the first two principal component projections in figure 4, these inner ear characteristics, shared by the EUP and Q-S specimens, also influenced the position of the early Holocene fossil from Shum Laka (SE II) which exhibits a genetic signal of deep ancestry (A00 Y-chromosome lineage; Lipson et al., 2020). Located close to Qafzeh 11, this member of the Early Holocene African (EHA) comparative sample is separated from the other individual from Shum Laka (SE I), whose Y-chromosome haplogroup (B) is common among recent hunter-gatherers from Central Africa. Interestingly, the similarities of Hofmeyr to Nalet Khater or Ishango differ in relation to the part of the bony labyrinth investigated, namely the semi-circular canals or the cochlea. The independent physiological roles of each component of the inner ear likely imply that they could have evolved separately as noted within the Neanderthal clade (Quam et al., 2016; Conde-Valverde et al., 2019). The affinities of Hofmeyr with EUP and Q-S regarding the size and proportions of the semi-circular canals, and its similarity with Ishango based on its large cochlea could be interpreted as reflecting different paths within Late Pleistocene modern human evolution (Crevecoeur et al., 2022). Given that the strong phylogenetic signal of cochlear dimensions may be confidently used to assess biological affinities between human populations (Braga et al., 2015; Conde-Valverde et al., 2019), we believe that these results help to support the hypotheses of a certain level of phylogenetic discontinuity between Late Pleistocene and present-day populations, even those that are geographically proximate, within the African continent.

Despite the fragmentary nature of the Late Pleistocene fossils, these results echo the paleogenetic hypotheses

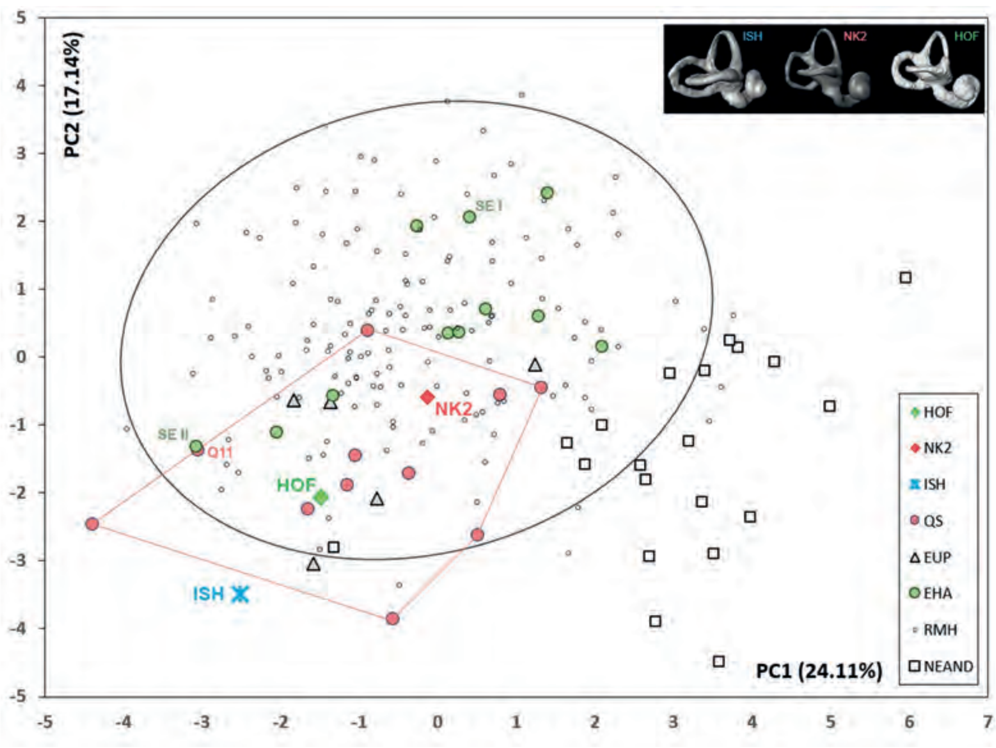

Fig. 4 – Bivariate plot of the projection of the first and second principal component of the PCA on fourteen variables that account for the general size and shape of the bony labyrinth. Composite image of the virtual reconstruction of Ishango, Nazlet Khater 2 and Hofmeyr bony labyrinth structure. HOF = Hofmeyr, NK2 = Nazlet Khater 2, ISH = Ishango 37, QS = Qafzeh and Skhul, EUP = European Upper Palaeolithic fossils, EHA = Early to mid-Holocene specimens from north-east and central Africa (Shum Laka, Lothagam, Gogoshiis Qabe, Hara Idé 2), RMH = Recent modern human, NEAND = Neandertal specimens (see Crevecoeur et al., 2022). The black ellipse represents 95% of the RMH variation. The pink line delimits the Q-S convex hull.

***Fig. 4** – Diagramme bivarié de la projection de la première et de la deuxième composante principale de l'ACP sur quatorze variables rendant compte de la taille et de la forme du labyrinthe osseux. Image composite de la reconstruction virtuelle de la structure du labyrinthe osseux des fossiles d'Ishango, de Nazlet Khater 2 et d'Hofmeyr. HOF = Hofmeyr, NK2 = Nazlet Khater 2, ISH = Ishango 37, QS = Qafzeh et Skhul, EUP = fossiles* Homo sapiens *du Paléolithique supérieur européen, EHA = spécimens du début de l'Holocène d'Afrique du nord-est et d'Afrique centrale (à savoir Shum Laka, Lothagam, Gogoshiis Qabe, Hara Idé 2), RMH =* Homo sapiens *récents, NEAND = Néandertaliens (voir Crevecoeur* et al.*, 2022). L'ellipse noire représente 95 % de la variation du groupe RMH. La ligne rose délimite le polygone convexe contenant les individus de Q-S.*

about deeply divergent, geographically separated populations in Africa during the Late Pleistocene (e.g. Quintana-Murci et al., 2008; Scheinfeldt et al., 2010; Schlebusch et al., 2017; Skoglund et al., 2017; Schlebush and Jakobsson, 2018; Lipson et al., 2020). The fossils under study are distinct from both extant African populations and many Holocene specimens. They exhibit diverse biological affinities with earlier Middle to Late Pleistocene fossils and European Upper Paleolithic *Homo sapiens* that appear related to plesiomorphic morphologies or part of the phenotypic diversity that is no longer documented in more recent populations. Similar observations made for some individuals from the terminal part of the Pleistocene (Crevecoeur et al., 2009; Harvati et al., 2011; Tryon et al., 2015) suggest that deep population substructures in Africa lasted at least until the mid-Holocene period and that some populations might not have contributed to present day diversity. In this regard, the metapopulation model of African population history is currently the best-fitting theory to reconcile palaeoanthropological and ancient and recent genetic data (Scerri et al., 2019).

It is of course possible that some of the observations made about Nazlet Khater 2, or others Late Pleistocene fossils could be interpreted as indicating signs of admixture with a "ghost archaic" population as some studies have suggested (e.g. Harvati et al., 2011; Durvasula and Sankararaman, 2020). However, given our poor understanding of African Late Pleistocene phenotypic and genetic diversity, as well as the recent work of M. Lipson et al. (2020) which also suggested the presence of a "ghost modern" population input in present day variation, we favor a conservative approach regarding these assertions. The identification of admixed phenotypes is currently limited by the absence of fossils from this "ghost archaic" population and will only be possible once African modern human past phenotypic diversity is properly encompassed.

2. NILE VALLEY POPULATION PROCESSES AT THE END OF THE PLEISTOCENE AND THE BEGINNING OF THE HOLOCENE

As described above, geological evidence points to generally dry conditions in Africa during the Last Glacial Maximum (LGM, ~ 23-18 ka; Gasse, 2000). The LGM was then followed by the African Humid Period (~ 15-5.5 ka) which ended abruptly with the second half of the Holocene and the onset of more arid conditions (DeMenocal et al., 2000). In the Nile Valley, climatic conditions are depicted as hyper-arid during the second half of the Late Pleistocene (Paulissen and Vermeersch, 1987). During the MIS 2 (27.8-14.7 ka; Sanchez Goñi et al., 2010), the Nile Valley probably functioned as a refuge for human populations. This is attested by the high density of archaeological contexts in Upper Egypt and Lower Nubia dated to the aridity peaks of the LGM and the second part of the Heinrich Stadial 1 (HS1b; 16-14.5 ka; Hoelzmann et al., 2004; Vermeersch and Van Neer, 2015; Castañeda et al., 2016; Vermeersch, 2020; Leplongeon, 2021). The Blue Nile and the White Nile were then highly seasonal rivers and the Sudd swamps had yet to develop (Williams et al., 2000, Hoelzmann et al., 2004). Around 15-14 ka, the present Nile-flow regime was re-established by the sudden overflow of lake Victoria in the White Nile, which caused severe flooding in the Nile Valley as far as Egypt (Williams et al., 2006). This period of hydrological instability was interrupted by a short-term return of drier and colder climatic condition that coincides with the Younger Dryas interval (YD; ~ 12.9-11.7 ka; Rasmussen et al., 2006). It was only after the Younger Dryas (~ 12.9-11.7 ka) that the monsoon conditions of the African Humid Period became more stable for human presence in the Nile Valley, as evidenced by the scarcity of traces of human occupation at the end of the Late Pleistocene and the beginning of the Holocene (~ 15-10.5 ka). Archaeological sites from this period are restricted to the floodplain in Upper Egypt and Lower Nubia (Nicoll, 2004; Kuper and Kröpelin, 2006; Schild and Wendorf, 2010; Vermeersch and Van Neer, 2015, Vermeersch, 2020; Leplongeon, 2021), and only a few sites have yielded complete human remains. Among these, the most emblematic are Jebel Sahaba (JS, site 117), Tushka (site 8905), Wadi Kubbaniya, and Wadi Halfa (WH, site 6B36; fig. 5; Hewes et al., 1964; Wendorf, 1968; Wendorf and Schild, 1986).

Culturally, a large variety of lithic assemblages, linked to Late Paleolithic, or Late Stone Age, industries based on the production of flakes and elongated products of small dimensions, including high proportions of backed tools (Schild and Wendorf, 2010; Leplongeon, 2021), has been identified in sites associated with the end of the Late Pleistocene (e.g. the Fakhurian, the Kubbaniyan, the Idfuan, the Ballanan-Silsilian, the Afian, the Isnan and the Qadan; Wendorf, 1968; Lubell, 1974; Wendorf et al., 1989; Schild and Wendorf, 2010; Vermeersch, 2010). The great variability of typological characteristics of these lithic assemblages has led to the recognition of different industries that seem to be regionally and chronologically constrained, with some industries occurring only in Lower Nubia or in Upper Egypt (Leplongeon, 2021). Archaeozoological analysis of these Late Pleistocene settlements indicate similar human subsistence strategies based on the exploitation of the Nilotic environment (Schild and Wendorf, 2010). Seasonally adapted fishing activities, shellfish consumption, medium and large ungulate hunting and plant tuber processing are documented at various locations (Van Neer et al., 2000; Linseele and Van Neer, 2010; Yeshurun, 2018). In this framework of limited subsistence strategy options and constrained geographical habitable environment, the development of a wide range of lithic cultural traditions is interesting. They don't seem to be related to specific activities and are characterized by distinctive sets of lithic tools and/or technology that could be associated with small hunting-fishing-gathering groups (Vermeersch, 2010). It has therefore been suggested that each of these lithic entities could represent

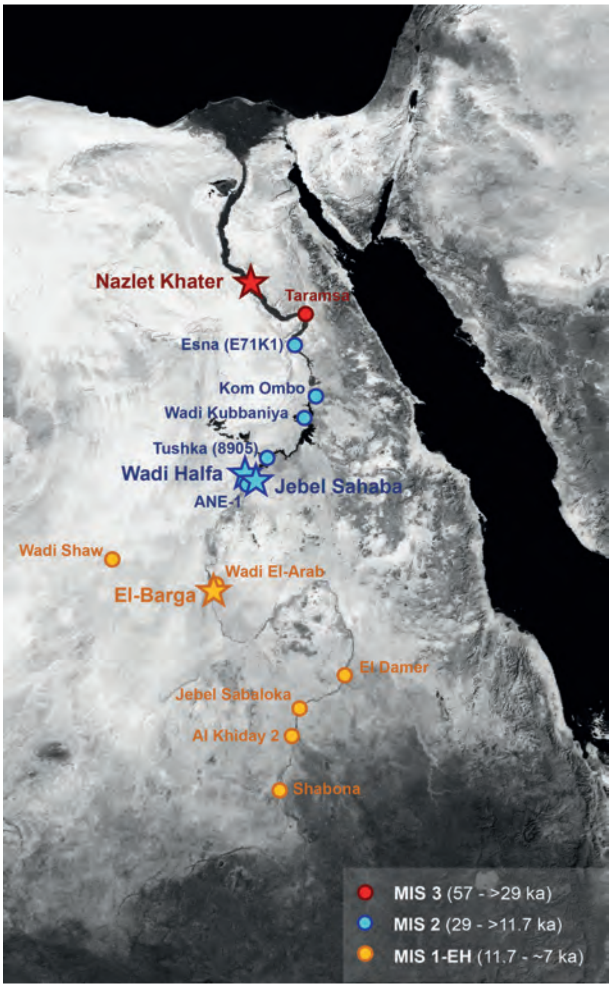

Fig. 5 – Map of the Nile Valley with the location of sites preserving human remains dated from the MIS 3 to the end of the early Holocene period (MIS 1-EH). Stars identify sites that are discussed in the text.

***Fig. 5** – Carte de la vallée du Nil avec la localisation des sites ayant livré des restes humains datés depuis le MIS 3 jusqu'au début de l'Holocène (MIS 1-EH). Les étoiles signalent les sites qui sont discutés dans le texte.*

a cultural tradition reflecting the structuration of human group identity in this restricted habitable area (Schild and Wendorf, 2010). The concomitant occurrence of large graveyards at the end of the Late Pleistocene in this area reinforces the hypothesis of strong social units of residential groups (Wendorf and Schild, 2004).

As mentioned earlier, the more numerous and best preserved human remains from this period come from the graveyard of Jebel Sahaba (site 117, MNI = 61; Wendorf, 1968), the Wadi Halfa cemetery (site 6B36, MNI = 36; Hewes et al., 1964) and the Tushka burial ground (site 8905; MNI = 12; Wendorf 1968). All are associated with the Qadan industry. The Qadan sequence is documented in Upper Egypt and Lower Nubia from the end of the Late Pleistocene (~ 18 ka) until the Holocene (Wendorf, 1968; Schild and Wendorf, 2010). In Jebel Sahaba, direct dating of five individuals based on the collagen and mineral fraction of the bones and teeth give a time range of between 18 ka and 11 ka (Wendorf and Schild, 2004; Zazzo, 2014). The oldest Tuskha human remains are dated between ~ 15-11 ka, based on geological and archaeological data, taphonomic observations and several radiocarbon dating results (Albritton and Wendorf, 1968). Although not directly dated, the Wadi Halfa cemetery is considered to be of equivalent age given its archaeological consistency with Jebel Sahaba and Tushka (Greene and Armelagos, 1972). The partial skeleton from Wadi Kubbaniya, also associated with the Qadan artefacts, represents the last and maybe the oldest well-preserved human remains from MIS 2 in the region. Sedimentological and lithic technological evidence could indicate a date as early as 20 ka for this deposit (Wendorf and Schild, 1986). The other human remains from this period (Kom Ombo, Esna and ANE-1) are fragmentary and/or poorly preserved (Reed, 1965; Wendorf, 1968; Lubell, 1974).

Since the first publications related to their find, the individuals from Wadi Halfa and Jebel Sahaba have been described as part of a highly robust population exhibiting a distinctive assemblage of cranial and dental traits compared to recent modern humans (Greene et al., 1967; Anderson, 1968; Greene and Armelagos, 1972). The dental elements are massive and exhibit high frequencies of complex traits that can be related to mass additive features (Greene et al., 1967; Irish, 2005). The cranial remains are also characterised by plesiomorphic features and robust morphologies in relation to powerful masticatory apparatus. Moreover, the level of similarity between the Wadi Halfa and the Jebel Sahaba individuals supports their association with the same Nubian Late Pleistocene population (Anderson, 1968; Greene and Armelagos, 1972). As J.L. Angel and J.O. Kelley (1986) later argued, given its large face and robust mandible, the Wadi Kubbaniya skeleton would fit perfectly in the center of this Nubian Late Pleistocene variation. This robust phenotype is associated with a high average stature (~ 1 m 67) and structural conformation of the lower limb that suggests an active and mobile lifestyle (Shackelford, 2007; Holliday, 2015). In addition, these populations appear to exhibit a higher phenotypic variation than the more recent Holocene populations (Crevecoeur et al., 2009). The figure 6 illustrates the extreme dental size and the range of variation shown by the Nubian Late Pleistocene sample (LPNAE, here composed of Jebel Sahaba, Wadi Halfa and Tuskha) with regard to the lower second molar crown diameters.

These dental dimensions may be related to the complexity of the crown morphology exhibited by Jebel Sahaba and Wadi Halfa, with a high frequency of six-cusped lower first molars and at least five-cusped lower second molars (Greene et al., 1967; Irish, 2000 and 2005). The number of cusps on the lower molars is one of the most suitable non-metric dental trait for identifying population affinities as it preserves the maximum number of neutral genetic signals (Rathmann and Reyes-Centeno, 2020). Interestingly, Nazlet Khater 2 fits in the center of the LPNAE variation, as do several African specimens attributed to the MIS 5 to MIS 3 period, here referred

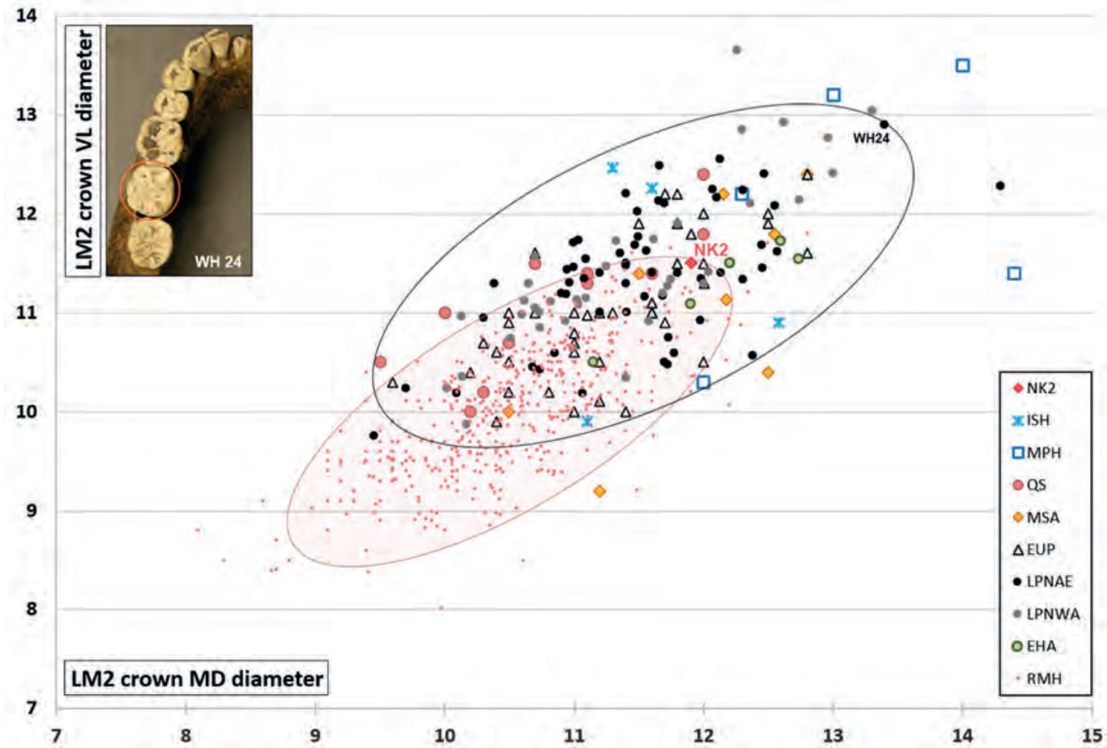

Fig. 6 – Bivariate plot of the lower second molar crown dimensions in centimeters. VL = vestibule-lingual, MD = mesiodistal. NK2 = Nazlet Khater 2, ISH = Ishango, MPH = Middle Pleistocene Hominin, QS = Qafzeh and Skhul, MSA = African specimens attributed to the MIS 5 to MIS 3 period (i.e. Temara, Dar-es-Soltan, Haua Fteah, Klasies River Mouth, Mumba Rock Shelter, Equus Cave and Witkrans), EUP = European Upper Palaeolithic fossils, LPNEA = Late Pleistocene specimens from north-east Africa (i.e Jebel Sahaba and Wadi Halfa), LPNWA = Late Pleistocene specimens from north-west Africa (i.e. Taforalt and Afalou), EHA = Early to mid-Holocene specimens from northeast Africa (Lothagam, Gogoshiis Qabe, Mille Logghia and Lake Besaka 2), RMH = Recent modern human (database, see Kieser, 1990). The ellipses represent 95% of the sample variation.

***Fig. 6** – Diagramme bivarié des dimensions de la couronne de la deuxième molaire inférieure en centimètres. VL = vestibulo-lingual, MD = mésiodistal. NK2 = Nazlet Khater 2, ISH = Ishango, MPH = hominines du Pléistocène moyen, QS = Qafzeh et Skhul, MSA = spécimens africains attribués à la période allant du MIS 5 au MIS 3 (à savoir Temara, Dar-es-Soltan, Haua Fteah, Klasies River Mouth, Mumba Rock Shelter, grotte d'Equus et Witkrans), EUP = fossiles* Homo sapiens *du Paléolithique supérieur européen, LPNEA = spécimens de la fin du Pléistocène supérieur du nord-est de l'Afrique (à savoir Jebel Sahaba et Wadi Halfa), LPNWA = spécimens de la fin du Pléistocène supérieur du nord-ouest de l'Afrique (à savoir, Taforalt et Afalou), EHA = spécimens du début de l'Holocène d'Afrique du nord-est (à savoir Lothagam, Gogoshiis Qabe, Mille Logghia et lac Besaka 2), RMH =* Homo sapiens *récents (base de données, voir Kieser, 1990). Les ellipses représentent 95 % de la variation de l'échantillon.*

to as the MSA sample (i.e. Dar-es-Soltan, Equus Cave, Haua Fteah, Klasies River Mouth, Mumba X, and Witkrans).

In line with what was observed for Nazlet Khater 2, the combination of plesiomorphic and unique morphometric features in the LPNAE sample, that sit on the fringe, or outside, recent phenotypic diversity, could be the consequence of population isolation and division/fragmentation in Middle Nile Valley at a time of extreme climatic conditions (Kuper and Kröpelin, 2006; Crevecoeur, 2008; Vermeersch and Van Neer, 2015; Pagani and Crevecoeur, 2019). In this context of environmental pressure and geographic constraints, the identification of traces of interpersonal violence on the bones of individuals from different LPNAE sites have attracted a great deal of attention and generated debate about Late Pleistocene warfare (Anderson, 1968, Keeley, 1996; Thorpe, 2003; Wendorf and Schild, 2004; Guilaine and Zammit, 2005; Daković, 2014). The oldest case is documented on the partial skeleton from Wadi Kubbaniya where two bladelets were found inside the volume of the body between the rib cage and the lumbar vertebrae. A chip of flint was also found embedded in a partially healed trauma on the left humerus. Finally, this individual also exhibits a healed fracture of the right ulna (Angel and Kelley, 1986; Wendorf and Schild, 1986). Similar observations of embedded lithic and healed fractures have been documented on some individuals buried in the Wadi Halfa cemetery (Hewes et al., 1964; Saxe, 1971; Greene and Armelagos, 1972). However, the most emblematic case is clearly the cemetery of Jebel Sahaba, where anthropological examinations of the skeletons by J. E. Anderson (1968) and B. Butler (1968) revealed the presence of traces of interpersonal violence on the bones of at least half of the Jebel Sahaba individuals. In addition, abundant lithic artefacts were discovered within the body volume or directly embedded in the bones (Wendorf, 1968). On these issues, we can confirm that more than half of the injured Jebel Sahaba individuals undoubtedly exhibit projectile impact marks (61%), and almost all of them showing signs of trauma (92.7%). We also confirmed that these individuals exhibit clear signs of acts of interpersonal violence involving projectile weapons. The injuries are independent of the age-at-death and sexual diagnosis of the individuals. In addition, the concomitant occurrence of healed and unhealed traumas on the same individuals increases through time, with adolescents, young adults and adults exhibiting this association progressively more frequently (Crevecoeur et al., 2021 and this volume). This observation suggests that acts of interpersonal violence were repeated over time. We suggest that adaptation of the subsistence strategies to territorial and environmental stresses triggered by climatic changes at the end of MIS 2 may be responsible for these sporadic, but recurrent, small-scale conflictual events between semi-sedentary hunter-fisher-gatherer groups.

With the stabilization of more humid conditions during the Early Holocene period (~ 10.5-7.3 ka), Prehistoric settlements moved to the eastern Sahara that turned into a savannah-like environment, probably more hospitable than the Nile Valley (Nicoll, 2001 and 2004; Kuper and Kröpelin, 2006; Bubenzer and Riemer, 2007; Manning and Timpson, 2014). No precisely dated archaeological sites are documented in the Egyptian Nile Valley during the Early Holocene, but only periodic traces of human presence related to seasonal activities are suspected (Vermeersch, 2001; Kuper and Kröpelin, 2006; Dittrich, 2015). The only two regions that have yielded clear archaeological records of human occupations near the Nile Valley during this Saharan exodus are central Sudan and Nubia (fig. 5). Evidence includes several archaeological sites related to the Khartoum Mesolithic culture that were excavated near the confluence of the White Nile and Blue Nile in central Sudan (Clark, 1989; Haaland, 1993; Usaï et al., 2010; Salvatori, 2012; Suková and Varadzin, 2012; Williams et al., 2015) and sites near Kerma, like Wadi El-Arab and El-Barga, that document human occupation near the Nile Valley between ~ 10.5-7.3 ka (Honegger, 2006, 2011 and 2012; Honegger and Williams, 2015). The decline in human occupation in the Sahara from 7.3 ka to 5.5 ka relates to the cessation of regular monsoon rains that forced human populations to relocate to new ecological niches and/or to begin the exodus to the Sudanese plains and the Egyptian Nile Valley (Nicoll, 2001 and 2004; Vermeersch, 2001; Kuper and Kröpelin, 2006; Manning and Timpson, 2014).

In parallel with these climatic fluctuations, the beginning of the Holocene witnessed the appearance of new subsistence strategies with the emergence of herding activities. The origin and spread of pastoralism in North Africa is the subject of intense debate about whether it results from one or several independent African domestication centers or is linked to the diffusion and adoption of the practice from other continents (Wendorf and Schild, 1998; Kuper and Riemer, 2013; Stock and Gifford-Gonzales, 2013; Brass, 2018). Circumstantial evidence of early cattle domestication is reported from Nabta Playa and Bir Kiseiba about ~ 10-8 ka, which corresponds to the period of stabilization of more humid climatic conditions (Wendorf and Schild, 1980; Gautier, 2001; Jórdeczka et al., 2013). While there is a lack of data on early domestic Holocene bovid remains, large bovids have been documented in association with archaeological contexts from the end of the Late Pleistocene in the Nile Valley, suggesting that bovids had specific significance prior to domestication (e.g. Tuskha, site 8905; Wendorf, 1968; Marshall and Hildebrand, 2002). In addition, the early dates for potential cattle domestication at Nabta Playa and Bir Kiseiba are concomitant with the apparition of the oldest form of pottery in the Sahara and the Nile Valley (Jesse, 2010; Haaland, 2015). Wavy-line and dotted wavy-line potteries are recorded in the earliest phases at Nabta Playa and Bir Kiseiba (Close and Wendorf, 2001; Jesse, 2010). These behavioral changes at the beginning of the Holocene among hunter-gatherer communities might therefore be viewed as a way to accommodate the new climatic conditions of subtle rainfall variations compared to the preceding period of probably more stable, acute aridity by way of more predictable food availability and storage (Marshall and Hildebrand, 2002; Jesse, 2010). The introduction of domestic sheep and goats in Africa is clearly an exogenous contribution, since no wild ancestor is present in Africa (Marshall and Hildebrand, 2002; Lesur-Gebremariam, 2010; Lesur et al., 2014). The oldest occurrence of bones from domestic ovicrapines are documented in the Red Sea mountains (Marinova et al., 2008; Vermeersch et al., 2015) and in the western desert (Gautier, 2001 and 2014) from ~ 8.2 ka onwards. These dates are consistent with the oldest remains recorded in the south Sinai and are earlier than domestic goat and sheep remains from Northern Egypt, which would suggest their introduction to southern Egypt and north Sudan from southwestern Asia prior to the major diffusion of fully-fledged pastoralism along the Nile Valley around ~ 7.0 ka, originating from the Levant (e.g. Close, 2002; Marshall and Hildebrand, 2002; Kuper and Kröpelin, 2006; Kuper and Riemer, 2013; Lesur et al., 2014).

While changes in subsistence strategies emerged in the western desert and the Red Sea mountains at the beginning of the Holocene, they do not seem to be related to a fundamental break in the hunter-fisher-gatherer tradition since in many of these contexts, hunting of wild mammals and gathering of wild seeds were still dominant food procurement activities (Kuper and Riemer, 2013; Vermeersch et al., 2015). It was only in the second half of the Holocene (after 7.0 ka), concomitant to the decrease in the monsoonal rains and the resettlement of populations in the Nile Valley refuge zone, that northeast African populations truly developed pastoral ways of life (Kuper and Kröpelin, 2006; Kuper and Riemer, 2013). Evidence of cultural convergence in terms of material uses and funerary practices can be observed in the Neolithic of the Nile Valley from the same period (i.e. during the 5th millennium BCE; Wengrow et al., 2014). This timescale (~ 7.3-5.7 ka) also corresponds to the expansion period of the Y-chromosome haplogroup R-V88 into the Sahelian/Savannah pastoralist gene pool that seems to be associated with an Asia-to-Africa back migration (Cruciani et al., 2010; Kulichová et al., 2017).

Given this climatic, behavioral and cultural framework of change at the beginning of the Holocene in the Nile Valley, the cranio-facial phenotypic differences documented between Nubian Late Pleistocene individuals (Jebel Sahaba, Wadi Halfa) and mid-Holocene to recent populations in this region have been widely discussed. For some authors, the differences in cranial and dental morphology are linked to a gradual adaptation to changes in subsistence activities (Greene et al., 1967; Carlson and Van Gerven, 1977; Galland et al., 2016). This morpho-functional hypothesis postulates population continuity in the Nile Valley during the Holocene and attributes the strong morphological differences to changes in diet, caries-related selection and gracilization processes (Carlson and Van Gerven, 1977). For others, these differences, notably in non-metric dental trait variations, are genetically related and suggest some level of population discontinuity at the beginning of the Holocene (Groves and Thornes, 1999; Irish, 2000 and 2005; Holliday, 2015). However, the absence of Early Holocene samples in these studies that would allow the hypotheses of continuity or replacement of populations in the Nile Valley to be tested limits the discussion.

The Early Holocene site of El-Barga, situated in Nubia more than 10 km east of the city of Kerma, offers a unique opportunity to address these questions of Early Holocene population processes in the Nile Valley (fig. 5). Excavated since 2001 by the Swiss archaeological mission in Sudan (Honegger, 2006), the site has preserved two archaeological assemblages, a Mesolithic settlement with habitat structures and burials, and an Early Neolithic cemetery. The two occupations are located in the same area and dated by radiocarbon isotopic analyses on shells and ostrich eggshells directly associated with the burials (Honegger and Williams, 2015). The Mesolithic assemblage, situated at the top of the hill, has been dated to ~ 10.2-9.1 ka, and the Early Neolithic cemetery is dated to 8.1-7.5 ka, which corresponds to the earliest Neolithic occupation in Nubia (Salvatori and Usaï, 2008). Preliminary analyses of funerary practices, associated artefacts, as well as morphometric comparisons of the human remains, suggest substantial biological and cultural differences between the two human occupations, separated by about a millennium (Honegger, 2006 and 2011; Crevecoeur, 2012b).

Morphometrically, the El-Barga Mesolithic skeletons (EBK_M) can be described as extremely robust. They exhibit strong muscular attachments on the cranium and the infra-cranium skeleton. Regarding dental dimensions and morphology, the Mesolithic sample possesses higher dental diameters on average than the Early Neolithic group (EBK_N). In addition, there is a statistically significant difference in terms of shape of the lower second molars (LM2) and the lower second premolars (LP2). The latter observation is related to the fact that Mesolithic individuals exhibit a higher frequency of lower second molars with fifth cusps compared to the Neolithic group, while differences in the shape of the LP2s depend on the proportionally wider bucco-lingual diameters of the Epipalaeolithic individuals (Benoiston et al., 2018). Comparative morphometric analyses of dental remains show strong biological affinities between the Mesolithic sample from El-Barga and the Nubian Late Pleistocene population from Jebel Sahaba. These characteristics significantly differentiate the Mesolithic and Early Neolithic samples at El-Barga (Benoiston et al., 2018). In-depth investigations of the dental tissue proportions between both El-Barga samples have highlighted variations in size and conformation of these inner structures that support the hypothesis of a biological differentiation between the two El-Barga populations. For instance, the results from the permanent upper central incisors (UI1s) show that the Mesolithic sample exhibits higher values of crown, enamel and dentine volumes than the Neolithic sample, as illustrated in figure 7. The latter figure also maps the repartition of the enamel in both samples. The Mesolithic UI1s possess a significantly higher enamel thickness on average than the Early Neolithic group, notably on the buccal surface of the tooth. This result indicates a difference in conformation of the dental tissue that is independent of the size of the tooth (Benoiston et al., 2018). Although the development of the permanent incisor is more plastic than the posterior teeth (Braga and Heuzé, 2007), the dominance of genetic factors compared to environmental ones in the dental crown development is underscored (e.g. Townsend and Brown, 1978; Dempsey and Townsend, 2001; Hlusko et al., 2004; Townsend et al., 2009). Thus, it is unlikely that the differences in dental tissue proportion would only be related to dietary changes in the El-Barga case in such a short timescale and at the onset of pastoralism. On the contrary, we believe that these results indicate major biological differences between both groups, suggesting possible biological discontinuity between the Mesolithic and the Neolithic populations from El-Barga.

This hypothesis is supported by the results of craniometric comparisons. The Mesolithic individuals from El-Barga exhibit long and wide mandibles, characterized by high mandibular corpus and wide ramus, while the Neolithic mandibles differ significantly with regard to these dimensions. Their mandibles are shorter, narrower and characterized by a consistently low height of the mandibular corpus. Differences in craniofacial morphology are also striking, as illustrated in figure 8 and by the results of a PCA anlysis on seven size-adjusted variables (fig. 8). In the projection of the first and third principal components in figure 8, the El-Barga individuals cluster in very different areas of the plot in relation to their chronological affinities. The El-Barga Mesolithic group cluster with Late Pleistocene specimens from north-east Africa (LPNAE; i.e. Jebel Sahaba, Wadi Halfa) along the positive value of the PC1 that correlates with the relative length and breadth of the face compared to the neurocranial conformation. On the other hand, the El-Barga Neolithic individuals are clearly dissociated from this positive

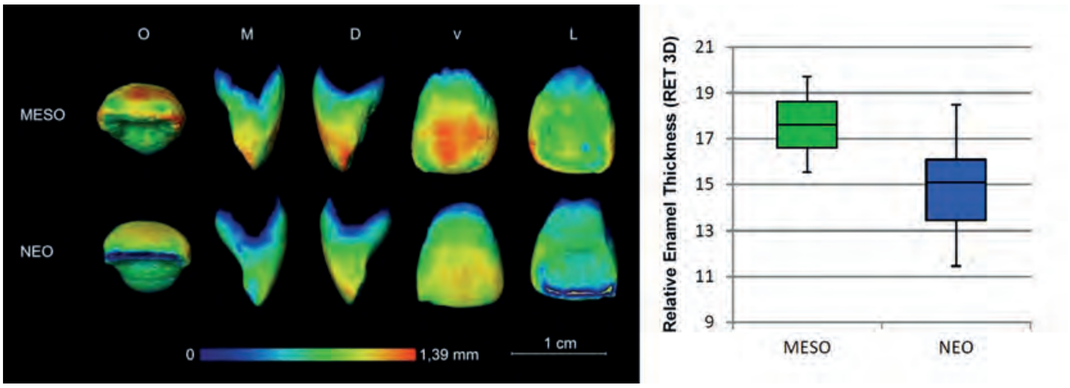

Fig. 7 – Right: Cartographic representation of the enamel thickness variation for the El-Barga Mesolithic and Neolithic UI1s. The teeth are represented in occlusal (O), medial (M), distale (D), vestibular (V) and lingual (L) views. Left: Boxplot of the mean and range of variation of the relative enamel thickness (RET 3D) of the UI1s for the Mesolithic and Neolithic samples of El-Barga (following Benoiston et al., 2018).

Fig. 7 *– À droite : représentation cartographique de la variation de l'épaisseur de l'émail pour les UI1 mésolithiques et néolithiques d'El-Barga. Les dents sont représentées en vues occlusale (O), médiale (M), distale (D), vestibulaire (V) et linguale (L). À gauche : Boxplot de la moyenne et de l'écart-type de l'épaisseur relative de l'émail (RET 3D) des UI1 pour les échantillons mésolithiques et néolithiques d'El-Barga (d'après Benoiston* et al., *2018).*

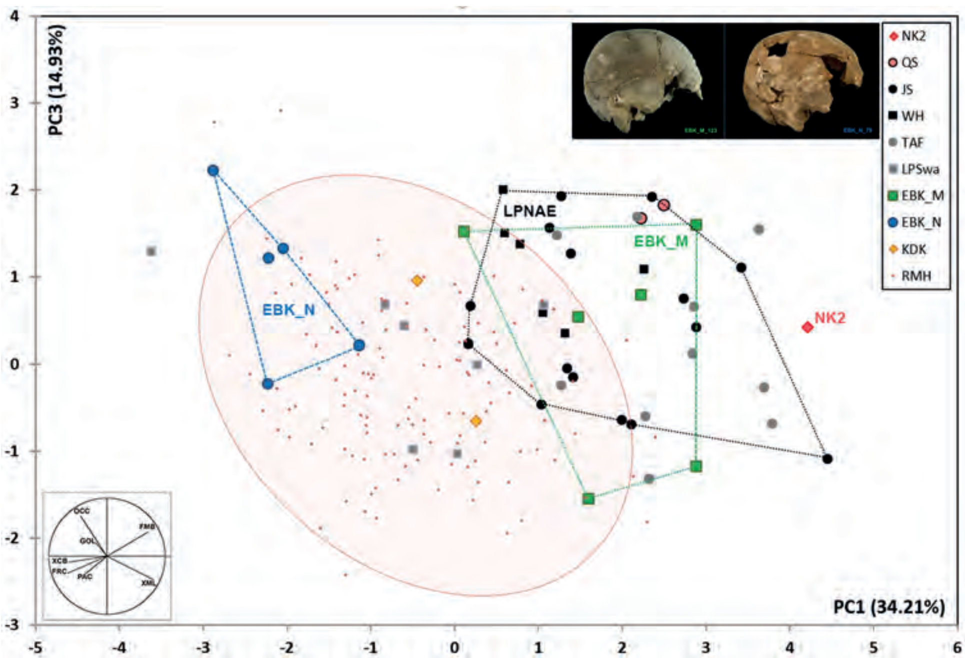

Fig. 8 – Bivariate plot of the projection of the first and third principal component of the PCA on size-adjusted cranial dimensions. Bottom left: Correlation circle showing the position of the variables in relation to the two plotted PCs. FMB, bifrontal breadth; XML, malar length; FRC, frontal chord; PAC, parietal chord; OCC, occipital chord; XCB, maximum cranial breadth; GOL, maximum cranial length. NK2 = Nazlet Khater 2, QS = Qafzeh and Skhul, JS = Jebel Sahaba, WH = Wadi Halfa, TAF = Taforalt, LPSwa = Late Pleistocene from south-west Asia (i.e. Natufian; see Bocquentin, 2003), EBK_M = Mesolithic from El-Barga, EBK_N = Neolithic from El-Barga, KDK = Kadruka 1 sample, RMH = Recent modern human (here Egyptian population; see Howells, 1996). The pink ellipse represents 95% of the RMH variation (Howells, 1996). The dotted lines delimit convex hulls of selected samples. Photograph inserted in the top right part of the graph illustrates the cranium of EBK_M_123 and EBK_N_79 individuals in lateral view.

Fig. 8 *– Diagramme bivarié de la projection de la première et de la troisième composante principale de l'ACP sur les dimensions crâniennes normées. En bas à gauche : cercle de corrélation montrant la position des variables par rapport aux deux composantes principales projetées. FMB, largeur bifrontale ; XML, longueur malaire ; FRC, corde frontale ; PAC, corde pariétale ; OCC, corde occipitale ; XCB, largeur crânienne maximale ; GOL, longueur crânienne maximale. NK2 = Nazlet Khater 2, QS = Qafzeh et Skhul, JS = Jebel Sahaba, WH = Wadi Halfa, TAF = Taforalt, LPSwa = spécimens de la fin du Pléistocène supérieur d'Asie du sud-ouest (à savoir les Natoufiens ; voir Bocquentin, 2003), EBK_M = individus mésolithiques d'El-Barga, EBK_N = individus néolithiques d'El-Barga, KDK = individus néolithiques de Kadruka 1, RMH =* Homo sapiens *récents (ici population égyptienne ; voir Howells, 1996). L'ellipse rose représente 95 % de la variation du groupe RMH. Les lignes pointillées délimitent les polygones convexes contenant les individus des échantillons sélectionnés. La photographie insérée dans la partie supérieure droite du graphique illustre les crânes des individus EBK_M_123 et EBK_N_79 en vue latérale.*

PC1 grouping. Their position in the upper left quadrant is influenced by their proportionally longer occipital chord. It is worth noting that the Late Pleistocene individuals from southwest Asia (LPSwa), as well as the individuals from the later Nubian Neolithic site of Kadruka 1 (KDK) are included, with most of the EBK_N specimens in the Egyptian recent human variation used here as a reference.

All the anthropological evidence points to significant craniofacial and dental differentiation in terms of size and conformation between both El-Barga samples. Following D. S. Carlson and D. P. Van Gerven (1977), and more recently, M. Galland et al. (2016), the strong phenotypic differences observed on more chronologically separated samples (namely, the LPNAE sample in comparison to the Mid-Holocene (< 5.5 ka) Nile Valley populations) are related to changes in masticatory function and diet. Analysis of the only anthropological sample from the beginning of the Holocene in the Nubian part of the Nile Valley calls this hypothesis into question. El-Barga fills a chronological gap in the Early Holocene record and the comparative analyses of the human remains from both occupations underline strong phenotypic differences between them. These changes are documented on a short timescale (one millennium) and during a period of limited climatic and environmental change. In addition, while incipient pastoralism can be identified during the EBK-N period, both El-Barga populations still seem to have relied mainly on Nilotic resources (Linseele, 2012), leaving little evidence of a radical change in lifestyle or diet between the Mesolithic and the Neolithic groups. It is only by the end of the 6th millennium that evidence establishes the development of fully-fledged pastoralism in Nubia (Kuper and Kröpelin, 2006). Therefore, we consider that our results support the hypotheses of biological discontinuity between the two El-Barga groups. Without excluding the possibility of a certain level of continuity, the anthropological study of the El-Barga assemblage suggests a complex history of population processes in the Nile Valley during this crucial, but poorly documented period of the beginning of the Holocene.

3. THE HORN OF AFRICA AT THE END OF THE PLEISTOCENE AND THE BEGINNING OF THE HOLOCENE

Ideally located between Africa and Eurasia, the Horn of Africa has the potential to play a crucial role as a migratory corridor out of and back to Africa. However, the level of resolution offered by the Nile Valley to discuss population processes and phenotypic diversity at the end of the Late Pleistocene and the beginning of the Holocene is currently unavailable in the Horn of Africa. While the region is well-known for its Plio-Pleistocene hominin record and the discovery of the early representative of *Homo sapiens* (e.g. Asfaw et al., 1999 and 2002; White et al., 2003; Alemseged et al., 2006), research into the Late Pleistocene and Early Holocene periods is less frequent. The earliest major contribution to our understanding of the MSA and LSA archaeological sequences in this area was proposed by J. D. Clark (1954), and although research increased from the 1970s onward, relatively few well-dated Late Pleistocene human occupations have been identified compared to other African regions (Brandt, 1986; Assefa, 2006; Ménard et al., 2014; Pleurdeau et al., 2014; Brandt et al., 2017; Leplongeon et al., 2017; Tribolo et al., 2017). If we focus on the number of sites preserving Late Pleistocene and Early Holocene human remains, the dearth of paleoanthropological data is striking (fig. 9).

For the beginning of the Late Pleistocene, the number of sites with securely dated archaeological sequences is

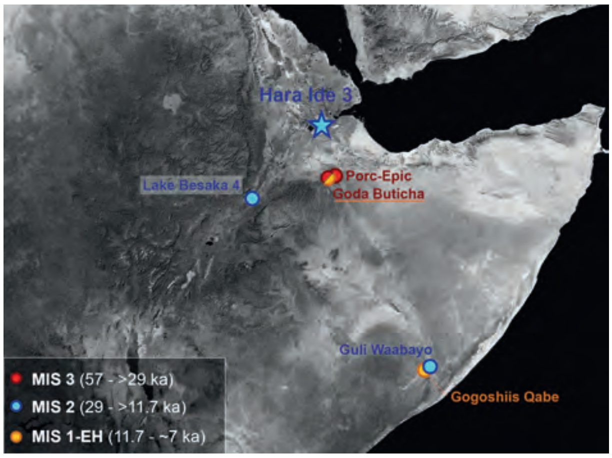

Fig. 9 – Map of the Horn of Africa with the location of sites preserving human remains dated from the MIS 3 to the end of the early Holocene period (MIS 1-EH). Star identifies the Hara Idé 3 site discussed in the text.

***Fig. 9** – Carte de la Corne de l'Afrique avec la localisation des sites ayant livré des restes humains datés depuis le MIS 3 jusqu'au début de l'Holocène (MIS 1-EH). L'étoile indique le site Hara Idé 3 évoqué dans le texte.*

very low and the quasi absence of sites dating to MIS 4 also raises questions about the possible absence of human presence in vast areas of the Horn of Africa (Brandt et al., 2017). During MIS 3, archaeological sequences provide evidence of continued occupation by hunter-gatherer groups (Assefa, 2006). Among these sites, only two in the Dire Dawa region have yielded human remains: Porc-Épic and Goda Buticha (fig. 10; Vallois, 1951; Pleurdeau, 2003; Pleurdeau et al., 2014).

In Porc-Épic, a poorly preserved mandibular corpus fragment was found in 1933 during H. Breuil, P. Teilhard de Chardin and P. Wernert's excavations (fig. 10a; Clark and Williamson, 1984). H.-V. Vallois (1951) noted the absence of mental protuberance, the presence of archaic features on the symphysis, and the size and robustness of the corpus which led him to propose an association with archaic populations. The stratigraphic position of the mandibular fragment is unknown, but a high-resolution low-background gamma-ray spectrometry applied

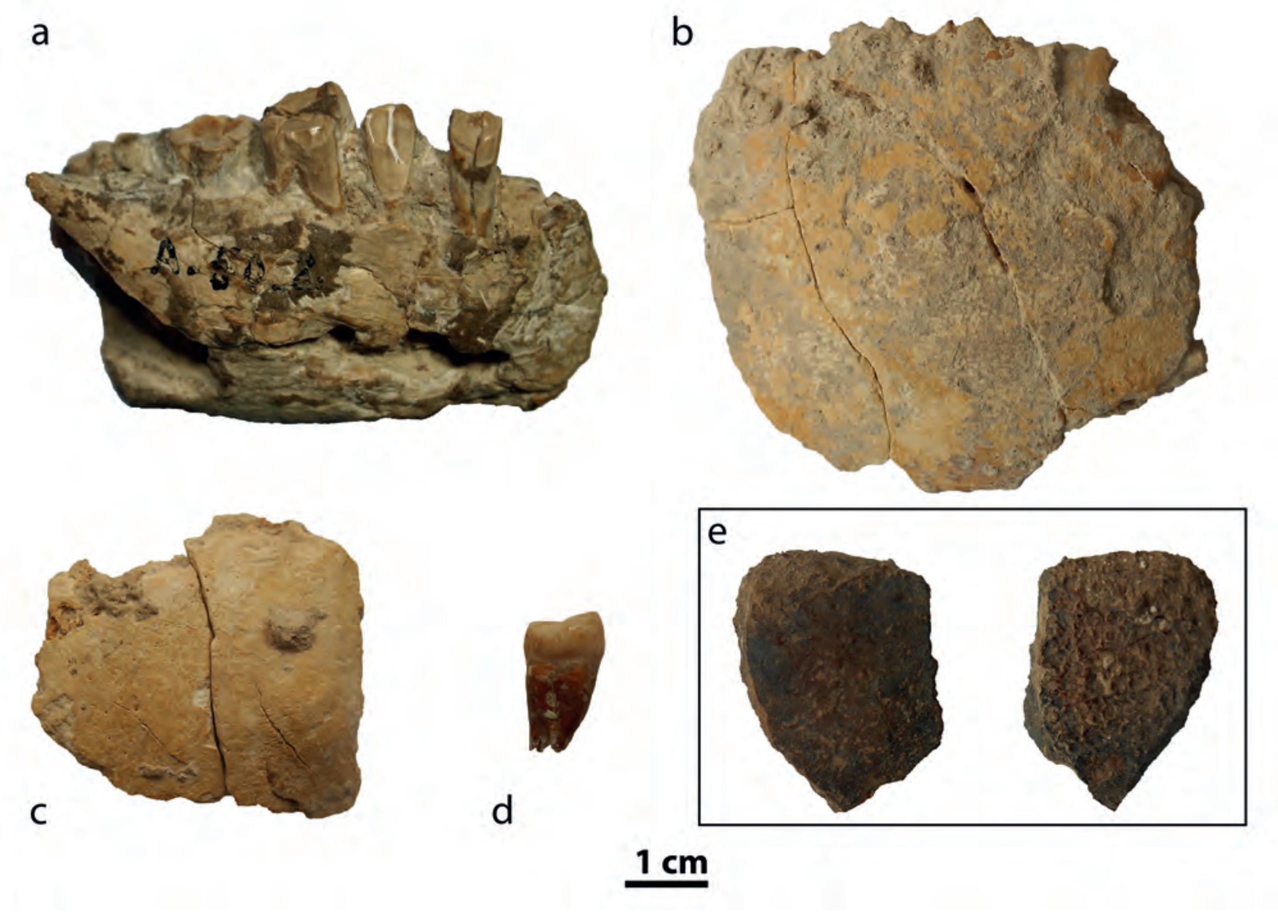

Fig. 10 – Composite image of MIS 3 human remains from Porc-Épic (a to d) and Goda Buticha (e): a, mandibular corpus described by H.-V. Vallois (1951); b, left parietal fragment; c, left occipital fragment; d, first upper left premolar; e, cranial vault fragments.

***Fig. 10** – Image composite des restes humains MIS 3 de Porc-Épic (a à d) et de Goda Buticha (e) : a, corps mandibulaire décrit par H.-V. Vallois (1951) ; b, fragment de pariétal gauche ; c, fragment d'occipital gauche ; d, première prémolaire supérieure gauche ; e, fragments de voûte crânienne.*

directly to the mandible yielded a date of 50 ka that is consistent with the chronological time range of the sedimentary accumulation dated by obsidian hydratation and radiocarbon between ~ 77-40 ka (Michels and Marean, 1984; Assefa, 2006; Leplongeon, 2014). Three additional unpublished human remains from Porc-Épic, two cranial fragments and a first upper left premolar (UP1) were discovered during the 1998 fieldwork conducted by Z. Assefa and D. Pleurdeau to obtain new data on Porc-Épic's stratigraphic sequence (fig. 10b, 10c and 10d; Pleurdeau, 2003 and 2004). They are associated with Unit III, dated by radiocarbon around 40 ka (Pleurdeau, 2005; Assefa, 2006; Leplongeon, 2014). The last human remain, a cranial vault fragment, dated from MIS 3, comes from the nearby cave of Goda Buticha (fig. 10e). It is associated with Level IID whose *terminus ante quem* of 36.6-33 ka is given by two radiocarbon dates on charcoal (Assefa et al., 2014; Pleurdeau et al., 2014). Given the state of preservation and the fragmentary nature of these MIS 3 human remains, it seems impossible to characterize the phenotypic diversity of human populations in this area in the Late Pleistocene. While the mandibular corpus of the Porc-Épic mandible is indeed robust, with corpus dimensions on the edge of recent human variation (fig. 11), the first upper premolar crown does not exhibit any complexity and its diameters are included in the Late Pleistocene and Early Holocene African variation.

The figure 11 also illustrates the position of the mandibular remains from the other Late Pleistocene and early Holocene Horn of Africa specimens (LPHA and HHA samples). All of them cluster close to Porc-Épic and Nazlet Khater 2, exhibiting robust mandibular corpus dimensions.

Human remains associated with MIS 2 in the Horn of Africa are as scarce as those from MIS 3, although more complete (fig. 9). One reason is probably tied to the stratigraphic hiatus documented in several sites in this region between ~ 30-11 ka (Assefa, 2006; Pleaurdeau et al., 2014; Brandt et al., 2017; Tribolo et al., 2017; Jones, 2020; Khalidi et al., 2020). In Somalia, the sites

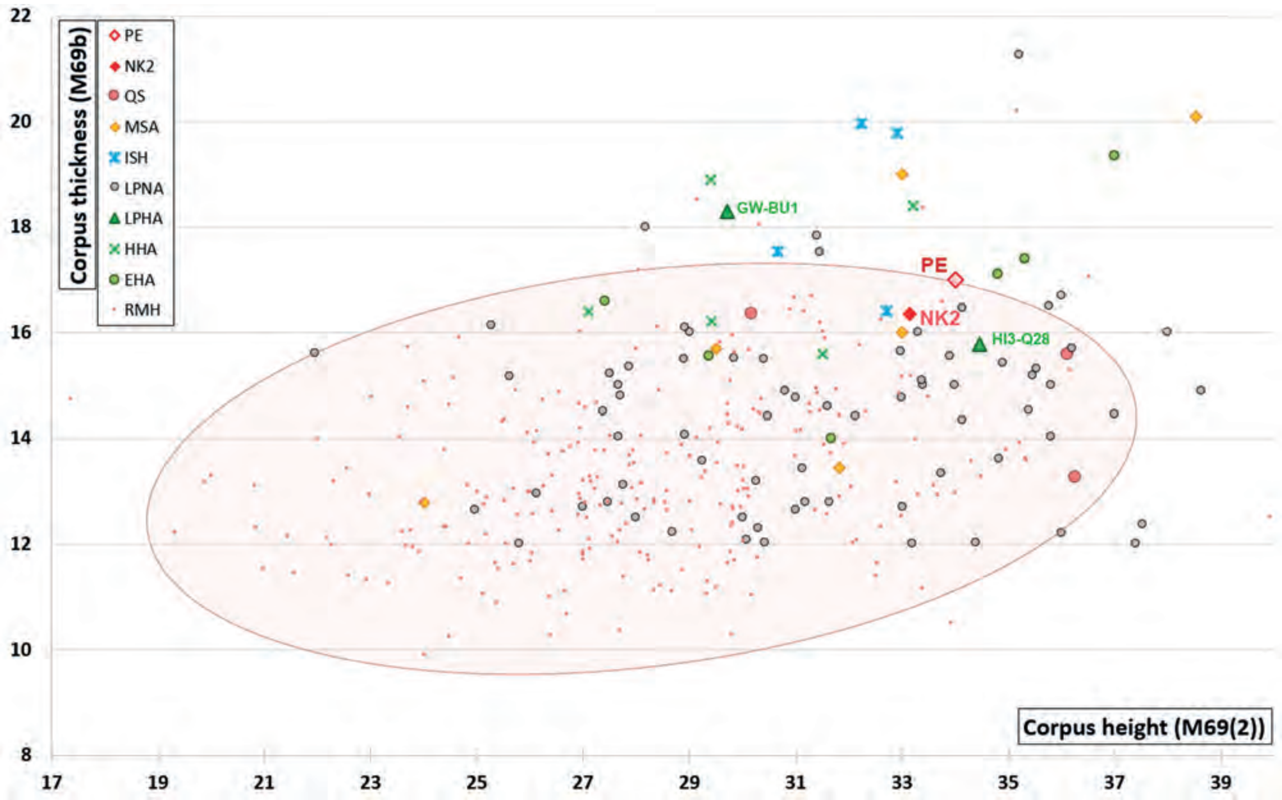

Fig. 11 – Bivariate plot of the mandibular corpus dimensions between the first and second lower molars in centimeters [M69b = corpus thickness; M69(2) = corpus height; see Braüer, 1988]. PE = Porc-Épic, NK2 = Nazlet Khater 2, QS = Qafzeh and Skhul, MSA = African specimens attributed to the MIS 5 to MIS 3 period (i.e. Border Cave, Temara, Dar-es-Soltan, Klasies River Mouth, Loiyangalani and Mumba Rock Shelter), ISH = Ishango, LPNA = compilation of LPNAE and LPNAW samples (i.e. Jebel Sahaba, Wadi Halfa, Wadi Kubbaniya and Taforalt), LPHA = Late Pleistocene specimens from the Horn of Africa (i.e. Guli Waabayo, GW-BU1, and Hara Idé 3, HI3-Q28), HHA = Early and Mid-Holocene samples from the Horn of Africa (i.e. Lake Besaka 2, Gogoshiis Qabe and Mille-Logghia), EHA = Early to Mid-Holocene specimens from east Africa (Lothagam), RMH = Recent *Homo sapiens* (see Ribot , 2011). The ellipse represents 95% of the variation.

Fig. 11 *– Diagramme bivarié des dimensions du corps mandibulaire entre la première et la deuxième molaire inférieure en centimètres [M69b = épaisseur du corps ; M69(2) = hauteur du corps ; voir Braüer, 1988]. PE = Porc-Épic, NK2 = Nazlet Khater 2, QS = Qafzeh et Skhul, MSA = spécimens africains attribués à la période allant du MIS 5 au MIS 3 (à savoir Border Cave, Temara, Dar-es-Soltan, Klasies River Mouth, Loiyangalani et Mumba Rock Shelter), ISH = Ishango, LPNA = compilation d'échantillons LPNAE et LPNAW (à savoir Jebel Sahaba, Wadi Halfa, Wadi Kubbaniya et Taforalt), LPHA = spécimens de la fin du Pléistocène supérieur de la Corne de l'Afrique (à savoir Guli Waabayo, GW-BU1, et Hara Idé 3, HI3-Q28), HHA = spécimens de la première moitié de l'Holocène de la Corne de l'Afrique (à savoir lac Besaka 2, Gogoshiis Qabe et Mille-Logghia), EHA = spécimens du début de l'Holocène d'Afrique du nord-est (à savoir Lothagam), RMH =* Homo sapiens *récents (ici base de données africaine Ribot, 2011). L'ellipse représente 95 % de la variation.*

from Rifle Range and Guli Waabayo preserved sedimentary records covering the Last Glacial Maximum (Jones et al., 2018; Jones, 2020). The latter also delivered the oldest human remains from MIS 2. Direct dating on bone apatite of the remains from Guli Waabayo Burial 1 (GW-BU1) was achieved during the ANR Big Dry program (18683 ± 82 BP, UBA-34897 Muse17239). The result is consistent with chronological reassessment of the Guli Waabayo rock shelter, indicating human activity between ~ 26-6 ka (Brandt, 1986; Jones, 2020). The ANR program also provided a chronological background to a deciduous upper central incisor identified in the faunal collection from the Lake Besaka 4 locality (fig. 9) with the dating of an associated ostrich eggshell to 11699 ± 47 BP (UBA-34907 Muse17252; Clark and Williams, 1978; Brandt, 1982).

The limited record of human occupation in the Horn of Africa during the Last Glacial Maximum may be related to partial abandonment of the area during this period of extreme aridity (Tierney and DeMenocal, 2013). Analyses of lacustrine sediments, isotopic proxy for hydroclimate and pollen sequences have provided a clear image of the impact of large-scale climate changes in the Horn of Africa. The results consistently highlight dramatic hydroclimate changes from MIS 3 until the end of the African Humid Period (e.g. Gasse, 1977 and 2000; Lamb et al., 2002; Marshall et al., 2009; Tierney and DeMenocal, 2013; Foerster et al., 2015; Fersi et al., 2016). Arid conditions prevailed during MIS 3 until the Last Glacial Maximum, followed by a severe dry period associated with the Heinrich Event 1 in the North Atlantic. The abrupt transition to more humid conditions was interrupted by a return to a dryer environment during the Younger Dryas. The strong climatic variations and hydrological instability, notably documented by the fluctuation in lake levels, unquestionably challenged the adaptation capacities of human groups in this area (Gasse, 1977 and 2000; Marshall et al., 2011; Khalidi et al., 2020).

Two exceptions are currently known from the Horn of Africa, that suggest the region experienced heterogenous human responses to the environmental changes caused by the cooling and drying of MIS 2. G. Ossendorf et al. (2019) documented MSA occupations of the Fincha Habera rock shelter in the Bale mountains (~ 4,000 m above sea level) between 47-31 ka with intensive hunting of giant mole rats. E.A. Hensel et al. (2021) reported an occupation throughout the LGM of Sidocho rock shelter (1,930 m above sea level) in the southwestern Ethiopian highlands. The MIS 2 lithic assemblage from Sidocho rock shelter is dominated by microblades lacking retouch and made from obsidian (Hensel et al., 2021). Thus, the lithic industry differs substantially from that at Porc-Épic and Goda Buticha, in which microliths are present, but the assemblages are dominated by larger, retouched tools and small, narrow unifacially or bi-facially flaked points made predominately on chert (Pleurdeau, 2004 and 2005; Leplongeon, 2014; Leplongeon et al., 2017; Pleurdeau et al., 2014). The other exception lies in Somalia. The continuous occupations documented in Somalia appear to correlate with more stable climate conditions in this specific area (Reid et al., 2019). Arguments in favor of the possible absence of human occupation, or the splitting up and maybe isolation of human groups in the Horn of Africa at the end of the Late Pleistocene and the beginning of the Holocene, are found in late occurrence pottery, herding (< 4 ka) and agricultural activities (< 3 ka) compared to adjacent African regions (Cauliez et al., 2008; Lesur et al., 2014; Gutherz et al., 2015; Khalidi et al., 2020). In addition, reduced mobility and specialized hunting strategies are documented in sites preserving archaeological records from this period, such as Guli Waabayo (Jones et al., 2018; Jones, 2020). Finally, the hypotheses of possible long-term isolation and adaptation of populations from this region are also supported by genetic studies (Luis et al., 2004; Rowold et al., 2007; Gallego Llorente et al., 2015).

Within this context, the discovery of a new site in the Republic of Djibouti in 2003, Hara Idé 3 (HI3), tentatively associated with the end of the Late Pleistocene and the beginning of the Holocene, with well preserved human remains, was fortuitous (fig. 9). Hara Idé 3 is located on the southern shore of the Dagadlé oued in the Gobaad basin, 30 km southeast of lake Abhe. The Gobaad basin is a large complex of basaltic grabens that document the fluctuation of lake Abhe during the Pleistocene (Gasse, 1977; Vellutini and Piguet, 1994). This depression has been extensively surveyed for Prehistoric occupation since the 1980s and the discovery of Oldowan assemblages (Chavaillon et al., 1987). Later archaeological programs succeeded one another, focused on identifying occupation sites in relation to first food production societies in the region (Gutherz and Joussaume, 2000; Gutherz, 2008; Gutherz et al., 2015, Cauliez et al., 2018; Cauliez, 2019). From MIS 4 to the Holocene, the Gobaad basin was repeatedly, and to various extents, filled by the transgressions of Abbe lake in relation to paleoclimatic fluctuations (Gasse, 1977 and 2000). Changes in the lakeshore levels affected human occupation in this region and are responsible for the burying and/or erosion of archaeological evidence preceeding the last great transgression (~ 10 ka; fig. 12; Gasse, 2000; Gutherz et al., 2015; Coudert et al., 2018). This is why the discovery of hundreds of human bones and tooth fragments embedded in a lacustrine limestone matrix at Hara Idé 3, together with various faunal remains and lithic artifacts that were initially associated with Late Pleistocene and Early Holocene deposits, was so exceptional. These remains were collected between 2003 and 2005 during rescue excavations directed by H. Duday in the framework of the franco-djiboutian archaeological mission. Given the potential importance of the site, additional archaeological campaigns were organized between 2016 and 2019 in order to clarify the geological and chronological context of these remains.

The geological data from the new excavation campaigns and the dating results allowed the chronostratigraphic context of the Hara Idé 3 archaeological site to be secured. Given the scarcity of human remains in the Horn of Africa for the end of the Late Pleistocene, the discovery of new human remains dated to the Late Upper Pleistocene (~ 18-13.5 ka) in this poorly documented part of the world is crucial to the discussion about the adaptation and/or isolation of human populations in Africa during these times of intense climatic variation (Crevecoeur et al., 2019). Preliminary morphometric investigations of the most complete mandible from the site and found in the pit structure (HI3-Q28; fig. 13) highlighted the robustness of the corpus and the mandibular ramus (Matu et al., 2017). In multivariate comparative analyses, the Hara Idé 3 mandible shows affinities with earlier specimens from the Late Pleistocene, characterized by a relatively long and thick mandibular corpus and a short wide ramus. This conformation explains its position on the upper left quadrant of the graph in figure 13. HI3-Q28 mandible lies at the edge of extant human variation and, given these proportions, can be differentiated from Holocene individuals from the Horn of Africa (HHA) as well as from Nile Valley Late Pleistocene specimens (fig. 13).

These results show that HI3 shares some features with NK2 or Ishango, but seems to differ from the variation in the Late Pleistocene sample from the Nile Valley (LPNAE). Its mandible possesses morphometric characteristics that distinguish it from extant populations. The HHA specimens (here represented by Gogoshiis Qabe, Mille-Logghia and Lake Besaka 2) exhibit great variability, two of them being at the edge of extant human variation, but none of them plots close to Hara Idé 3. This variation in conformation is mirrored by great variation in size. While the latter specimens have a thick and wide mandible associated with large teeth (fig. 13), others, like individuals from Goda Buticha, are characterized by medium to small post-cranial and dental remains (Pleurdeau et al., 2014). These observations of large variations in size and shape between the different sites, although based on limited data from the Holocene period in the Horn of Africa, call into question the relationship between Late Pleistocene specimens like Hara Idé 3 and the Holocene populations in this region, as well as their level of isolation.

4. CONCLUSIONS

In this review of the paleoanthropological data available in northeast Africa during the second half of the Late Pleistocene and the beginning of the Holocene, we sought to highlight general trends regarding past modern human phenotypic variation, leading to a discussion of population diversity, adaptation and affinities during this period of major climatic and cultural changes.

In the Nile Valley, anthropological data indicate the persistence of robust phenotypes associated with plesi-

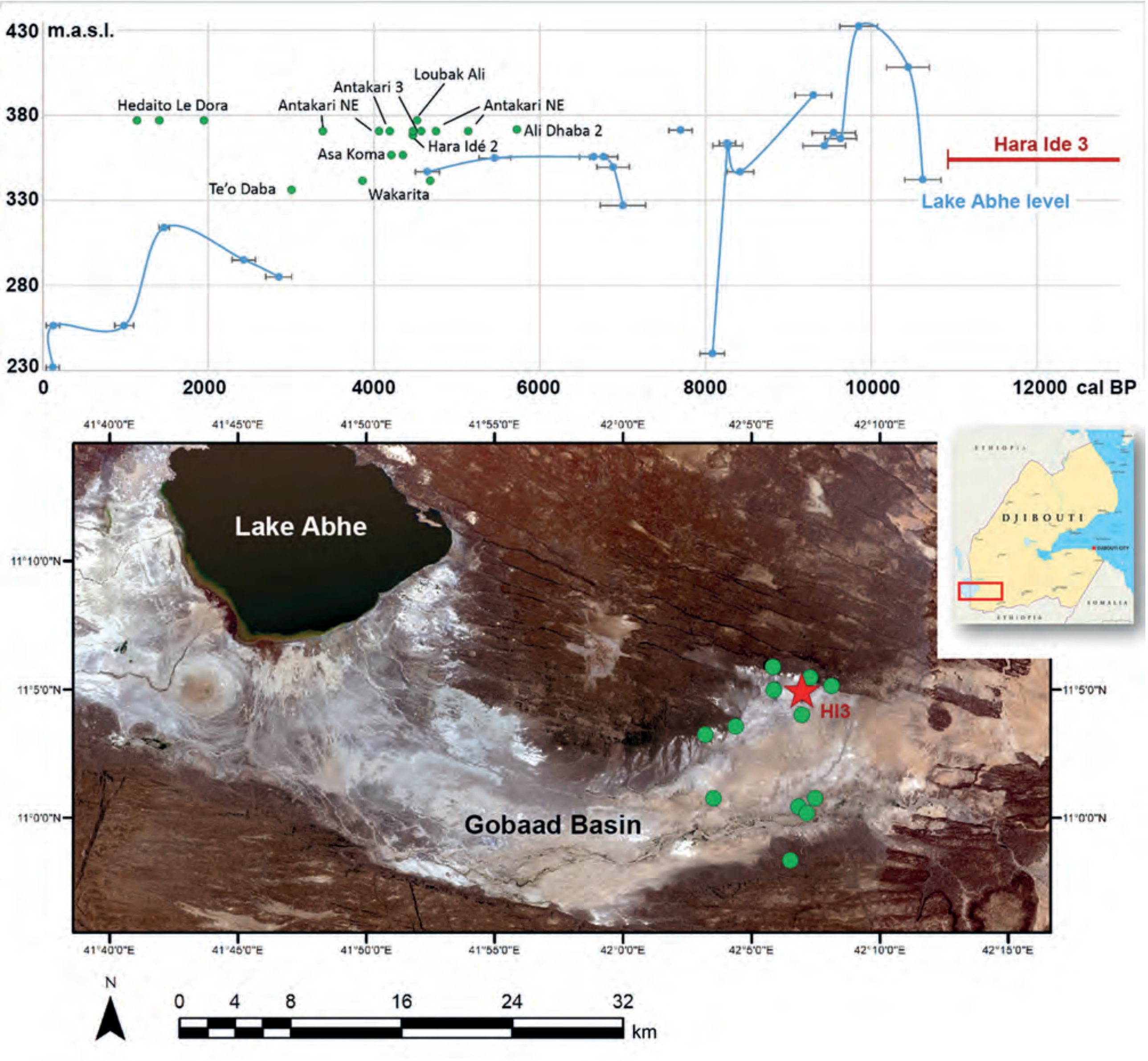

Fig. 12 – Top: Lake Abhe fluctuation level (blue line; see Gasse, 1975) during the Holocene and altitudinal position of Hara Idé 3 and Mid-Holocene archaeological sites investigated by the PSPCA project (Cauliez, 2019). Bottom: Localisation of the sites in the Gobaad basin (following Bruxelles and Mologni, 2019). m a.s.l.: meters above sea level.

***Fig. 12** – En haut : niveau de fluctuation du lac Abhé au cours de l'Holocène (ligne bleue ;voir Gasse, 1975) et position altitudinale du site archéologique d'Hara Idé 3 et des sites datant du milieu de l'Holocène fouillés dans le cadre du projet PSPCA (Cauliez, 2019). En bas : localisation des sites dans le bassin de Gobaad (d'après Bruxelles et Mologni, 2019). m a.s.l. : mètres au-dessus du niveau de la mer.*

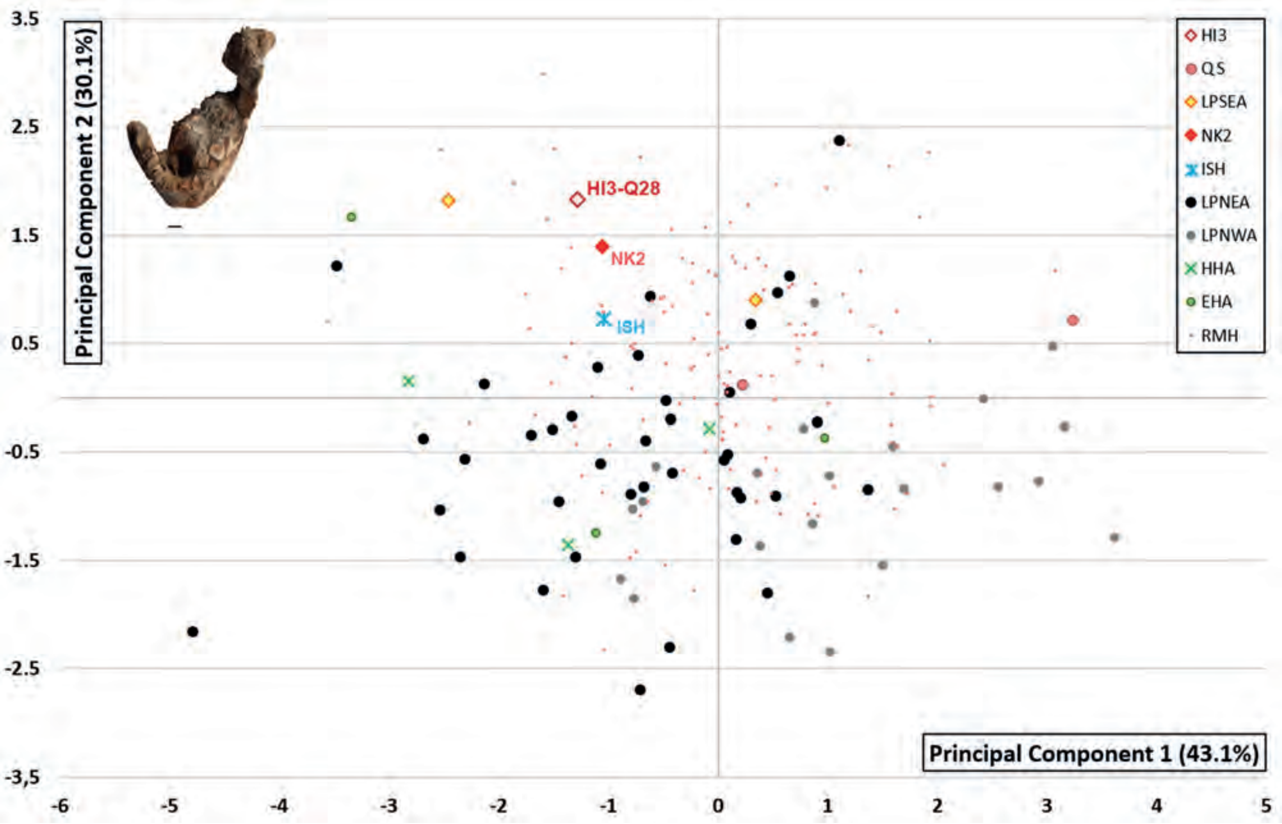

Fig. 13 – Bivariate plot of the first and second principal component of the PCA on size-adjusted mandibular dimensions. HI3 = Hara Idé 3 (HI3-Q28), QS = Qafzeh and Skhul, LPSEA = Late Pleistocene specimens from east and south Africa (i.e. Olduvai Hominid 1 and Springbok Flats), NK2 = Nazlet Khater 2, ISH = Ishango, LPNEA = Late Pleistocene specimens from north-east Africa (i.e. Jebel Sahaba and Wadi Halfa), LPNWA = Late Pleistocene specimens from north-west Africa (i.e. Taforalt and Afalou), HHA = Early and Mid-Holocene samples from the Horn of Africa (Lake Besaka 2, Gogoshiis Qabe and Mille-Logghia), EHA = Early to Mid-Holocene specimens from east and south Africa (Lothagam, Gamble Cave and Fish Hoek Cave), RMH = Recent *Homo sapiens* (see Ribot, 2011). Photograph inserted in the top left part of the graph illustrates the mandible HI3-Q28 in superior view.

Fig. 13 *– Diagramme bivarié de la première et de la deuxième composante principale de l'ACP sur les dimensions mandibulaires normées. HI3 = Hara Idé 3 (HI3-Q28), QS = Qafzeh et Skhul, LPSEA = spécimens du Pléistocène supérieur d'Afrique de l'Est et du Sud (Olduvai Hominid 1 et Springbok Flats), NK2 = Nazlet Khater 2, ISH = Ishango, LPNEA = spécimens de la fin du Pléistocène supérieur du nord-est de l'Afrique (à savoir Jebel Sahaba et Wadi Halfa), LPNWA = spécimens de la fin du Pléistocène supérieur du nord-ouest de l'Afrique (à savoir, Taforalt et Afalou), HHA = spécimens de la première moitié de l'Holocène de la Corne de l'Afrique (à savoir lac Besaka 2, Gogoshiis Qabe et Mille-Logghia), EHA = spécimens de la première moitié de l'Holocène d'Afrique de l'Est et du Sud (à savoir Lothagam, Gamble Cave, Fish Hoek Cave), RMH =* Homo sapiens *récents (voir Ribot, 2011). La photographie insérée dans la partie supérieure gauche du graphique illustre la mandibule HI3-Q28, en vue supérieure.*

omorphic features related to size and shape from MIS 3 until the end of the Late Pleistocene. These characteristics that lie at the edge of recent modern human diversity are also present in the only Early Holocene sample from the Nile Valley. Although based on a very limited number of fossils, the data support hypotheses of population isolation and biological continuity of human groups in the Nile Valley from the end of the Late Pleistocene until the beginning of the Holocene. After ~ 8 ka, human remains from Nubia, notably, show a more gracile cranio-dental phenotype, whose origin could be related to the arrival of new populations in the area concomitant with the spread of pastoralism.

While changes in climate conditions also influenced human settlements in the Horn of Africa, dynamic population issues are more difficult to address with the limited fossil records available. Scattered morphological information from a few Late Pleistocene fossils from Ethiopia, Somalia and the Republic of Djibouti seem to indicate overall robust phenotypes, while Holocene specimens express greater diversity in terms of shape and size dimorphism. Cultural changes in the Horn of Africa in relation to herding and agriculture appear quite late compared to the Nile Valley region. In addition, although ideally situated between Africa and Asia, the role of the Horn of Africa as a migratory corridor during the Late Pleistocene and the beginning of the Holocene is currently little supported by genetic or cultural data. Rather, scenarios involving population isolation and the development of specific adaptation are favored.

The combination of plesiomorphic and unique morphometric features seen in Late Pleistocene African specimens in the Nile Valley and the Horn of Africa from MIS 3 to the Holocene could be the consequence of population isolation and division/fragmentation, whose origin could be at least partially related to climate variations. In this regard, paleoanthropological data are consistent with a genetically-driven model of modern human origin and diversification that support hypotheses of African multi-regionalism and deep population substructures. The paleoanthropological data from the Nile Valley and the Horn of Africa have potential implications concerning the debate about plausible population dynamics that could have led to the out-of-Africa expansion. The genomes of non-Africans harbor the signature of a bottleneck, or a reduction in overall diversity, which can be dated to around 70 ka (Malaspinas et al., 2016). Putting together genetic evidence for a Northern exit OoA (Pagani et al., 2015), archaeological and palaeoclimatic evidence for a drastic reduction in human presence along the lower Nile Valley from MSI 4 (70-60 ka) until ~ 25 ka (Vermeersch et al., 1990; Van Peer, 2004; Vermeersch and Van Neer, 2015), as well as the paleoanthropological data presented here suggesting isolation and fragmentation of Late Pleistcocene human populations in the Nile Valley, we may postulate that the progressive drying out of the North-East African region from 70 ka triggered a population bottleneck (Pagani and Crevecoeur, 2019). The majority of these fragmented human groups may eventually have died out or merged back with the broader sub-Saharan population. A small subset of them may instead have reached the Mediterranean shores and subsequently expanded west, along the North African coast, and east towards Eurasia. Such a scenario would imply that the potential cause of the genetic bottleneck that characterizes all non-African groups was the gradual increase in aridity of the Nile corridor rather than the out-of-Africa expansion of a few wanderers during environmentally permissive conditions. It also suggests that this bottleneck did not take place at the gateways of Africa, but rather, within Africa (along the Nile basin). This highly speculative scenario should now be confronted to comparative analyses of Late Pleistocene specimens from Eurasia to outline possible affinities and illustrate how the analysis of African human remains from MIS 3 onwards is crucial to further understanding the evolutionary history of our species.

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A Comparative Look at Technical Traditions in the Horn of Africa and the Nile Valley at the End of the Pleistocene

Regards croisés sur les traditions techniques dans la Corne de l'Afrique et dans la vallée du Nil à la fin du Pléistocène

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Abstract: Today, the Horn of Africa and north-eastern Africa are connected geographically by the Nile and its tributaries, several of which originate in the Horn. This connectivity evolved over the course of the Pleistocene and despite its potentially central role in the dispersal of humans within and out of Africa, the interactions between human groups of the two regions remain poorly understood. Indeed, archaeological data from these two regions are seldom compared – particularly those that concern the end of the Pleistocene between 60000 and 15000 BP (covering Marine Isotopic Stages 3 and 2).

The archaeological data from this period are generally associated with the end of the Middle Stone Age (MSA)-Middle Palaeolithic (MP) or the Late Stone Age (LSA)-Upper Palaeolithic (UP). The dynamics of the transition between these periods remain poorly defined and as broad entities, they exhibit a great deal of technical variability. Furthermore, the period was a time of great climatic variability characterised by a general tendency towards aridification (the 'Big Dry'), punctuated by irregular periods of humidity. This climatic variability and its diverse regional environmental responses across the eastern part of the African continent may have posed major adaptive challenges to human populations.

This paper aims to examine the lithic variability documented for the end of the Pleistocene in both the Horn of Africa and north-eastern Africa, with a particular focus on technological change that occurred in the context of the MSA-MP/LSA-UP-LP transition and in relation to the variability within the LSA-UP-LP. The main trends are then compared between the two regions, allowing us to evaluate the presence of possible parallel techno-cultural trajectories in both regions.
Keywords: Horn of Africa, Nile valley, Late Pleistocene, lithic technology, transition.

Résumé : La Corne de l'Afrique et l'Afrique du Nord-Est présentent de nos jours un lien géographique naturelle le long du Nil et de ses affluents, plusieurs sources du Nil étant localisées dans la Corne. Cette connectivité a évolué tout au long du Pléistocène, et ses conséquences sur les interactions possibles entre les groupes humains de ces deux régions restent mal connues, malgré le rôle central de ces régions dans les questions de dispersion humaine au sein et hors d'Afrique. En effet, les données archéologiques issues de ces deux régions sont rarement comparées, surtout pour la période de la fin du Pléistocène, entre 60000 et 15000 BP (stades isotopiques marins 3 et 2).

Les données archéologiques de cette période sont généralement attribuées à la fin du Middle Stone Age (MSA)-Paléolithique moyen (PM) ou au Later Stone Age (LSA)-Paléolithique supérieur (PS). Les modalités des transitions MSA-MP/LSA-PS restent encore peu définies, et ces deux entités incluent une grande diversité technique. En outre, cette période correspond à une grande variabilité climatique caractérisée par une tendance générale vers une aridification du climat (« the Big Dry ») ponctuée irrégulièrement de périodes

plus humides. Cette variabilité climatique se traduit par des réponses environnementales différentes d'une région à l'autre, ce qui a probablement posé des défis d'adaptation importants pour les populations humaines de cette époque.
Cet article a pour objectif d'examiner la variabilité lithique de la fin du Pléistocène au sein de la Corne de l'Afrique d'une part et de l'Afrique du Nord-Est d'autre part, en portant une attention particulière aux changements technologiques dans le cadre des transitions MSA-PM/LSA-PS et de la variabilité au sein du LSA-PS. Les principales tendances identifiées seront ensuite comparées entre les deux régions, ces « regards croisés » nous permettons d'évaluer la présence d'éventuelles trajectoires technoculturelles parallèles aux deux régions.
Mots-clés : Corne de l'Afrique, vallée du Nil, Pléistocène récent, technologie lithique, transition.

1. INTRODUCTION

While the African continent occupies an important place in research on the origins and development of *Homo sapiens* during the second part of the Middle Pleistocene and the beginning of the Upper Pleistocene, the more recent prehistory of this continent, from 70 kya, remains comparatively little studied. This period is nonetheless key in the history of human evolution, constituting a major phase in the shaping of diversity in modern humans both at the biological and cultural level (see for example Mirazón Lahr, 2016; Pagani and Crevecoeur, 2019). The ANR Big Dry project (ANR-14-CE31-0023; Bon et al., this volume) was conceived and carried out in order to compensate for the lack of data relating to this period through an emphasis on eastern Africa, which occupies a key position in the population dynamics of *Homo sapiens* both within and outside of the continent (Molinaro and Pagani, 2018). In particular, the Horn of Africa (Ethiopia, Eritrea, Somalia, Somaliland and Djibouti) and north-eastern Africa (Egypt and Sudan; particularly those regions within the Nile Valley) exhibit a natural geographical connectedness along the Nile and its tributaries, many of which originate in the Horn (fig. 1). Despite the importance of identifying this spatial relationship within the archaeological data, particularly that pertaining to the period during which *Homo sapiens* dispersed out of Africa, the field data from these regions has rarely been compared. In particular, the question remains open as to whether this geographical link, and its development alongside the pronounced climatic shifts at the end of the Pleistocene, finds echoes within the cultural production of the populations of these regions.

Indeed, the Horn has most often been lumped in with regional studies of eastern Africa, in spite of the mounting evidence that speaks against the homogeneity of data from this large region, in particular between the Horn of Africa and the Great Lakes area of the Rift Valley (Leplongeon et al., 2020b; here: fig. 1). The act of comparing the recent Pleistocene prehistory of the Horn of Africa and of the Nile Valley, as intuitive as it may seem, is not without difficulty. Indeed, different research traditions have presided over the study of these two regions and guided the collection of diverse archaeological data, thus making any direct comparisons difficult even if only by the use of differing nomenclatures.

In order to approach this challenge, the first part of this article consists of a synthesis of the archaeological documentation for each of these regions at the end of the Pleistocene and particularly for the period between 70 and 15 kya, taking into account new field data collected in the context of the ANR Big Dry project. Building on this foundation, the second part of the article aims to propose a series of comparisons related to the cultural trajectories observed in the Horn of Africa and north-eastern Africa, taking into account the strongly-contrasting paleo-environmental contexts of the two regions.

1.1. General palaeo-climatic context

The period in question stretches from the Marine Isotopic Stage (MIS) 4 to the beginning of MIS 1 (71-15 kya) and therefore overlaps significantly with the last glacial period. Although generally arid, this period is also characterised by strong climatic oscillations. MIS 4 and 3, for example, appear to have been punctuated by humid episodes, specifically at the beginning of MIS 4 and around 55-50 kya in eastern Africa, as well as around 45-35 kya in northern Africa (Blome et al., 2012). MIS 2, sometimes known as the 'Big Dry', encompasses notably the Last Glacial Maximum (LGM; ~ 23-19 kya; Waelbroeck et al., 2009). This was generally an arid period in eastern Africa, although it was straddled on both sides of the LGM – before 24 kya and after 18-16 kya – by more humid episodes (Gasse et al., 2008). The drying up of multiple East African lakes around ~ 16-17 kya, such as Lake Victoria (Stager et al., 2002) and Lake Tana (Lamb et al., 2007 and 2018) among others, had significant consequences on the flow and course of the White Nile, which almost completely dried up during parts of the year, and on the Blue Nile, which became a river with significant seasonality and a greatly-reduced flow (Williams, 2019 and 2020). These conditions contrast strongly with the environmental conditions of MIS 5, characterised by the formation of a mega-lake (> 45000 km^2) on the White Nile from 110 kya onwards (Barrows et al., 2014). Despite the prevalence of more humid conditions at the beginning of MIS 2, as witnessed by the replenishing of subterranean waters in the eastern Sahara, North-eastern Africa is characterised by an even more arid (hyper-arid) climate during MIS 2, particularly during the LGM (Pachur and Hoelzmann, 1991; Abouelmagd et al., 2014).

In contrast, the end of MIS 2 and the beginning of MIS 1 coincide with the beginning of the African Humid Period (AHP; DeMenocal et al., 2000), marked by a distinct rise in precipitation in eastern Africa that allowed

Fig. 1 – Map of the region considered in the paper, showing the geographical extension of the Nile Basin (after Williams, 2019, fig. 1) and Nubia (Auenmüller, 2019). Produced on QGIS v. 3.15 (QGIS Development Team, 2017) and Natural Earth Data. For site names, refer to figures 2 and 6 captions.

***Fig. 1 –** Carte de la région étudiée dans l'article, montrant l'extension géographique du bassin du Nil (d'après Williams, 2019, fig. 1) et de la Nubie (Auenmüller, 2019). Document créé avec QGIS v. 3.15 (QGIS Development Team, 2017) et Natural Earth Data. Pour les noms des sites, voir légendes des figures 2 et 6.*

the reconnection of the White Nile with the Lake Victoria basin (Williams et al., 2006) and led to major flooding episodes on the Nile. However, the AHP is not a uniform and synchronous entity across the continent. North-eastern Africa for example exhibited an extremely arid climate until around 12-11 kya (Kuper and Kröpelin, 2006; also see discussion in Williams, 2019, p. 105).

This brief summary underlines the significant climatic and environmental variability in both time and space for these two regions. Our comparison will therefore aim to discern the ways in which these variations affected human populations in these areas by reflecting on potential complementarities between them during certain periods and, by contrast, if these two regions witnessed the development of distinct adaptation strategies in order to deal with different environmental challenges.

1.2. General techno-cultural context

Archaeological sites dated to the period between 70 and 15 kya testify to a significant diversity in their lithic assemblages, commonly categorised as Middle Palaeolithic (MP) or Middle Stone Age (MSA) at the beginning of the period, and Upper Palaeolithic (UP), Late Palaeolithic (LP) or Late Stone Age (LSA) at its end. While Palaeolithic (LP, MP, UP) terminology is used in north-eastern Africa, Stone Age terminology (MSA, LSA) is used in the Horn. The MP-MSA is broadly characterised by the use of a variety of core reduction methods, often aimed at exploiting core surfaces (such as the Levallois and Discoidal methods) for the production of flakes, and in certain cases blades and points. The primary retouched tools are retouched or shaped points, as well as scrapers. The LSA in the Horn is most often defined by the production of blades and bladelets associated with a miniaturisation of the toolkit. Backed tools frequently occupy an important place within assemblages, occasionally forming geometric shapes (such as segments). Burins as both tools and cores are equally common. In the Nile Valley, the UP is characterised instead by volumetric blade core reduction associated with a toolkit consisting primarily of retouched blades, whereas the LP may be distinguished on the basis of its bladelet production, often transformed into backed pieces, which are often retouched into geometrics.

Whatever terminology is used (MSA-LSA or MP-UP/LP), the Horn of Africa and the Nile Valley are sites of major technological transformations during the period between 70 kya and 15 kya.

1.3. Clarification of definitions

The MSA-MP is generally considered to stretch from 300 kya to 50 kya or even as late as 30 kya and up to the Holocene (e.g. Scerri et al., 2021). The LSA-UP extends from 50-30 kya up to the Holocene. The limits (both chronological and technological) between these different phases of the Palaeolithic are sometimes blurry. This is partly due to ambiguities that arise when dealing with the transition between the MSA-MP and the LSA-UP as they are far from being abrupt or clean-cut. The starkest case is that of blade production industries at the end of the Pleistocene and the decision to consider them indicators of either the MSA-MP or the LSA-UP. This choice seems to mainly have its origins in the research histories of both regions. It is therefore pertinent to ask whether industries attributed to the MSA-MP by certain researchers would not be attributed to the LSA-UP by others and vice versa. In such a situation, it is important to go back to the definitions of core reduction methods, in particular the Levallois concept.

The Levallois concept has traditionally been seen as emblematic of the MSA-MP while displaying a wide technical diversity, notably through Levallois blade production. According to É. Boëda (1994 and 1995), Levallois core reduction is defined as a particular way of managing the volume of the core and its convexities involving hard-hammer and direct percussion, and resulting in predetermined removals of various shapes and sizes according to two broad modalities: preferential and recurrent. The Levallois concept is seen in cores composed of two opposing surfaces that are convex asymmetrical and hierarchized, with one side acting as the striking surface and the other as the production surface. The pieces are knapped along an axis parallel to the intersection of the two surfaces, making use of a striking platform whose preparation makes it perpendicular to the intersection of the surfaces. With the exception of Levallois *débordant* products linked to the management of lateral convexities, the Levallois concept as defined by É. Boëda (1994 and 1995) does not allow for the exploitation of the intersection of the core surfaces. This specification in the definition is fundamental for distinguishing between productions designed following a planimetric conception of core reduction (for example Levallois methods, planimetric in the sense of Van Peer et al., 2010) and those produced following a volumetric conception of core reduction organised around highly semi-circular geometries. This volumetric conception of core reduction is distinguished from the Levallois conception by virtue of its exploitation of a volume, implying the use of the total perimeter of the core whose production capacity is in theory equal to its volume. The so-called planimetric core reduction process (such as the Levallois) is rather limited to the productive exploitation of only one surface of the core (Boëda, 1990; Delagnes and Meignen, 2006). The distinction between these two conceptions – planimetric (or surface) and volumetric – is particularly meaningful to our perception of the evolution of lithic production between 70 kya and 15 kya, and therefore we make careful note of it in the following synthesis.

2. THE END OF THE PLEISTOCENE IN THE HORN OF AFRICA

The archaeological record in the Horn of Africa for the end of the Middle Pleistocene and Upper Pleistocene, i.e. from the MSA to the emergence of the LSA, exhibits numerous asynchronicities and local specificities in cultural expression, as well as data of varying quality. Furthermore, most known sites are concentrated primarily within the Ethiopian Rift Valley system and its immediate vicinity, leaving large areas of the Horn of Africa unexplored (fig. 2). Nevertheless, this synthesis will adopt a malleable chronological and technical framework so as to better explain the techno-cultural processes at work at the end of the Pleistocene on the basis of the most reliable data.

2.1. Emergence and decline of MSA technical traditions: transitions with permeable borders

A number of important sites in Ethiopia show that the MSA had already fully developed within the Horn of Africa before ~ 279 kya (Gademotta ETH-72-8B: Morgan and Renne, 2008) and more broadly towards the end of the Middle Pleistocene (KHS and AHS in Kibish: Shea, 2008; Kulkuletti ETH-72-1 and Gademotta ETH-72-7B: Wendorf and Schild, 1974; Garba III: Mussi et al., 2014). Although poorly studied, the oldest technologies already exhibiting basic MSA characteristics can be seen much earlier, around 500 kya (Brooks et al., 2018; Sánchez-Dehesa Galán, 2020). *Homo sapiens* remains have also been recovered from deposits dated to the end of the Middle Pleistocene, min. 233 ± 22 kya (Kibish: McDougall et al., 2005 and 2008; recently redated in Vidal et al., 2022) and ~ 160 kya (Herto: Clark et al., 2003). These were considered to be the oldest in Africa until the individuals found at Jebel Irhoud in Morocco were dated to around ~ 300 kya (Hublin et al., 2017; Richter et al., 2017). However, in addition to these early sites with typical MSA industries, other Ethiopian sites have produced Acheulean industries with quite recent dates for this period, such as at Mieso (~ 200 kya, De la Torre et al., 2014), as well as industries exhibiting a combination of Acheulean and MSA characteristics, such as at Herto (~ 160 kya, Clark et al., 2003; Sahle et al., 2019). These assemblages recall the inter-stratification of MSA (Sangoan) and Acheulean industries dated between ~ 220 et ~ 150 kya at Sai Island (site 8-B-11) in the Nile Valley (Van Peer et al., 2003 and

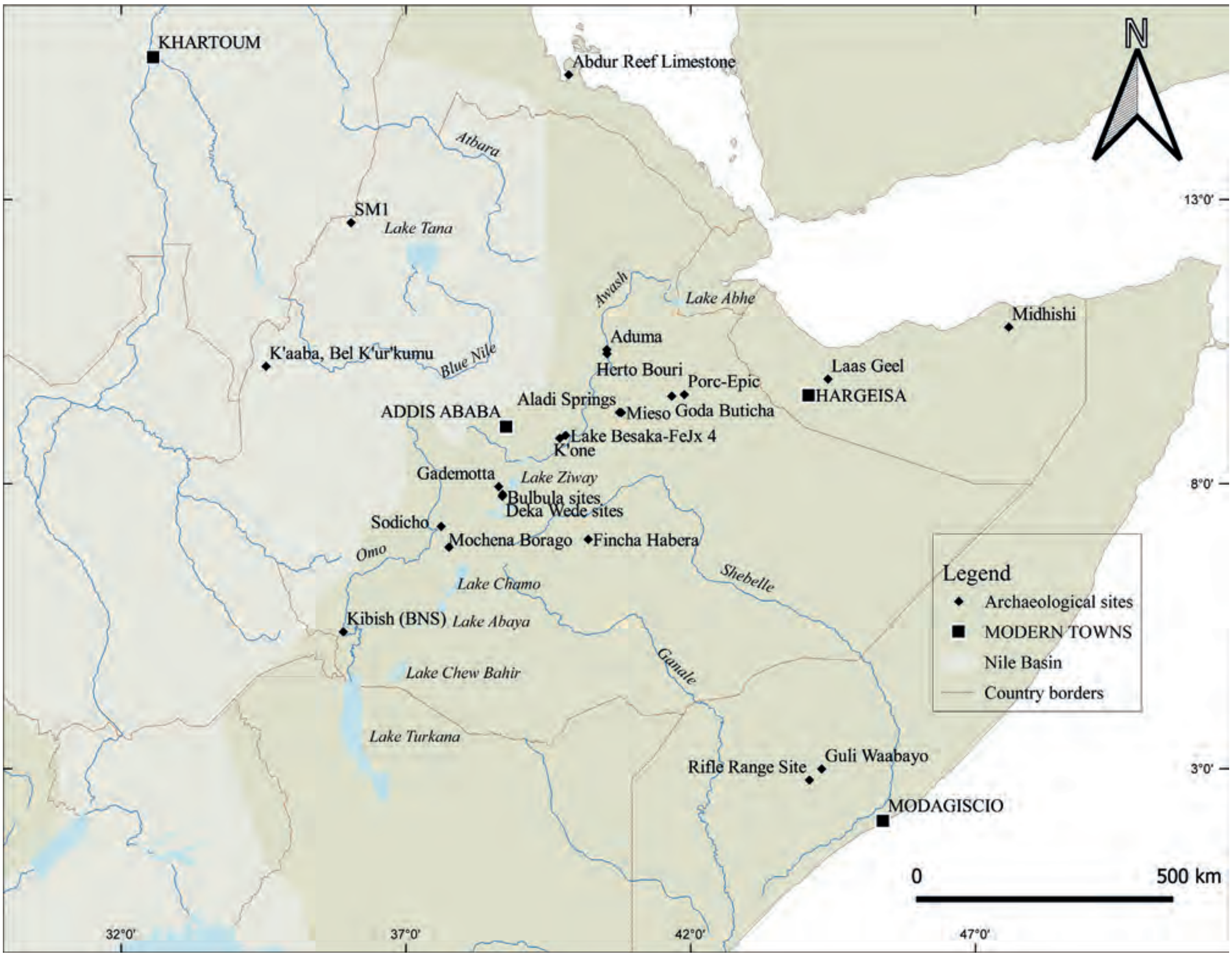

Fig. 2 – Map of the Horn of Africa (extension of the Nile Basin after Williams, 2019, fig. 1): Location of main sites mentioned in the text. Produced on QGIS v. 3.15 (QGIS Development Team, 2017) and Natural Earth Data.

***Fig. 2 –** Carte de la Corne de l'Afrique (extension géographique du bassin du Nil d'après Williams, 2019, fig. 1) : localisation des principaux sites mentionnés dans le texte. Document créé avec QGIS v. 3.15 (QGIS Development Team, 2017) et Natural Earth Data.*

2004). The beginnings of the MSA towards the end of the Middle Pleistocene cannot therefore be seen as an abrupt and widespread technical change in the Horn of Africa. Rather, it must be seen as a gradual, asynchronous and patchy emergence over nearly 150 thousand years, during a time when the Acheulean was still predominant in certain areas.

The acceleration of the climatic oscillations and the increase in their amplitude from 500 kya onwards are often arguments to explain the cognitive and biological evolution of the genus *Homo* at the Acheulean-MSA transition, and during the course of the Middle Pleistocene as they adapted their ways of life to rapid and unpredictable environmental changes (Brooks et al., 2018; Potts et al., 2018; Scerri et al., 2018). In line with these hypotheses that place an emphasis on climatic variation as a motor for change, Brandt and colleagues (2017) suggest that the particularly cold and arid conditions of MIS 4 would have triggered a restructuring of the technical sphere as well as that of mobility, communication and group organisation. It is therefore possible that during the Upper Pleistocene, marked by the last glacial period (~ 110-15 kya), we may find the beginnings of changes leading to the decline of the MSA, which by the end of the LGM had given way completely to the LSA in the Horn of Africa.

At both the beginning or end of the MSA it seems that techno-cultural changes, which themselves may or may not have been shaped by environmental conditions, were the result of gradual complex and permeable processes as opposed to clear ruptures. While the full development of LSA technologies is already evident from the beginning of MIS 1 – with industries based on the production of blades, bladelets, burins and backed pieces – it seems that they must have partially co-existed with Late MSA technical traditions particularly visible in the use of Levallois methods and the presence of points, in some cases until the Holocene. However, the mixed MSA/LSA character of several of these industries from the Late Pleistocene and Early Holocene, often described as being transitional, should be considered in light of the often-unreliable contexts in which they were recovered and that may point to stratigraphic mixing between MSA and LSA layers. Despite their recurrence, it is therefore not proven beyond a doubt that the MSA/LSA transition can be characterised by such a techno-cultural form, or at least not uniformly across the Horn of Africa.

Going back further in time, the available MIS 3 site corpus for the region may well indicate local evolutions towards the new technologies of the LSA along heterogeneous trajectories. For this reason, it is unrealistic to expect a single model for the MSA/LSA transition for the whole of the Horn of Africa. Finally, the definitions of the MSA and LSA, simultaneously static at high resolution and imprecise at a more granular resolution, present an additional difficulty in discerning the transition mechanisms at the end of the Pleistocene. It is therefore necessary here to return to the available data in order to better contextualise this question.

2.2. Chronology and technologies of the MSA between MIS 5 and MIS 3

Any account of the human techno-cultural dynamics at the end of the Pleistocene in the Horn of Africa must consider the available data since MIS 5 (~ 130-71 kya), given the considerable number of sites attributed to the Upper Pleistocene that have not been precisely dated, as well as the processes of change that seem to have occurred over the *longue durée*. In general, comparisons made at the scale of the whole of eastern Africa show that the MSA in the Upper Pleistocene (also known as the Late MSA) is marked by a diversification of assemblage compositions and by the occupation by populations occupying more contrasting environments than during MIS 5 (Basell, 2008; Tryon and Faith, 2013; Blinkhorn and Grove, 2018). As an example, the oldest MSA coastal site in the Horn of Africa, Abdur Reef Limestone in Eritrea, is also dated to the beginning of MIS 5, at 125 ± 17 kya (Bruggemann et al., 2004).

MIS 5 in Ethiopia is represented by a series of open-air sites such as BNS (Bird's Nest Site), the most recent of the Kibish Formation, dated to 104 ± 1 kya (McDougall et al., 2005; Yellen et al., 2005). F. H. Brown and colleagues (2012) propose a correlation between the Aliyo Tuff of Member II of the Kibish Formation, dated to 104 ± 1 kya, and the tuff composing Unit 15 of Gademotta that directly covers the site ETH-72-6 (Wendorf and Schild, 1974). This correlation would place ETH-72-6 in MIS 5, despite a *terminus post quem* of ~ 183 kya (Morgan and Renne, 2008). In the Middle Awash, MSA assemblages contained in the Faro Daba Beds of the Halibee Member have an age constrained between ~ 106 and ~ 96 kyr, using $U/^{230}Th$ burial dating of ostrich eggshell (OES; Niespolo et al., 2021). Uranium-Thorium dates from OES fragments at the site of SM1 in north-western Ethiopia, located along one of the main tributaries of the Blue Nile (the River Shinfa), provide an average date of around 75 kya, though the archaeological data are not yet published (Davis, 2019; Loewy et al., 2020).

A number of other sites may have an age that would place them towards the end of MIS 5 but that could equally be more recent, and are more generally considered to be Late MSA. One of these sites is A5 in the Aduma complex in the Middle Awash, which has an early date around ~ 90 kya obtained from the underlying sediments of Ardu B (Yellen et al., 2005). Another site, ETH-72-5 at Gademotta, is situated above Unit 15 already mentioned as dating to 104 ± 1 kya (Wendorf and Schild, 1974; Brown et al., 2012). The important site of Porc-Épic has provided only contradictory and unsatisfying dates, with estimations ranging between 75 and 61 kya (Michels and Marean, 1984), while other estimations place some MSA layers at the site around 50 kya (Yokoyama and Falgueres, unpublished but cited in Leplongeon, 2014) or between 40-25 kya (Assefa, 2006). This site exhibits a long sequence with MSA levels that could be attributed to either MIS 5, 4, or 3. The same goes for the site of K'one locality 5 extension, characterised by the Levallois method of Nubian type, whose date of MIS 4 was estimated purely on the basis of sedimentological arguments that correlated the silts in which the artefacts had been recovered to an arid phase of the Upper Pleistocene (Kurashina, 1978; Brandt, 1986). In the upper part of the MSA levels in the cave of Midhishi 2, in Somaliland, a piece of charcoal produced a date of > 40 kya lying beyond the limit of the radiocarbon method, and indicating a minimal age during MIS 3 but which may in fact be much older (Brandt, 1986).

Archaeological data from the region corresponding to MIS 4 are practically non-existent. The Ethiopian site of Goda Buticha is one of the only sites to have yielded an absolute date that may be related to MIS 4. The date of around 63 ± 7 kya comes from the OSL dating of sediments from layer IIf at the bottom of the long sedimentary and archaeological sequence of the site (Tribolo et al., 2017). Nevertheless, the archaeological material unearthed in this layer was grouped together with the almost identical material from layers IIe and IId, dated respectively to 43 ± 5 kya and 24.8 ± 2.6 kya. This ensemble IId-IIf can therefore be attributed to the period between ~ 63 kya and ~ 25 kya, centered primarily on MIS 3 (Leplongeon, 2013; Leplongeon et al., 2017; here: fig. 3, no. 6). Similarly, the high-altitude site of Mochena Borago, located further south in Ethiopia, has produced MIS 3 industries in the Block Excavation Area dated between > 49 kya BP and ~ 36 kya cal. BP (Brandt et al., 2017; here: fig. 3, nos. 1-5). Even further to the south, another high-altitude site located at nearly 3,500 m above sea level, known as Fincha Habera, has delivered dates between ~ 47 kya and ~ 31 kya, corresponding to the end of MIS 3 (Ossendorf et al., 2019). Similar dates have been proposed for a series of open-air sites located in the Ziway-Shala basin in central Ethiopia (Deka Wede 1, Deka Wede 4, Bulbula 1 sector 3, Bulbula 4) that lie atop a layer dating to ~ 45-43 kya cal BP, thus attributed to the end of MIS 3 (Ménard and Bon, 2023). However, the only directly-dated site is that of Deka Wede 1 (DW1), for which two charcoal have produced dates between ~ 34 kya cal BP and 31 kya cal BP (Ménard et al., 2014, Douze et al., in prep.). In the Middle Awash, assemblages contained in the Wallia beds of the Halibee members have dates comprised between ~ 31-32 kyr and are attributed to the LSA, but their characteristics are not yet fully published (Niespolo et al., 2021). Finally, in the Rift Valley in southern Ethiopia, close to the Kenyan border, renewed excavations in the Gotera zone (Chavaillon and Chavaillon, 1985) may indicate the presence of sites attributed to MIS 4-3 (E. Spinapolice, pers. comm.; Fusco et al, 2021).

From a technological point of view, with the possible exception of the LSA in the Middle Awash, all lithic assemblages recovered between MIS 5 and MIS 3 can be considered fully MSA. They exhibit characteristics that were recurrent throughout the period (and that were already present from at least MIS 8), and that were employed in a variable manner by knappers at different sites. These characteristics are the use of Levallois methods following various modalities, the occasional use of the Discoid method and, to a lesser extent, the implementation of a volumetric conception of core reduction. The objectives of the core reduction were primarily the production of flakes, but also of blades and points in various proportions and dimensions, some of which exhibit miniature dimensions (< 3 cm). Late MSA sites demonstrate the growing significance of blade production from both bidirectional opposed and unidirectional cores according either to a planimetric conception – as seen for instance at the Ziway-Shala MIS 3 sites (fig. 4) – or a volumetric conception. There is a wide range of retouched tools from the MSA in the Horn of Africa. Best represented are shaped or retouched points (unifacial, partly-bifacial or bifacial) that vary strongly in both morphology and typology (and probably function), as well as various types of scrapers made on diverse blanks, few end-scrapers, notched pieces and borers. Given that only one backed piece was discovered within the MSA levels of Goda Buticha (levels IId-IIf) as well as several fragments of backed tools at Mochena Borago (T-Group), it is difficult to draw any conclusions about the importance of this type of retouched tool in the context of MIS 3 (Brandt et al., 2017; Leplongeon et al., 2020a).

Further characteristics of these Late MSA industries are visible on a more local level. In south-eastern Ethiopia for instance, the sites of Porc-Épic and Goda Buticha exhibit almost no evidence for the production of unretouched points and instead a preponderance of retouched points of highly-diversified typologies (Perlès, 1974; Pleurdeau, 2005 and 2004; Leplongeon, 2013; Leplongeon et al., 2017; here: fig. 3, no. 6). This contrasts strongly with K'one locality 5 extension, located in the north of the Main Ethiopian Rift, where Nubian Levallois methods for the production of technological points dominate. The sites of Mochena Borago and Fincha Habera in southern Ethiopia show evidence for bipolar-on-anvil production on small obsidian blocks within the assemblages (Brandt et al., 2012 and 2017; Ossendorf et al., 2019; here: fig. 3, no. 4), a feature poorly documented in other areas. Similarly, the production of flakes of small dimensions (≤ 3 cm) at the site of Aduma 5, in the Middle Awash, is claimed to be a local variation and led to the introduction of new terminology such as "micro-Levallois" and "micro-Aduma" core types (Yellen et al., 2005). Finally, the Ziway-Shala MIS 3 sites are characterised by bidirectional opposed recurrent Levallois core reduction for blade, elongated flake and point production, showing very finely-crafted faceting of the striking platforms, as well as large pieces with convergent edges with inverse basal thinning (Ménard et al., 2014).

This mosaic of technological specificities draws on a common source and seems to exhibit local cultural adaptations of the MSA that can be identified in geographically-distinct zones dispersed across the Horn of Africa at both individual sites and in local groupings. Despite the difficulty of assessing the chronological relations between sites in certain cases, the idea that environmental conditions played a role in these local expressions finds an echo in the "kaleidoscope of palaeoenvironments"

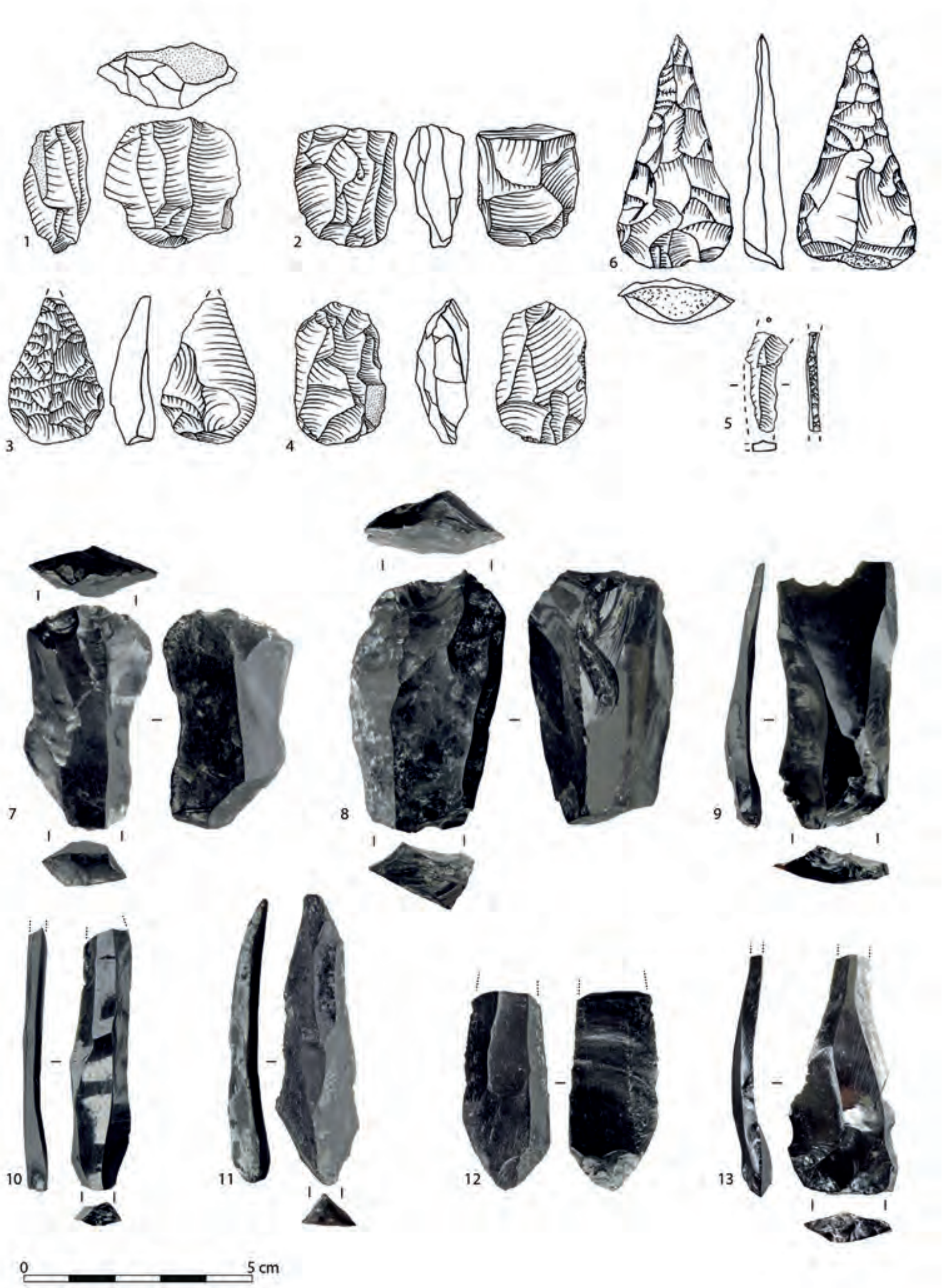

Fig. 3 – Examples of artifacts from MIS 3 sites from the Horn of Africa. 1: Double platform core, Mochena Borago, Goup-S (drawing and terminology after Brandt et al., 2012); 2: Multiplatform core, Mochena Borago, Group-T (drawing and terminology after Brandt et al., 2012); 3: Partly-bifacial point, Mochena Borago, Group-T (drawing and terminology after Brandt et al., 2012); 4: Bipolar core, Mochena Borago, Group-S (drawing and terminology after Brandt et al., 2012); 5: Backed piece, Mochena Borago, Group-T (drawing and terminology after Brandt et al., 2012); 6: Bifacial point, Goda Buticha, layers IId IIf (drawing A. Leplongeon); 7-8: Bidirectional cores on flake, Deka Wede 4 (photos K. Douze); 9: Bidirectional elongated flake, Deka Wede 4 (photo K. Douze); 10-11: Blades, Deka Wede 4 (photos K. Douze); 12: Retouched tool with basal thinning, Deka Wede 4 (photo K. Douze); 13: Convergent bidirectional flake, Deka Wede 4 (photo K. Douze). All in obsidian except no. 6 in flint.

***Fig. 3 –** Exemples d'artefacts découverts dans des sites MIS 3 de la Corne de l'Afrique. 1 : Nucléus à double plan de frappe, Mochena Borago, Goup-S (dessin et terminologie d'après Brandt* et al., *2012) ; 2 : nucléus à multiples plans de frappe, Mochena Borago, Group-T (dessin et terminologie d'après Brandt* et al., *2012) ; 3 : pointe parti-bifaciale, Mochena Borago, Group-T (dessin et terminologie d'après Brandt* et al., *2012) ; 4 : nucléus bipolaire sur enclume, Mochena Borago, Group-S (dessin et terminologie d'après Brandt* et al., *2012) ; 5 : pièce à dos, Mochena Borago, Group-T (dessin et terminologie d'après Brandt* et al., *2012) ; 6 : pointe bifaciale, Goda Buticha couches IId IIf (dessin A. Leplongeon) ; 7-8 : nucléus bidirectionnels sur éclat, Deka Wede 4 (clichés K. Douze) ; 9 : éclat allongé bidirectionnel, Deka Wede 4 (cliché K. Douze) ; 10-11 : lames, Deka Wede 4 (clichés K. Douze) ; 12 : outil retouché à amincissement basal, Deka Wede 4 (cliché K. Douze) ; 13 : éclat convergent bidirectionnel, Deka Wede 4 (cliché K. Douze). Tous en obsidienne sauf numéro 6 en silex.*

described by M. Pickford (2009) to characterise the eastern African Rift and its surrounding area. Over the course of the Upper Pleistocene, given the relentless degradation of climatic conditions – in particular from MIS 4 onwards – the Horn would have offered a diversity of habitats in limited spaces that may have encouraged local adaptations. In this context, the range of geological zones occupied (Asrat et al., 2008), from the Rift floor shaped by intense volcanic activity (the sites of Ziway-Shala) to the Jurassic limestone cliffs at the junction of the Somalian plateau and the Afar (Goda Buticha, Porc-Épic) and to the silicic mountains of the rift escarpments (Mochena Borago, Fincha Habera), is without doubt partly responsible for the diversity of technical behaviours observed, in addition to the various locally available and dominant raw materials (for example Pleurdeau, 2005; Ossendorf et al., 2019; Fusco et al., 2021).

Whereas all MSA sites dating to the end of the Middle Pleistocene, and certainly most of those from MIS 5, are open-air settlements, numerous sites dating to MIS 4/3 and MIS 3 are cave and shelter occupations, occasionally located in high-altitude zones (> 2000 m). These latter sites offer a range of vertically-distributed ecozones favourable to occupation by small groups of hunter-gatherers, and do not require seasonal movements over long distances (Vogelsang and Wendt, 2018; Ossendorf et al., 2019). In the same way, lakeshores also functioned as "magnets for occupation" during the MSA. It was the case in the endorheic basin of Ziway-Shala, which despite its low water level during MIS 3 nonetheless experienced a period of landscape stabilisation with occupations concentrated on the basin floor, riverbanks or on canyon slopes (Bon et al., 2013; Ménard et al., 2014). While the Horn of Africa – and in particular the Rift Valley – may be perceived as a favourable context for human expansion, the archaeological record in the area as it appears now, suggests a series of isolated occupations over long periods of time.

2.3. MIS 2 and the question of MSA/LSA transitional industries

The MIS 2, as recorded for example in the lake sediments of Chew Bahir in Ethiopia, contained periods of (hyper-)aridity and perhaps more importantly episodes of rapid and relatively abrupt arid-humid oscillation (Trauth et al., 2019). The impact of these particular MIS 2 climatic and environmental conditions on human populations remains difficult to evaluate due to the lack of archaeological data from this period. Furthermore, several site sequences are characterised by a sedimentary hiatus corresponding to this period (Goda Buticha and Mochena Borago: Pleurdeau et al., 2014; Brandt et al., 2017; Tribolo et al., 2017). The hypothesis in which the mountainous plateaux of south-western Ethiopia acted as a refuge for human populations during this period (Brandt et al., 2012; Foerster et al., 2015, p. 337) has recently been the subject of renewed attention. On the one hand, the stratigraphic sequence of Mochena Borago (situated around 2,200 m a.s.l on Mount Damota) does

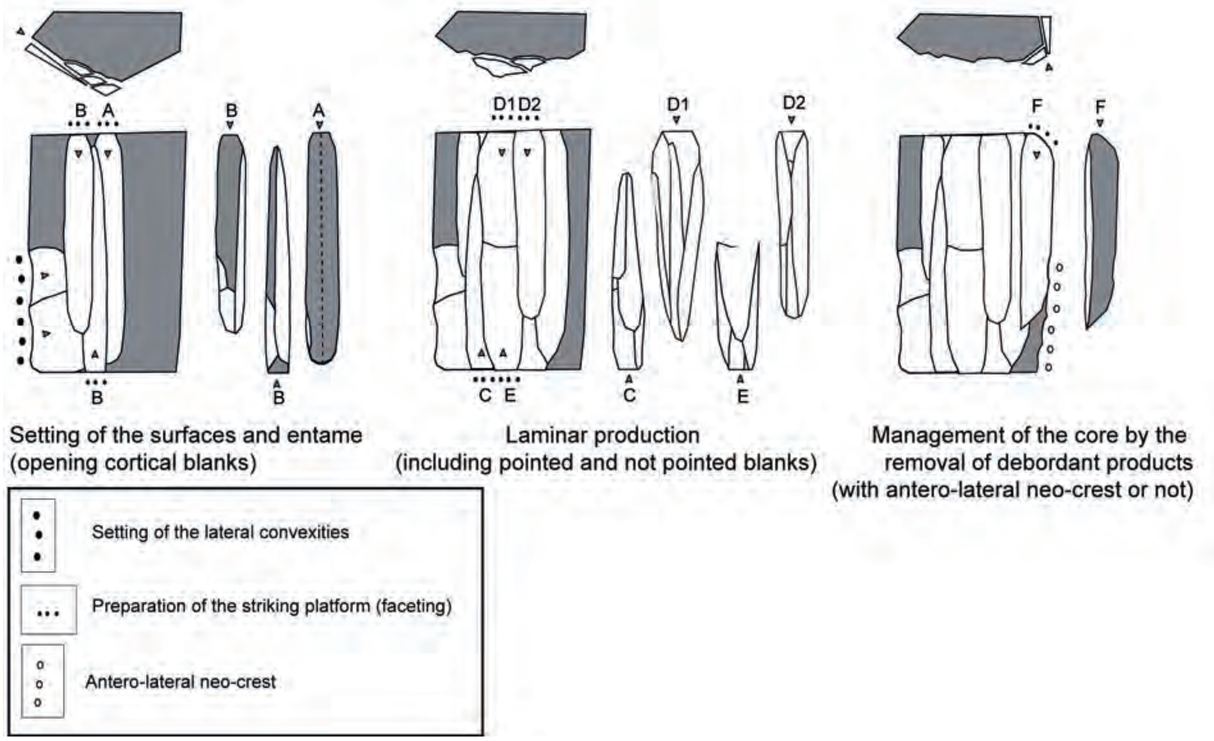

Fig. 4 – Operation scheme for blade production at the MIS 3 sites of B1s3 et DW1, Ziway-Shala basin (Ménard et al., 2014; CAD C. Ménard).

***Fig. 4** – Schéma opératoire de production luminaire à B1s3 et DW1, sites MIS 3 du bassin de Ziway-Shala (Ménard* et al., *2014 ; DAO C. Ménard).*

not exhibit any MIS 2 level (Brandt et al., 2017). On the other hand, Sodicho Rock Shelter located around 40 km from Mochena Borago at 1,900 m altitude a.s.l. exhibits a long stratigraphic sequence dating to MIS 2 and associated with human occupations, from which the material is currently in the process of being published (Hensel et al., 2019 and 2021). The sedimentary data from the site of Sodicho suggests an occupation of the site when arid conditions are documented in the region, supporting the environmental refugium hypothesis during MIS 2 for at least one part of the mountainous plateaux of south-western Ethiopia. In contrast, the sedimentary sequence at the site from 17 kya cal. BP testifies to more humid conditions that could be correlated to the AHP, and which correspond largely with sterile archaeological units, suggesting an abandonment of the site by humans.

Between the industries that come before and after MIS 2 there are significant technical changes. The underlying question is the one of the emergence of the LSA in the Horn of Africa, which seems to occur relatively late (during the MIS 2) in this region. It is therefore important to identify if the changes linked to this emergence, particularly technical ones, appear in rupture or in continuity with the MSA. From the mid-twentieth century, it was considered that a transitional period between the MSA and LSA was apparent in the Horn of Africa, given repeated discoveries of assemblages with both MSA and LSA characteristics, with Levallois and Discoidal products as well as shaped or retouched points occurring alongside large backed tools, microliths, and significant (often predominant) blade productions. This association of elements led J. D. Clark to propose a distinct regional nomenclature for these assemblages that he considered as markers of the end of the Upper Pleistocene, between the MSA and the LSA, during an arid period (Clark, 1954, p. 158). These included the Hargeisan in northern Somalia, which he considered to be a distinct variant of the Magosian of southern Somalia and the Ogaden – due to differences in the types of angle burins and end-scrapers in particular – and as a successor to the Stillbay, which according to the author was the last MSA culture. Given the scarcity of sites relating to this Hargeisan "culture" – an issue acknowledged by J. D. Clark – the use of the term "Hargeisan" as a cultural-historical entity was little by little abandoned despite occasionally still being used (Brandt and Gresham, 1990; Gutherz et al., 2014). Since then, many of these assemblages with transitional characteristics have been re-studied and others revealed, though with questionable sedimentary contexts that do not always allow their transitional nature to be confirmed.

The review of the few sites in the Horn of Africa with assemblages composed of both MSA and LSA elements – and therefore potentially transitional – reveals that they most often occurred during MIS 2, and have often uncertain chrono-stratigraphic contexts. In Somaliland, assemblages attributed to the Hargeisan were recovered from Unit CSUb at Midhishi 2 dated to around 1890 ± 340 BP (Brandt, 1986), as well as at Laas Geel Shelter 7, where layers SU709-SU7011 provided conflicting dates between the 13th millennium cal BP and 40 kya BP (Gutherz et al., 2014). In Ethiopia, the site of Aladi Springs delivered an assemblage associating typical MSA and LSA artefacts, which was already described as unreliable by J. D. and K. D. Williamson (1984) and whose age is uncertain though possibly a little older than ~ 17-12 kya BP, according to the date obtained for the clayey layers directly above (Gossa et al., 2012). The lower horizon at site FeJx4 from Lake Besaka was considered to be MIS 2, with dates between 27120-21850 cal. BP (Brandt, 1986), placing it among the oldest expressions of the LSA in Ethiopia (also see Gasse and Street, 1978). A new date produced in the context of the ANR Big Dry indicates a minimum age of around ~ 13.6-13.4 kya cal. BP, which leaves open the hypothesis that the context is potentially younger (Habte, 2020).

It is clear that the corpus of sites with so-called transitional industries as well as absolute dates within MIS 2 are rather unconvincing (see also Leplongeon et al., 2020b). As mentioned earlier, it is only recently that two new sites with contexts reliably-dated to MIS 2 were discovered, which are currently in the process of being published. These include the site of Sodicho, located in south-western Ethiopia (Hensel et al., 2019and 2021), the Oulen Dorwa assemblages in the Middle Awash (Niespolo et al., 2021) and the side of Aga Dima S2 (ADS2) in the Ziway-Shala Basin.

The material from the site of Sodicho is in the process of being published, but a preliminary description of the lithic assemblage from part of the lower levels of the sequence, dated between ~ 27-13.5 kya cal. BP, shows dominant bladelet production. No retouched tools were identified in the studied sample (Hensel et al., 2021, p. 12; here: fig. 5, nos. 1-3). Similarly, the material from the Oulen Dorwa assemblages in the Middle Awash is in the process of being analysed. It is attributed to the LSA and is associated with numerous OES fragments, ^{14}C dated to between 23.9 and 21.4 kya cal. BP (Niespolo et al., 2021). The characteristics of the lithic assemblages appear at first sight broadly similar to the ones of Sodicho (bladelet production from pyramidal cores, with few retouched tools), but both assemblages need to be further characterised before they can be included in comparative analyses.

The site of ADS2 is a sedimentary trap whose lower layers (b to d) are reliable and dated between ~ 31-26 kya cal. BP, at the MIS 3-MIS 2 boundary (Habte, 2020; Douze et al., in prep.). The lower part of the sequence of ADS2 is probably both contemporaneous (level d) with and successive (levels c and b) to the sites dated to the end of MIS 3 in the Ziway-Shala Basin (DW1, DW4, B1s3, B4) located a few kilometers away and below. Elevated slightly above its surroundings, Aga Dima may have been occupied during the minor lake transgression recorded in the Deka Wede and related to the turning point between MIS 3-MIS 2, a phase during which the MIS 3 sites situated by the river were submerged. The question is whether this slight temporal stagger is enough to explain how a technical industry so strongly anchored in the know-

Fig. 5. Examples of artifacts from MIS 2 sites from the Horn of Africa. 1-3: Bladelet cores, Sodicho, Late Pleistocene (drawings and terminology after Hensel et al., 2021); 4-5: Volumetric small elongated flake cores, Aga Dima S2, Level c (photos K. Douze); 6: Bidirectional core on flake, Aga Dima S2, Level d (photo K. Douze); 7: Bidirectional core on flake, Aga Dima S2, Level c (photo K. Douze); 8: Elongated bidirectional flake, Aga Dima S2, Level c (photo K. Douze); 9: Blade, Aga Dima S2, Level c (photo K. Douze); 10: Bidirectional point with basal thinning, Aga Dima S2, Level d (photo K. Douze); 11: Elongated flake with basal thinning, Aga Dima S2, Level c (photo K. Douze); 12: Backed bladelet, Aga Dima S2, Level d (photos K. Douze); 13: Backed bladelet, Aga Dima S2, Level c (photos K. Douze). All in obsidian.

***Fig. 5** – Exemples d'artefacts de sites MIS 2 de la Corne de l'Afrique. 1-3 : Nucléus à lamelles, Sodicho, Pléistocène final (dessins et terminologie d'après Hensel* et al.*, 2021) ; 4-5 : petits nucléus volumétriques à éclats allongés, Aga Dima S2, niveau 6 (clichés K. Douze) ; 6 : nucléus bidirectionnel sur éclat, Aga Dima S2, couche d (cliché K. Douze); 7 : nucléus bidirectionnel sur éclat, Aga Dima S2, couche c (cliché K. Douze) ; 8 : éclat bidirectionnel allongé, Aga Dima S2, couche c (cliché K. Douze); 9 : lame, Aga Dima S2, couche c (cliché K. Douze) ; 10 : pointe bidirectionnelle à amincissement basal, Aga Dima S2, couche d (cliché K. Douze) ; 11 : éclat allongé à amincissement basal, Aga Dima S2, couche c (cliché K. Douze) ; 12 : lamelle à dos, Aga Dima S2, couche d (cliché K. Douze) ; 13 : lamelle à dos, Aga Dima S2, couche c (cliché K. Douze). Tous en obsidienne.*

hows of the MSA could be subsequently accompanied by a new, typically LSA component at ADS2.

At ADS2, the blade character of the industry – already present during MIS 3 at the neighboring sites on the lacustrine plain (DW1, DW4, B1s3, B4) – is further reinforced by the presence of blades and bladelets that are more centered and straight, resulting from more volumetric core reductions (fig. 3, nos. 10 and 11; fig. 5, no. 8). The presence of tools with basal thinning as well as unifacial and partly-bifacial points that form the third most important group of tools at ADS2 testify to a strong similarity with the MIS 3 sites of the lacustrine plain (fig. 3, no. 12; fig. 5, nos. 10 and 11). However, the backing process, i.e. for the manufacture of backed tools and truncated pieces, is represented in the assemblages of ADS2 while being completely absent from older sites in the same area (fig. 5, nos. 12 and 13). The backing process was nonetheless carried out just as much on large blanks of the same type as those produced at the end of the MSA, as on bladelets, with the latter present only in small quantities sometimes reaching small dimensions (≤ 3 cm long). The use of flakes or blades as blanks for cores is a common feature across all sites, although at ADS2 removals are also concentrated on the edges of these core blanks for the production of bladelets on the narrow surface, aside from real burins that also appear for the first time (11% of all tools). The blades are more robust and narrow than those obtained from the planimetric conception of core reduction. The bidirectional exploitation, which is common to all the sites of the Ziway-Shala basin (fig. 3, nos 7 and 8; fig. 5, nos. 6 and 7) is also implemented through a volumetric conception of core reduction at ADS2. The half-crest blades are also more numerous. Together, these elements suggest a gradual technological and typological shift that introduces, for the first time in the Ziway-Shala area, elements that are undoubtedly characteristic of the LSA (volumetric debitage, significant production of burins and backed pieces; Ménard, 2015; Habte, 2020). The association of these techno-typological characteristics makes attributing this site to either the MSA or LSA quite difficult, though it is tempting to see it as Early LSA with a Late MSA technical persistence. The stratigraphic truncation of the sediments after 26 kya cal BP at ADS2, as well as the absence of published lithic data for the period between 26 and 15 kya here or elsewhere in the Horn of Africa (beyond the brief description of Sodicho, Hensel et al., 2021) prevents us from evaluating whether the later LSA industries are in cultural continuity with the LSA components of the ADS2 industries, both being chronologically separated by more than 10 millennia, even at a local scale.

Given the poor resolution of the archaeological documentation for MIS 2, it is difficult to know whether the extreme aridity of MIS 2 rendered human occupation in the Horn of Africa invisible, or if it caused populations to abandon the region. The recently published data from Sodicho (Hensel et al., 2021) attest to a retreat of populations towards refuge zones, more of which may be identified in the future. In any case, our understanding of the processes of decline of MSA technical traditions and the subsequent rise of LSA technical systems during this isotopic stage has been strongly impacted by these climatic changes and yet the processes of this shift are difficult to grasp. The site of ADS2 nonetheless shows that before the LGM, at least locally, certain techniques that were to become characteristic of the LSA were already present, whereas later in the same area, no techno-typological similarity with the MSA is observed after the LGM, during MIS 1 (Ménard et al., 2014). As for Sodicho, although the authors do not propose a taxonomical attribution for the assemblages of MIS 2, it is nonetheless clear that these assemblages, which remain to be described, will deliver precious information regarding this issue.

2.4. Synthesis of the contribution of the Big Dry project to the question of the MSA-LSA transition in the Horn of Africa

Our studies, together with the other available data, allow a new look at the MSA-LSA transition by questioning the meaning of the presence and/or absence of certain elements considered as techno-cultural markers, such as 1) backed pieces and microlithism, 2) blade production, and 3) Levallois core reduction and points.

In general, backed pieces occur very occasionally in pre-MIS 1 contexts (Leplongeon et al., 2020a). The only sites where backed pieces have been found in contexts securely dated to MIS 3 are Mochena Borago, where they appear in the form of tool fragments (Brandt et al., 2012 and 2017; here: fig. 3, no. 5), and Goda Buticha IId-IIf (N = 1; Leplongeon, 2014; Leplongeon et al., 2017), where such pieces may be the result of intrusions from LSA layers immediately above. In contrast, the site of ADS2, dated to the beginning of MIS 2, has provided a small number of backed pieces (n = 18/385 retouched pieces) made on varied blank types and of varying dimensions (fig. 5, nos. 12 and 13). These backed pieces are made either on blanks that are very similar to those produced at MSA sites from the end of MIS 3 in the area, namely on large elongated pieces resulting from bidirectional opposed core reduction, or on bladelets from which one of the cutting edges has been modified by abrupt retouch. These data seem to indicate that the emergence of this type of modification occurs towards the end of the Pleistocene in the Horn of Africa, possibly associated with the emergence of LSA technical systems. However, and this is an important fact, it can be dissociated from the emergence of what has been traditionally named "microlithism" (Leplongeon, 2014).

Indeed, the miniature dimensions (≤ 3 cm) of a significant proportion of the artefacts from certain assemblages is a common feature at several Late MSA sites for the production of flakes and bladelets (for example Aduma A5, Porc-Épic, Mochena Borago, Goda Buticha) and is already apparent during the Early MSA for flake productions (for example Kibish, Gademotta ETH-72-8B, Garba III). The production of tools of very small dimensions in some industries seems to be an adaptive behavior in the context of peculiar functional or economic situations that occurred during different phases of the Palaeolithic, and is therefore not in itself a techno-cultural criteria distinctive of the LSA (for example: Douze, 2012; Pargeter and Shea, 2019; Gallotti et al., 2020; Spinapolice, 2020). In addition, the oldest LSA sites dated to the Terminal Pleistocene, such as B1s1 in the Ziway-Shala basin (Ménard et al., 2014; Ménard, 2015), as well as Macho Hill (Humphreys, 1978) and the lower layer FeJx4 at Lake Besaka (Brandt, 1982), also exhibit industries with non-miniaturised backed pieces, though made on more standardised blanks than at ADS2. In other words, the act of producing blanks of small dimensions and/or manufacturing backed pieces, must be dissociated from the emergence of a "microlithic industry" understood as the strict expression of industries with a dominant bladelet component associated with the manufacture of geometric microliths (such as segments) – criteria to which the LSA *sensu stricto* was often reduced.

Another major aspect here is the importance of blade production as a criterion for the distinction between the MSA and the LSA. It seems that the blade component of certain Late MSA industries is quite similar to that of the earliest LSA industries, as seen in those MIS 3 industries from the Ziway-Shala basin that are characterised by a predominant blade production. However, the technical systems that produced these blades are clearly different with respect to the LSA due to the almost exclusive use of planimetric conceptions in the form of Levallois blade core reduction at MIS 3 sites, which contrasts starkly with blade production on semi-conical, or at least volumetric cores at LSA sites dating to MIS 1 (Ménard et al., 2014). However, as the identification of the MIS 3 local "identities" described above might lead to a biased view of the evolutionary dynamics at play in the Horn, it should be qualified that outside the example of Ziway-Shala, studies have shown an elongation of the products from the MIS 3 to the Early Holocene (Leplongeon et al., 2017). Blade production seems well represented within assemblages everywhere from MIS 3 onwards and is the result of planimetric conceptions (among which Levallois) and occasional volumetric conceptions of core reduction, or a combination of both, according to the site (Leplongeon et al., 2017). The blade criterion is therefore not decisive on its own for distinguishing between the MSA and the LSA at the end of the Pleistocene. It seems that across our studies, the assemblages in which blade production is dominant, independently of the methods used to obtain the blades, are dated to the end of the MIS 3 and to MIS 2, peaking during MIS 1, rather than in the Holocene (flake and bladelet industries) or to periods before MIS 3 (flake, point, and occasional blade industries).

Finally, the use of Levallois methods and the production of points, generally considered to be key indicators of the MSA, have been recovered from several assemblages dating to the Holocene (Goda Buticha level IIc: Leplongeon et al., 2017; K'aaba upper levels and Bel K'urk'umu: Fernández et al., 2007), in association with flake and bladelet industries more typical of the Holocene. At these sites, the question remains open as to whether these Levallois methods were reinvented or if they persisted until the Holocene as these sites exhibit a stratigraphic hiatus between the MIS 3 and Holocene levels (Goda Buticha), a chronological hiatus between the MSA and LSA assemblages (K'aaba) or an absence of MSA layers at the site (Bel K'urk'umu). For now, regarding Levallois core reduction, the use of non-standardized descriptive vocabulary hampers our understanding of this technological convergence. It is becoming more and more critical to reach a better common assessment of the Levallois concept and the meaning of its diversity based on MSA and LSA lithic material, particularly in order to draw a distinction between flake productions from cores with hierarchized surfaces and true Levallois productions (according to Boëda, 1994). As for points, their occurrence within LSA layers takes varied forms, including primarily unifacial points of small dimensions (< 4 cm long) with bilateral retouch at Goda Buticha (level IIc) or those of K'aaba. Their recurrence over the course of prehistory no longer needs to be demonstrated, putting into question their status as latent MSA indicators, especially in situations where they are not dominant.

Taking into account all of these parameters, the MSA-LSA transition appears to have been a gradual, multi-facetted process without a stark rupture between the MSA and the LSA, and whose roots may be found during the Late MSA or perhaps even as early as MIS 4. In the context of the Horn of Africa, according to the available data, the production of backed tools could be an indicative feature of the progressive replacement of MSA technical traditions by those of the LSA prior to the predominance of volumetric blade production within assemblages. In turn, the latter may signal the emergence of the LSA *stricto sensu,* with or without latent MSA features. However, the hiatus in the archaeological record between 25-15 kya in the Horn of Africa counters all attempts to observe the dynamics of change during this crucial period of full development of the LSA as described in this volume (Ménard et al., this volume). This is true for the Ziway-Shala basin but also for the sites of Goda Buticha and Mochena Borago, which also exhibit a chronological and sedimentary hiatus during MIS 2 within their long stratigraphic sequences (Pleurdeau et al*.,* 2014; Ménard and Bon, 2015; Brandt et al., 2017; Tribolo et al*.,* 2017). For these reasons, it is important to consider work carried out in the Nile Valley where MIS 2 occupations are particularly well-represented.

3. THE END OF THE PLEISTOCENE IN THE NILE VALLEY

The end of the Pleistocene in north-eastern Africa is distinguished from other regions of the continent by an archaeological record attributed to different chrono-cultural complexes, such as Middle Palaeolithic

(MP), Middle Stone Age (MSA), Upper Palaeolithic (UP) and Late Palaeolithic (LP). This terminological soup has probably contributed at least in part to the artificial isolation of north-eastern Africa with respect to neighbouring regions (see for example Van Peer, 2016). In this section, we will consider this terminological problem before reviewing the archaeological record from the Nile Valley at the end of the Pleistocene (fig. 6).

3.1. The archaeology of the Nile Valley at the end of the Pleistocene: between European and Africanist research traditions

Historically, European terminology has held a privileged position, particularly in the use of the terms "Middle Palaeolithic" and "Mousterian". This is related in part to the colonial history of northern Africa and therefore to the research traditions of the researchers involved. However, these denominations have tended to be replaced by the term "Middle Stone Age" for both north-eastern (Van Peer, 2004; Van Peer and Vermeersch, 2007; Wurz and Van Peer, 2012) and northern Africa (Dibble et al., 2013; Campmas, 2017), in a deliberate bid to reconcile the prehistory of the north of the continent with that of the regions south of the Sahara (see also Garcea, 2004).

While there is consensus around the use of MSA, and despite the increased use of LSA in northern Africa for later periods, the term "Upper Palaeolithic" remains predominant in the Nile Valley due to interpretations of certain characteristics of the material as exhibiting closer links to the Levant than to the rest of the continent (for example Wurz and Van Peer, 2012). It is nonetheless interesting to note that the term "Later Stone Age" is also used for the industries of the western Egyptian desert and in Sudan (Svoboda et al., 2013; Garcea, 2020; Kleindienst et al., 2020). The term "Late Palaeolithic", whose use is widespread thanks to research undertaken in the wake of the construction of the Aswan dam (the Nubian campaign), is used only in the Nile Valley and refers specifically to industries dated to the period between 25-15 kya. For more recent periods, the terms "Epipalaeolithic" (a term used mainly in the Levant) or "Mesolithic" (a European term) and later "Neolithic" are still used despite being recognised as somewhat problematic (for example Garcea, 2004).

In this article, with regards to the Nile Valley, we will default to those terms that remain the most widely-used, namely MSA for industries up to around 50 kya, UP for industries from the period between 50-25 kya and LP for industries dated to the period between 25-15 kya.

3.2. The end of the Middle Stone Age and the beginning of the Upper Palaeolithic: fragmentary data and specialised contexts

One of the main problems facing the study of prehistory in this region is the scarcity of stratified sites and the lack of an absolute chronology, with most remains of MSA occupation having been found in surface contexts.

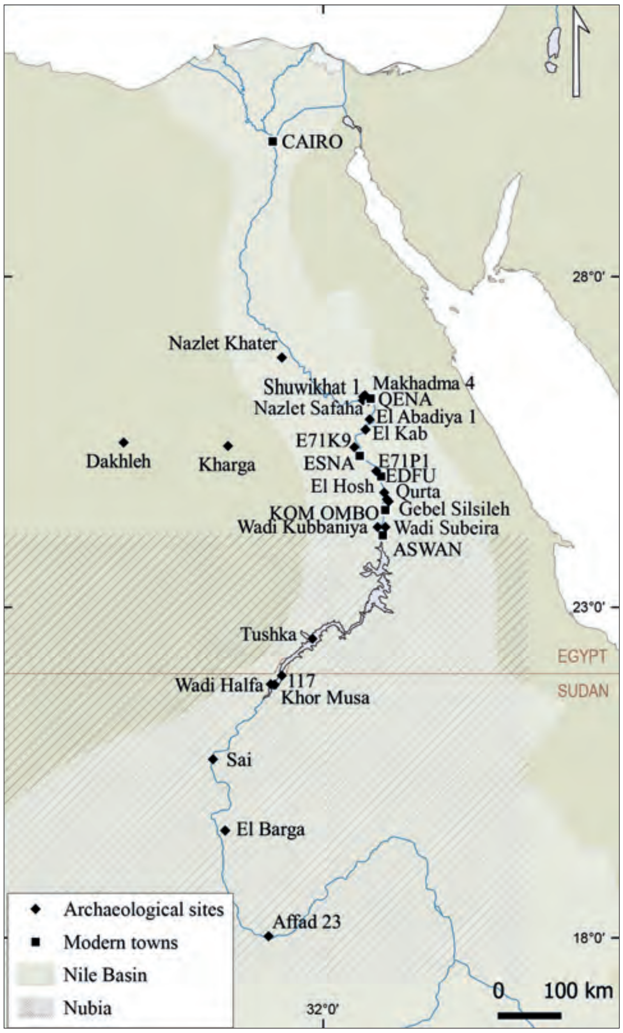

Fig. 6 – Map of the Nile Valley with the location of the main sites mentioned in the text. Geographical extension of the Nile Basin (after Williams, 2019, fig. 1) and of Nubia (after Auenmüller, 2019). Produced on QGIS v. 3.15 (QGIS Development Team, 2017) and Natural Earth Data.

***Fig. 6 –** Carte de la vallée du Nil indiquant la localisation des principaux sites mentionnés dans le texte. Extension géographique du bassin du Nil (d'après Williams, 2019, fig. 1) et de la Nubie (d'après Auenmüller, 2019). Document créé avec QGIS v. 3.15 (QGIS Development Team, 2017) et Natural Earth Data.*

Despite these limitations, this section attempts to reconstitute in a chronological manner the processes at play in the Nile Valley between the end of the MSA and the beginning of the UP.

Three phases may be distinguished in the MSA of north-eastern Africa. One pre-MIS 5 phase sometimes associated with Sangoan/Lupembian appears to be solidly anchored in the African MSA (for example Van Peer et al., 2003; Van Peer, 2016). Only a very few sites are dated to this early stage of the MSA. They are located in the Sudanese part of the Nile basin (for example Van Peer et al., 2003 and 2004; Spinapolice et al., 2018; Masojć et al., 2019 and 2021), and in the western Egyptian desert, namely in the Kharga Oasis (Caton-Thompson, 1952;

Kleindienst et al., 2008), and at Bir Sahara and Bir Tarfawi (Wendorf et al., 1993).

The second phase corresponds to MIS 5 and includes sites attributed to the Nubian complex, bringing together assemblages that have often been characterised by the production of points according to the Nubian Levallois method (for definitions of this variant of the Levallois see Guichard and Guichard, 1965; Usik et al., 2013; here: fig. 7, nos. 1 and 3). Some industries not included in the Nubian Complex are also associated with this second phase of the MSA, such as the Denticulate Mousterian (Marks, 1968c) or the Upper Levalloisian (Caton-Thompson, 1952; Kleindienst et al., 2008).

The Nubian Complex is generally associated with MIS 5 (Van Peer, 1998 and 2016; Vermeersch, 2020), even if only a few absolute dates are associated with sites of this complex whose chronological boundaries remain blurry. Outside north-eastern Africa, other assemblages exhibit the presence of the Nubian Levallois, particularly in the Horn of Africa at the site of K'one locality 5 extension (Kurashina, 1978), at Gademotta ETH-72-6 (Wendorf and Schild, 1974; Douze, 2012), in eastern Africa at Rusinga (Tryon and Faith, 2013), in Arabia (Rose et al., 2011; Crassard and Hilbert, 2013; Usik et al., 2013) or in the Levant (Goder-Goldberger et al., 2016 and 2017). Some of these assemblages have been attributed to the Nubian Complex and interpreted as related to human dispersals that took place during MIS 5 (Van Peer, 1998 and 2016; Usik et al., 2013; Rose and Marks, 2014; Goder-Goldberger et al., 2016), though this subject is strongly debated (Groucutt et al., 2015; Will et al., 2015; Scerri and Spinapolice, 2019; Groucutt, 2020; Hallinan and Shaw, 2020). The late Nubian Complex is characterised in north-eastern Africa by its great lithic variability, grouping together assemblages attributed to diverse chrono-cultural entities such as the Nubian Mousterian, the Khormusan, the N Group, and the Aterian (Van Peer, 1998 and 2016). While the Aterian (a techno-complex dating between ~ 130 kya and 40-30 kya in northern Africa) is well-represented in Egyptian oases (Dakhleh and Kharga: Kleindienst, 2001; Hawkins, 2012), the question of its geographic extension to the Nile Valley is debated (Kleindienst, 2001; Scerri, 2013 and 2017; but see also Carlson, 2015; Garcea, 2020a and 2020b).

The third phase of the MSA – corresponding to MIS 4 and 3 – produced only a few sites. In Egypt, these function as sites for the extraction of raw materials in the Nile Valley (Nazlet Safaha and Taramsa 1: Van Peer et al., 2010; Van Peer, 2016). In Sudan, the sites belonging to the Khormusan were generally considered to date to the period between 60-40 kya (Wendorf, 2001), but have recently been correlated to MIS 5a or MIS 4 on the basis of stratigraphy (Goder-Goldberger, 2013). A re-evaluation of the dates and the correlation of Khormusan sites with the base of the Late Middle Palaeolithic Aggradation led R. Schild and colleagues to propose that the Khormusan be correlated with MIS 4 (Schild et al., 2020). Despite the small number of sites, MIS 4 can be characterised in north-eastern Africa by its great technological variability, seen in various well-defined industries: the Safahan (Van Peer, 1991b and 1992; here: fig. 7, nos. 4 and 5), the Khormusan (Marks, 1968b) and the Taramsian (Van Peer et al., 2010) – the latter testifying to the beginning of a technological transition away from the MSA towards volumetric blade debitage (fig. 7, nos. 6 and 7). These assemblages may represent local developments (for example the sequence at Taramsa 1, Van Peer et al., 2010), even if similarities with the East African MSA have been noted for the Khormusan (Goder-Goldberger, 2013).

As with MIS 4, only a few MSA sites have been dated to MIS 3 in north-eastern Africa. In Sudan, only the complex of sites in the Affad basin, perhaps representing a series of dry-season hunting camps – particularly the site of Affad 23 – and recently dated to around 55 kya can be attributed to MIS 3 (Osypińska and Osypiński, 2016; Osypiński and Osypińska, 2016; Osypińska et al., 2020; Osypiński, 2020). The only sites in the Egyptian Nile Valley that have produced absolute dates within MIS 3 are the Upper Palaeolithic sites of Nazlet Khater 4 (NK4), ~ 44-38 kya cal BP (Vermeersch et al., 2002a; Leplongeon and Pleurdeau, 2011) and Phase VI at the site of Taramsa 1 ~ 45-40 kya cal BP (Van Peer et al., 2010). The site of Shuwikhat 1 (with a minimum date of 25 kya BP) has produced a blade industry dating to the end of the Upper Palaeolithic (the Shuwikhatian) and can be dated to MIS 3 (Vermeersch et al., 2000b; Vermeersch, 2020; here: fig. 7, nos. 8 and 10). A similar chronological context may be proposed for the assemblages of El Abadiya 1, also attributed to the Shuwikhatian and E71K9, though having been first associated with the non-Levallois Edfouan and only later re-attributed by means of typo-technological similarities with the Shuwikhatian (Schild and Wendorf, 2010, p. 111).

The question of human presence in the western Egyptian desert between MIS 4 and 2, a period during which the Sahara is considered to have been hyper-arid, is widely debated. Deposits of travertine and riparian marlstone containing molluscs and mammal teeth in the Dakhleh and Kharga oases have been subject to ESR dating (Electron Spin Resonance) and suggest the presence of water sources throughout this arid period, in opposition to hypotheses of an "uninhabitable" desert (Kleindienst et al., 2016 and 2020; Blackwell et al., 2017). Numerous surface assemblages are attributed to the Khargan (Caton-Thompson, 1952), whose characteristics (namely small core dimensions and Levallois flakes, as well as flake segmentation) drove those teams working in the oases to attribute them to a late phase of the MSA, and to correlate them with dates indicating the presence of water sources during MIS 3 (McDonald et al., 2016; Kleindienst et al., 2016 and 2020). However, in the absence of directly dated material associated with lithics, the chronological attribution of these industries, as well as their possible association with stone structures (site J, Kharga), remains the subject of some debate (see discussions in Vermeersch, 2009; McDonald et al., 2016; Kleindienst, 2020; Kleindienst et al., 2020).

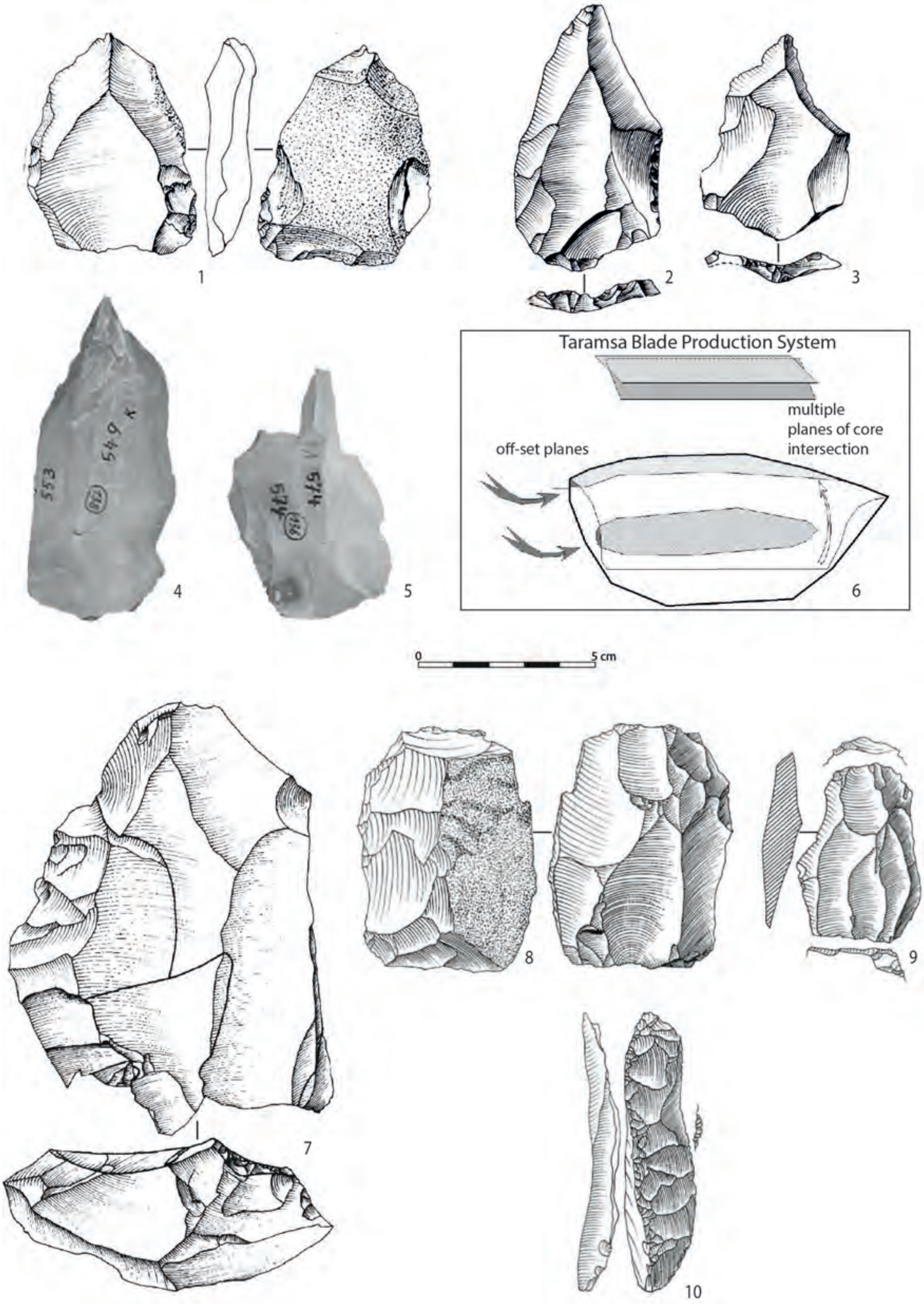

Fig. 7. Examples of Middle Stone Age and Upper Palaeolithic artifacts from the Nile Valley. 1: Nubian cores (Vermeersch et al., 2002b); 2-3: Nubian points from Nazlet Khater 1 (Vermeersch et al., 2002b); 4-5: Refits of Levallois Safahan artefacts from Nazlet Safaha 1 (Van Peer et al., 2002); 6: Schematic representation of the laminar production system at Taramsa (after Van Peer et al., 2010); 7: Blade core at Taramsa, Taramsa 1 Phase VI (Van Peer et al., 2010); 8-9: Blade cores with opposed knapping platforms (Vermeersch et al., 2000b); 10: Crested blade from Shuwikhat 1 (Vermeersch et al., 2000b).

Fig. 7. *Exemples d'artefacts du Middle Stone Age et du Paléolithique supérieur de la vallée du Nil. 1 : Nucléus nubien (Vermeersch* et al., *2002b) ; 2-3 : pointes nubiennes de Nazlet Khater 1 (Vermeersch* et al., *2002b) ; 4-5 : remontages d'artefacts Levallois Safahan de Nazlet Safaha 1 (Van Peer* et al., *2002) ; 6 : représentation schématique du système de production laminaire de Taramsa (Van Peer* et al., *2010) ; 7 : nucleus laminaire de Taramsa de la phase VI de Taramsa 1 (Van Peer* et al., *2010) ; 8-9 : nucléus laminaires à plans de frappe opposés (Vermeersch* et al., *2000b) ; 10 : lame à crête de Shuwikhat 1 (Vermeersch* et al., *2000b).*

The scarcity of sites dated to MIS 4-3 may indicate a low population density in the Nile Valley, perhaps due to the hyper-arid climate of this period. However, sites like Taramsa, Nazlet Safaha and NK4 suggest a particularly intensive exploitation of raw materials and may instead indicate a significant demographic pressure (Van Peer et al., 2010; Van Peer, 2016). In addition, geomorphological factors linked to a research bias may contribute to this state of affairs.

The sites of the Egyptian Nile Valley belonging to MIS 4 and 3 are thus primarily sites for the extraction of raw materials, with the possible exception of those sites attributed to the Shuwikhatian, if one accepts their chronological attribution to MIS 3. Comparisons with adjacent desert sites, as well as with those of the Sudanese Nile Valley, are somewhat difficult and reinforce, perhaps artificially, the impression that the Egyptian Nile Valley was isolated from its neighbouring regions at the end of the Pleistocene.

3.3. The Late Palaeolithic: occupation of the Nile Valley during MIS 2

3.3.1. General context

In contrast to the preceding period, numerous sites dated to MIS 2 are known in the Nile Valley, corresponding principally with two occupation phases: 23-20 kya cal. BP and 16-14 kya cal. BP, separated by a period with fewer sites (Vermeersch and Van Neer, 2015; Leplongeon, 2021). This important archaeological record from MIS 2 may well be correlated with a rise in population density in the Nile Valley, or at least in certain parts of the Nile Valley during MIS 2, suggesting that it acted as an environmental refuge during this hyper-arid period in the Sahara. The analysis of available dates for this period should nonetheless be treated with care, especially when interpreting them as proof of demographic changes. It is likely that this density reflects at least in part the intensity of research in certain areas and is therefore probably not representative of known archaeological data, with half of the available dates coming for example from the sites of Wadi Kubbaniya (see discussion in Leplongeon, 2021).

Only a few sites correspond to the beginning of MIS 1, between 14 and 11 kya in the Nile Valley. It is only from the beginning of the Holocene that sites become more numerous, with Mesolithic sites around Kerma, Sudan, dating to around 11 kya cal. BP (Honegger, 2019) and the Epipalaeolithic site of El-Kab in Egypt dating to 9 kya cal. BP (Vermeersch, 1978; Vermeersch and Van Neer, 2015). One exception may be Site 117 at Jebel Sahaba in Sudan (Wendorf, 1968), where dates were produced with a wide spread between 18 and 11 kya (also see Crevecoeur et al., 2021 and this volume). While it may be acceptable to consider numbers of known sites as a proxy for population density, the fluctuations observed over the course of MIS 2 and the geographic distribution of sites may be partly correlated – tentatively in the absence of further data – with the documented climatic and environmental fluctuations during this period.

The Nile has three principal tributaries: the White Nile, the Blue Nile, and the Atbara (fig. 6). While the flow of the Nile depends primarily on waters brought by the Blue Nile and the Atbara during humid seasons, it depends almost exclusively on those of the White Nile during the dry season (Williams, 2019). The drying out of east African lakes at the end of the Pleistocene, in particular Lake Victoria, the primary source of the White Nile, around ~ 17-16 kya (Johnson et al., 1996; Talbot et al., 2000; Williams et al., 2006 and 2015) would have had important consequences for the perennial character of the Nile (Williams, 2019 and 2020). These consequences are however debated. Two main models have been proposed for the behaviour of the Nile during MIS 2 and the LMG in particular, but no consensus has yet been reached by the scientific community. The first model, developed by F. Wendorf and R. Schild (Schild and Wendorf, 1989 and 2010; Wendorf and Schild, 1989) proposes that the Nile would have taken the form of a braided river during the LMG. Nile would have therefore been at this point a seasonal river with a slower flow, similar to the Atbara today.

P. Vermeersch (2006), followed by P. Vermeersch and W. Van Neer (2015), propose instead a model according to which the Nile would have been blocked at multiple points by sand dunes, creating lakes propitious to the survival of animals and also to human occupation. This hypothesis seems to be supported by a reinterpretation of stratigraphic data from the site of Makhadma 4 (Vermeersch et al., 2000a; Vermeersch, 2006; Vermeersch and Van Neer, 2015), as well as data from fish otoliths (Dufour et al., 2018). The authors propose that this model is applicable to several areas of the Nile Valley, namely near Aswan and Gebel Silsileh as well as Esna (Vermeersch and Van Neer, 2015, p. 160 and 163), despite its rejection by R. Schild and F. Wendorf (2010) on the basis of an absence of typically riparian deposits such as calcareous mars or diatomites. Only new geological work in these areas is likely to shed more light on these two hypotheses.

Whatever the model, paleo-environmental data and the presence of archaeological sites dated to this period seem to indicate that the Egyptian Nile Valley may have served as an environmental refuge during MIS 2 and particularly the LGM. Prevailing hyper-arid conditions in the adjacent desert areas exclude its role as a “corridor” with neighbouring regions (also see Leplongeon, 2021). It should be noted that there are no known sites dated to MIS 2 in the north of Egypt. Although this may reflect in part a research bias, it also seems to be due to the fact that MIS 2 is correlated with a significant drop in the water level of the Mediterranean. This drop induced a hollowing of the Nile river bed from the area of Qena onwards, with human occupations to the north of Qena probably being washed away or buried under metres of sediment deposited by the Nile following the rise in sea level in the Holocene (Sandford and Arkell, 1929; Wendorf and Schild, 1989).

Furthermore, the rise in precipitation in eastern Africa at the beginning of MIS 1 and the subsequent reconnection of Nile tributaries with various East African riparian basins led to significant flooding events (the “wild Nile”; Butzer, 1980), the environmental consequences of which likely deeply disturbed ecosystems and human populations in the Nile Valley. These environmental changes may explain in part the significant level of interpersonal violence documented for this period at the cemetery at Jebel Sahaba (Kuper and Kröpelin, 2006; Vermeersch and Van Neer, 2015; Crevecoeur et al., 2021).

In fact, MIS 2 sites in the Egyptian Nile Valley and in Nubia are generally interpreted as evidence for seasonal occupation with subsistence economies based largely on fishing (Tilapia and Catfish) and to a lesser extent on large mammal hunting (primarily Aurochs, Hartebeests, Dorcas Gazelles, and occasionally hippopotamuses or donkeys; see syntheses and discussions in Van Neer and Gautier, 1989; Van Neer et al., 2000; Schild and Wendorf, 2010; Coudert, 2013; Yeshurun, 2018), as well as on the exploitation of wild plants, notably at Wadi Kubbaniya (Hillman et al., 1989). Rock-art panels at Qurta, El Hosh and in Wadi Subeira, located close to sites from the Late Palaeolithic, are also related to this period (Huyge, 2009; Huyge et al., 2011; Kelany, 2012; Kelany et al., 2015). These bear representations of animals (mainly aurochs) and some human figures (“headless women”) in a very homogenous style. OSL dating of sediments covering one rock-art panel at one site, Qurta II, provided a *terminus ante quem* of 15 kya for these occupations (Huyge et al., 2011).

In terms of technical behaviour, MIS 2 sites in the Egyptian Nile Valley testify to a great diversity in lithic assemblages, distributed across numerous industries and taxonomic entities (Schild and Wendorf, 2010, table 1). The industries of the LP are frequently characterised by the production of elongated products of small sizes, produced from cores with opposed striking platforms, with both planimetric and volumetric conceptions (fig. 8, nos. 3 and 5). These blanks were transformed into backed pieces, whose variability is distinct from one industry to the next (see Close, 1989). However, a certain number of industries exhibit flake production instead, or an association between flake and blade production. Flake production in these industries is frequently carried out on a core, often of small dimensions, identified as being Levallois (Kubbaniyan industry) or else recalling the Levallois method (Halfan method, Marks, 1968a; here: fig. 8, nos. 1 and 2).

3.3.2. Variability in the Late Palaeolithic of the Nile Valley

The great diversity of technical facets documented over a relatively short period and in a limited geographical area (Upper Egypt and Nubia) has been the subject of much debate (for example by Schild and Wendorf, 2010, p. 110). The majority of the available LP data come from excavations carried out in the context of the Nubian Campaign and from those that continued directly afterwards until the end of the 1980s. The majority of these sites have since disappeared, having either been “drowned” by the Aswan Lake following the construction of the dam or destroyed by the continued expansion of irrigation systems. Despite the impressive quantity of accumulated data, in the absence of any recent excavations, only the systematic re-evaluation of contexts and materials with modern tools can reveal new patterns.

In this way, multiple factors of technical variability may be identified. However, it is necessary to point out that many of these factors are associated only with a few absolute dates, which were often obtained using material with a sometimes questionable association with the industry (Leplongeon, 2021). This complicates the interpretation of those lithic characteristics that seem atypical for assemblages attributed to the UP or LP. The discussion in the article by E. Paulissen and P. Vermeersch (1987) demonstrates this difficulty. This is particularly evident for the Halfan, the Sebilian, and the Levallois Edfouan (table 1), although the authors do stress that the stratigraphic positioning of the sites of these industries seems to be related to the aggradation of the Nile at the end of the Pleistocene, and that they do not have any other arguments in favour of proposing an older date for these industries. It appears however that in the absence of a solid chrono-stratigraphical context for some of these characteristics, it is impossible to reject completely the hypothesis according to which the technological variability witnessed during MIS 2 in the Nile Valley can be partly explained through the erroneous chronological attribution of some of these industries. However, even with those industries with unreliable attribution removed, there are still numerous documented industries for this period.

A second factor for this variability may be linked to the geographical distribution of the sites, with some industries being found only in Nubia between the first cataract (at the Aswan Dam) and the second (Wadi Halfa), whereas others are found only in Upper Egypt and in Egyptian Nubia between the first cataract and Dishna (Schild and Wendorf, 2010, here: table 1). The chronological distribution of sites within each of these areas is difficult to establish. Indeed, as we have noted, the available dates (numerous old radiocarbon dates, often not corrected for reservoir effects) prevent the establishment of a detailed chronology for these industries as well as any potential chronological succession, as has been evidenced at the micro-regional scale in the Levant, for example for the chrono-cultural sequences in the Negev Desert, and in the eastern and southern Levant (Goring-Morris, 1995; Maher et al., 2012; Garrard and Byrd, 2013; Enzel and Bar-Yosef, 2017). Because of this, it is only possible to speculate that variability in these industries either echoes complex social interactions as proposed for the Levant, or is linked to a certain fragmentation of populations along the Nile Valley in line with the environmental lake model proposed by P. Vermeersch and W. Van Neer (2015).

Industry and chronological range*	Geograph. distrib.**	Lithic characteristics***	Other characteristic finds
Idfuan/Shuwikhatian Min. age 25 ka	A	Technology: blade production using opposed platform cores and crested products; toolkit: denticulates, burins, endscrapers and burins[1]	
Fakhurian 23-25.6 ka cal BP	A	Technology: non-Levallois blade and bladelet production, single and opposed platform cores; toolkit: backed bladelets largely dominant, retouched pieces and perforators	
Levallois Idfuan	A	Levallois variant of the Idfuan? Technology: blade production using opposed platform cores, use of Levallois and Halfa methods; toolkit: notches and denticulates are dominant	
Gemaian Undated	B	Technology: Levallois, Halfan and Nubian-like cores; toolkit: denticulates and notches	Bone tool (N = 1)
Halfan 19-24 ka cal BP	B	Use of small Nile pebbles giving a microlithic aspect; technology: Halfan and Levallois cores; toolkit: Ouchtata and backed bladelets	
Kubbaniyan 19.3-23.5 ka cal BP	A	Technology: flake and bladelet production, use of single and opposed platform cores, occasional use of Levallois and Halfa methods; toolkit: Ouchtata and backed bladelets, burins. Egyptian variant of the Halfan?	Grinding implements, bone tools and ostrich eggshell beads
Ballanan-Silsilian 16.3-20.8 ka cal BP	A, B	Sometimes includes the use of exotic raw materials; Technology: mainly oriented towards the production of short elongated blanks (blade/let) with single and opposed platform cores; toolkit: backed pieces, truncations, proximally retouched blade(let)s and notched tools, occasional use of the microburin technique[2]	
Qadan 12-20.2 ka cal BP	Mostly B, one site in A (Wadi Kubbaniya)	Small dimensions of the artefacts; technology: mainly oriented towards flake production with single and opposed platform cores, several cores reminiscent of the Levallois methods for Qadan point production, bladelet production documented in some but not all sites; toolkit: Qadan points, burins, small scrapers and backed pieces (the latter only at some sites)[3]	Rare bone tools, grinding implements
Afian 14-16.8 ka cal BP	A	Technology: mainly oriented towards the production of wide and small elongated products, planimetric conception of debitage with high frequencies of faceted platforms; toolkit: truncations, backed bladelets and geometrics[4]	Grinding stones (Kom Ombo area) and if Makhadma 4 is included in the Afian, bone tools
Sebilian 12.6-16.9 ka cal BP	A, B	'very particular association of lithics'; technology: Discoidal and Levallois cores for the production of flakes; toolkit: truncated and backed flakes, use of the microburin technique	
Isnan 13.2-16.6 ka cal BP	A	Technology: production of flakes and rare blades from single and opposed platform cores; toolkit: high percentage of endscrapers, followed by notches and denticulates, rare backed pieces	Grinding implements
Arkinian (excluding el Adam variant) 11.9-12.8 ka cal BP	B	Bladelet and flake production from single and opposed platform cores, presence of bipolar reduction, stone anvils; numerous backed pieces and endscrapers	Grinding implements, bone spatula

Table 1 – Characteristics of the Late Palaeolithic cultural entities in the Nile Valley (*: after Leplongeon, 2021; **: after Schild and Wendorf, 2010, A = southern Egypt between Sohag and the first cataract, B = Egyptian and Sudanese Nubia between the first and the second cataract; ***: after Schild and Wendorf, 2010 except when mentioned otherwise – [1]characteristics after Vermeersch, 2020 [these characteristics, associated with minimal ages around 25 ka led to an attribution to the later Upper Palaeolithic, rather than the Late Palaeolithic], [2]characteristics after Smith, 1966 and Leplongeon, 2017, [3]characteristics after Usai, 2020, [4]characteristics after Leplongeon, 2017 [note that in this reference the attribution of Makhadma 4 to the Afian is questioned]).

Tabl. 1 *– Caractéristiques des entités culturelles du Paléolithique récent de la Vallée du Nil (* : d'après Leplongeon, 2021 ; ** : d'après Schild et Wendorf, 2010, A = sud de l'Égypte entre Sohag et la première cataracte, B = Nubie égyptienne et soudanaise entre la première et la deuxième cataracte ; *** : d'après Schild et Wendorf, 2010 sauf mentions contraires – [1]caractéristiques d'après Vermeersch, 2020 [ces caractéristiques, associées à un âge minimal autour de 25 ka, ont mené à une attribution de l'assemblage au Paléolithique supérieur récent plutôt qu'au Paléolithique récent], [2]caractéristiques d'après Smith, 1966 et Leplongeon, 2017, [3]caractéristiques d'après Usai, 2020, [4]caractéristiques d'après Leplongeon, 2017 [dans cet article, l'attribution de Makhadma 4 à l'Afien est remise en cause]).*

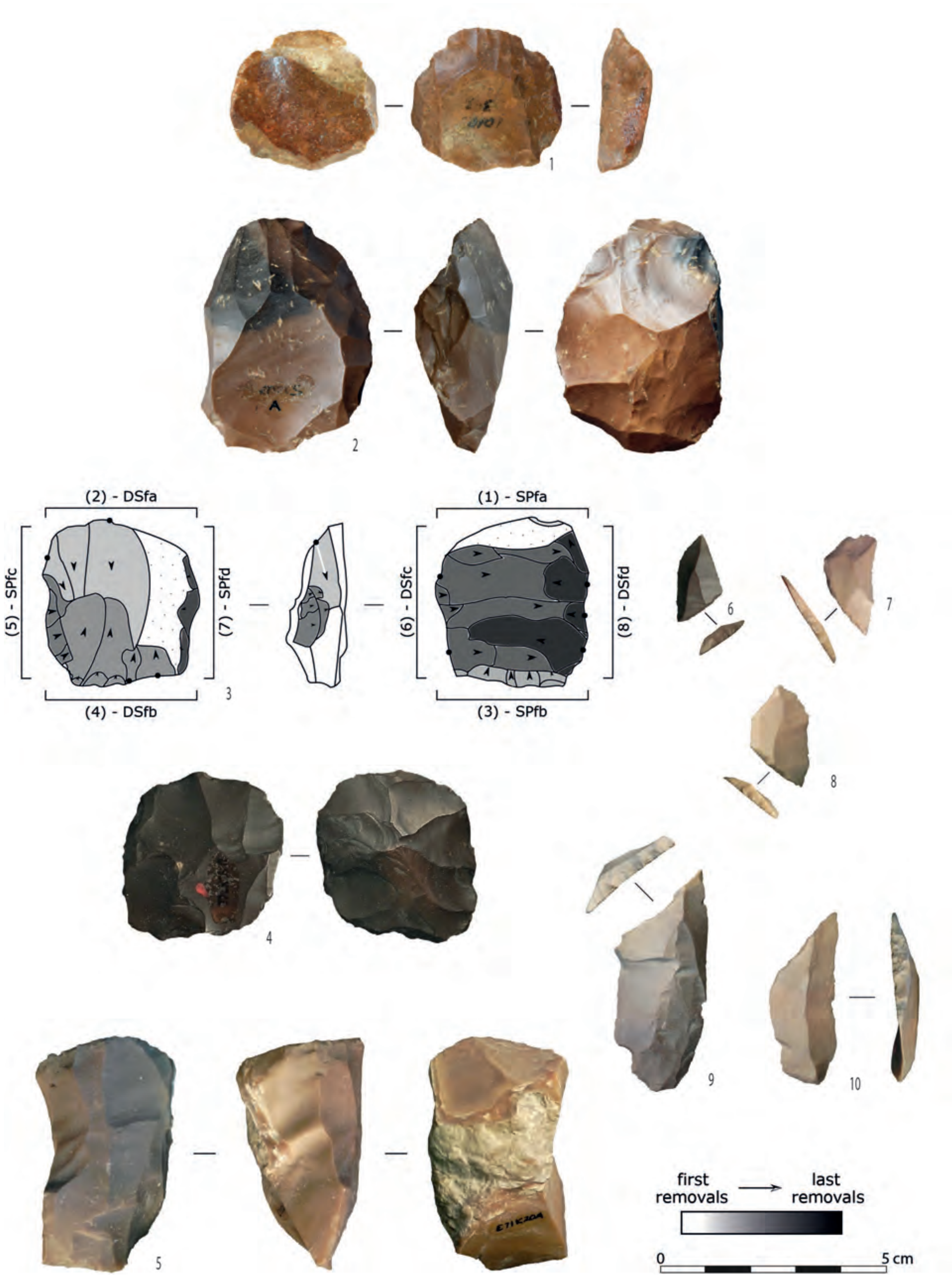

Fig. 8 – Examples of Late Palaeolithic artifacts from the Nile valley. 1: Halfian core from Halfian site 1018; 2: Halfian cores from Levallois Edfouen site E71P1A; 3-4: Orthogonal cores from Alfian site E71K18; 5: Cores with opposed knapping platforms from Silsilian site E71K20; 6-8: Proximal truncations from site E71K18C; 9: Proximal truncation from site E71K20; 10: Backed blade from site E71K20 (photos A. Leplongeon, taken courtesy of the Trustees of the British Museum; 3-10: Leplongeon, 2017).

***Fig. 8** – Exemples d'artefacts du Paléolithique récent de la vallée du Nil. 1 : Nucléus halfien du site halfien 1018 ; 2 : nucléus halfien du site Edfouen à Levallois E71P1A ; 3-4 : nucleus orthogonaux du site Afien E71K18 ; 5 : nucleus à plans de frappe opposés du site silsilien E71K20 ; 6-8 : troncatures proximales du site E71K18C ; 9 : troncature proximale du site E71K20 ; 10 : lame à dos abattu du site E71K20 (clichés A. Leplongeon, avec l'aimable autorisation du British Museum ; 3-10 : Leplongeon, 2017).*

Finally, a third factor for this variability may be linked to the functions of the sites or indeed to their season of occupation (for example Lubell, 1976). However, and in contrast with preceding periods, all sites seem to testify to the presence of similar faunal assemblages, while nevertheless indicating different seasons of occupation (see also Coudert, 2013).

3.4. From the Middle Stone Age to the Late Palaeolithic in the Nile Valley: ruptures and continuity

From the beginning of MIS 3 until the end of the LGM, archaeological data from the Nile Valley can be divided into multiple phases – corresponding to the final phase of the MSA, the UP and the LP – each separated by chronological intervals without any archaeological data, whether due to research biases, to variable conservation conditions or an actual absence of human occupations in the area. The resolution of the available data does not allow us to distinguish between these different hypotheses, and therefore it remains to evaluate the similarities and differences that can be observed in the lithic record during this period. In order to do this, we will rely on elements generally emphasised in attributing an assemblage to the MP-MSA and UP-LP-LSA: the presence of Levallois methods *versus* volumetric blade-bladelet technologies and the emergence of backed pieces.

3.4.1. The Levallois from MIS 3 to the end of the LGM in the Nile Valley: continuity, reinvention, experimentation?

The Levallois and the transition to the Upper Palaeolithic (~ 60-50 kya)

The end of the MSA in the Nile Valley is marked by great variability in Levallois methods (Van Peer, 1991a and 1992), which are often oriented towards producing elongated blanks through bi-directional methods and which frequently involve the minute facetting of the striking platform (high proportions of convex shaped butts or *chapeaux de gendarme*).

The site of Taramsa 1 (Van Peer et al., 2010) is particularly interesting regarding the question of Levallois variability. The site is characterised by multiple trenches dug out of an ancient wadi terrace for the extraction of blocks of chert. It was exploited over a long period that produced an extremely complex stratigraphy. Six main "phases of activity" have been identified, each characterised by multiple lithic assemblages within which numerous refittings were carried out, allowing for a precise analysis of the core reduction methods (Van Peer et al., 2010). Phase I (207 kya) was attributed to the Lupembian, Phase II (dated between 117 ± 10.5 et 88.8 ± 9.5 kya) to an early phase of the Nubian Complex, Phase III – to which is attributed a child burial – to the Nubian Complex (mean age 78.5 ± 5.6 kya), Phase IV (mean age 56.2 ± 5.5 kya) to the Taramsan, Phase V (mean age 40.9 ± 4.5 kya) to the Safahan and finally Phase VI (40.7-45.4 kya cal. BP) to the UP. In particular, the Taramsan is characterised by a specific core reduction method with distinct Levallois characteristics, but deviates from it by the presence of a somewhat peculiar distal striking platform, with more pronounced lateral convexities, and an exploitation plane slightly offset with respect to the intersection plane of the core (fig. 7, nos. 6 and 7). These characteristics, resembling volumetric debitage methods, led to the interpretation that the assemblages of Activity Phase IV and the Taramsan may represent a transition between Levallois production and the volumetric blade production of the Upper Palaeolithic (Van Peer et al., 2010, p. 241). However, it is likely that several "transitional" trajectories existed in parallel, with P. Van Peer et al. (2010, p. 241) suggesting that the production methods in activity Phase V at Taramsa are documenting a distinct transitional trajectory parallel to that seen in Phase IV. A successional relationship is suggested with the Nubian Levallois method for Phase IV and the Safahan Levallois method for Phase V.

Although these data all come from a single site, they seem to indicate that the tendency towards the use of volumetric blade technologies in the Nile Valley was in place from the beginning of MIS 3.

The Levallois in the Upper Palaeolithic (~ 50-25 kya)

The UP in Egypt was seen for a long time as characterised strictly by blade assemblages and the absence of Levallois methods. However, the publication of new sites and new analyses of assemblages attributed to the UP have allowed a certain nuancing of this vision. The characteristics of these assemblages are summarised below.

As already mentioned, the UP in the Nile Valley is represented by a very limited number of sites (Taramsa, Activity Phase VI, NK4, Shuwikhat, E71K9 and El-Abadiya Central Sector, the latter three grouped under the term "Idfuan-Shuwikhatian"). Phase VI at Taramsa 1 is characterised by a blade production method similar to that of the Taramsan (Phase IV), although its volumetric blade character is even more pronounced. This production is associated with the production of Nubian Levallois points (Van Peer et al., 2010, p. 181-182). Nazlet Khater 4 has produced an assemblage that is characterised primarily by volumetric blade production, leading to it being considered as an abrupt rupture with previous industries (Vermeersch et al., 2002a). It is nonetheless interesting to note that certain characteristics less frequent in the assemblage at NK4 are reminiscent of the MSA, such as the presence of flake production using the core surface and the presence of bifacial components (Leplongeon and Pleurdeau, 2011; Vermeersch, 2020). Of the sites attributed to the Shuwikhatian, only Shuwikhat 1 and El Abadiya have been subject to detailed analyses (Vermeersch et al., 2000b). They are characterised primarily by volumetric blade production on cores with opposed striking platforms. While Levallois methods are absent, certain characteristics such as the maintenance of core convexities, the somewhat planar character of the surfaces of exploitation of cores as well as the treatment of the striking platforms (by faceting) is perhaps indicative of a Levallois lineage (Vermeersch et al., 2000b, p. 156,180; here: fig. 7, nos. 8 to 10). However, the blade components of the assemblage, associated with few retouched tools but dominated by end-scrapers, burins and backed pieces have been considered sufficient for attribution of the assemblage to the UP (Vermeersch et al., 2000b; Vermeersch, 2020).

This short synthesis of several assemblages attributed to the UP in the Nile Valley shows that despite the lack of data for MIS 3 and their partial contradiction with the earliest published data on the Egyptian UP, the available archaeological record speaks for a hypothesis of gradual local transitions from Levallois core reduction methods towards volumetric blade core reduction. While their attribution to the UP seems justified by the predominance of blade productions frequently exhibiting a volumetric conception, in our opinion the technological characteristics that appear to be inherited from the Levallois deserve to be underlined.

The Levallois in the Late Palaeolithic (~ 25-15 kya)

One of the interpretations linked to the LP in the Nile Valley seeks to explain the presence (persistence?) of Levallois technologies up until this period (see discussion in Paulissen and Vermeersch, 1987). Faced with new data from the end of the MSA and the UP in the Nile Valley described above, and considering certain elements in continuity with the MSA, this late flourishing of Levallois methods in the Nile Valley should no longer be a surprise, though it nonetheless deserves re-evaluation. Indeed, while we accept that a certain Levallois heritage can be identified within the assemblages of the UP, clearly-defined Levallois methods are indeed much rarer or even absent in certain assemblages. Although many of the industries of the LP in the Nile Valley incorporate Levallois methods in their definition, a critical review of these industries will allow us to nuance this view.

Among the Levallois industries of the LP, only the Kubbaniyan has provided absolute dates and carefully-documented contexts – it is also interesting to note that the Levallois flakes and cores are present in smaller proportions in these assemblages – whereas for the Sebilian and the Gemaian, the stratigraphic integrity of the assemblages has been questioned (for example, Paulissen and Vermeersch, 1987). Sites with clear stratigraphic contexts will be essential in order to consider these industries as definitive parts of the LP.

Other industries exhibiting Levallois core reduction (the Levallois Idfuan and Halfan, see table 1) are characterised by a specific method: the Halfan. “Classic” Levallois debitage is present only in meagre proportions (see also Van Peer, 1991a). The Halfan method was defined by A. Marks (1968a) as a core reduction method for pre-determined flakes, based upon the bi-directional preparation of the core and involving the meticulous crafting of a faceted convex striking platform in addition to the preparation of distal convexities of the core by removing bladelets or elongated flakes (fig. 8, nos. 1 and 2). These steps give the core “the appearance of a Levallois core” (Marks, 1968a, p. 394) and the Halfan method is generally considered to be one of the Levallois methods used in the Nile Valley (Van Peer, 1991a and 1992). The abundance of Halfan cores associated with backed bladelets at certain sites located between the first and second cataracts has led to the definition of the Halfan as a distinct industry (Marks, 1968a). The Halfan method is also documented in other industries from the LP (for example in the Levallois Edfouan). The status of the Halfan method and its place within other Levallois methods are important factors to consider in the debate regarding the persistence of the Levallois into the LP. Indeed, it seems to be the most common method affiliated with the Levallois among LP industries. Determining if and by what means this method derives from other Levallois methods from the MP is critical to evaluate its role within a scenario of the continued existence (and therefore continuity) of the Levallois in the LP.

4. COMPARATIVE LOOK AT THE HORN OF AFRICA AND THE NILE VALLEY

Here, we comparatively evaluate techno-cultural dynamics at the end of the Pleistocene in both the Horn of Africa and the Nile Valley, two regions geographically connected by the Nile basin but whose archaeologies have yet to be interrogated in relation to one another. These dynamics take place in the context of the climatic deterioration of the Last Glacial period, culminating with the LGM, which profoundly affected the landscapes of these areas and exacerbated existing contrasts. In this context, the trajectories that lead to the decline of the MSA and the advent of LSA/UP-LP technical traditions are certainly distinct, though several convergences can also be noted and force us to attempt to interpret the value of this information. Before beginning with this task however, it is worth recalling that the archaeological records of these two regions are chronologically and contextually very disparate.

4.1. Two distinct regions: research bias or age-old reality?

The Horn of Africa and the Nile Valley can be fairly strongly distinguished with regards to the available data for the period between MIS 3 and the end of MIS 2. There are only a few contemporaneous sites in the two regions. A relatively large number of sites are attributed to MIS 3 in the Horn of Africa – or at least they are more numerous than in the Nile Valley – and by contrast very few sites are dated to MIS 2, whereas many sites are known for this period in the Nile Valley (table 2).

This differential chronological distribution of occupations in each of the regions could be seen as reflecting a true complementarity between them, with human populations having favoured one or the other according to the circumstances. However, archaeological data are far from being able to prove such a scenario, and if it is necessary to defend a model, it would undoubtedly be that of the entrenchment of populations within different areas of the Horn of Africa during MIS 3, with its limited zones of mobility (for example limited vertical mobility in mountain habitats). Furthermore, the archaeological record of the Nile Valley speaks for the occupation of sites with very specialised functions (for example for the extraction of raw materials), producing data that are difficult to compare with the Horn of Africa. Finally, the systematic sedimentary and chronological hiatus which covers the period of the LGM in the Horn of Africa (for example at Goda Buticha, Mochena Borago, ADS2 and without a doubt, at other sites interpreted formerly as transitional) presents a major research bias for assessing past reality regarding the differential population of these two regions. Was the Horn really depopulated while the Nile Valley was more densely populated during the LGM? The question remains open for the moment.

Other exacerbating factors demarcating the two regions include the types of known sites for the period, which vary widely from shelters, caves, lake-shore or at high altitude occupations in the Horn, whereas in the Nile Valley they are almost exclusively open air and near water sources.

Furthermore, the available remains for the Horn at the beginning of MIS 1 are primarily lithic artefacts, as many sites show very random – and more often no – preservation of organic remains. In the Nile Valley by contrast, for example in MIS 2, the preservation of organic remains (faunal and plant remains; e.g. traces of rhizome crushing at Wadi Kubbaniya: Hillman et al., 1989) as well as the spatial organisation of sites with the presence of structures (post holes interpreted as fish-smoking structures at Makhadma 4 Kubbaniya: Vermeersch et al., 2000a), enables the relatively extensive reconstruction of human-environment relations in this region. These differences in the nature of the preservation of remains, in addition to limiting the evaluation of behavioural convergences between the two areas, has led to research questions that are necessarily different from one region to the other.

Finally, and perhaps more insidiously, these regions are distinguished from one another by their research traditions, with research in the Horn of Africa following the models of the MSA and LSA developed in and for Africa, while research in the Nile Valley has oscillated between research questions that are distinctly Africanist and those that are turned towards the Near East and Europe, particularly regarding the origins of the UP. The Palaeolithic of the Nile Valley also benefitted from numerous research projects from the 1960s to 1980s, often initiated in the context of the Nubian Campaign and its numerous and ambitious archaeological and geomorphological projects. This contrasts with the scarcity of recent studies in the region, in particular concerning the LP. Inversely, the Horn of Africa has seen a resurgence of research since the 1990s, notably on questions related to the end of the MSA and the beginning of the LSA, a period that is at present neglected in the Nile Valley.

The different research traditions and questions have led to the use of terminologies that are hardly comparable, both in the naming of the industries and for the description of their components. The objective of this comparative overview is not to question the use of a particular nomenclature, but rather to surpass the oftentimes paralyzing obstacles created by divergent terminologies by instead describing the lithic variability at the end of the Upper Pleistocene in the two regions as well as their respective techno-cultural trajectories (table 2).

4.2. Confronting the two regions: trajectories towards new production systems?

Our approach here is to summarise the available data for both regions by chronological phase and by confronting data from both simultaneously, in order to comprehend the processes of change, whether they occurred following ruptures or in continuity.

4.2.1. MIS 5 (~ 130-70 kya)

The MSA at the beginning of the Upper Pleistocene in the Horn of Africa is characterised by the production of flakes, points, and elongated products, essentially by Levallois methods. There is a significant variability of the Levallois methods used, such as the Nubian core reduction at K'one and at ETH-72-6 (if one accepts the attribution of these sites to the beginning of the Upper Pleistocene), the micro-Levallois and micro-Aduma at Aduma, and more generally an implementation of multiple modalities and management types in the Levallois operative schemes within assemblages. Volumetric blade production is also known but remains sporadic, as is the case from the beginning of the MSA.

In parallel, the MSA in the Nile Valley at the beginning of the Upper Pleistocene, and more specifically at the end of MIS 5, corresponds mainly to the Nubian Complex, although the exact chronological extent and technical variability within the latter remain poorly known. It is characterised by the use of Nubian Levallois methods for the production of points, alongside other Levallois methods, namely of recurrent modality and centripetal core management types. The Nubian Complex covers a wide diversity of industries.

4.2.2. MIS 4-beginning of MIS 3 (~ 70-35 kya)

No site in the Horn of Africa has produced absolute dates clearly relating to MIS 4. The beginning of MIS 3 is in contrast increasingly represented, particularly in recent excavations (Goda Buticha, Mochena Borago, Fincha Habera). The MSA here is characterised by significant variability in debitage methods, which are mainly

	MIS 5		MIS 4		MIS 3		MIS 2		Early MIS 1 (15-12ka)	
	NV	**HoA**	**NV**	**HoA**	**NV**	**HoA**	**NV**	**HoA**	**NV**	**HoA**
General Classification	MSA	MSA	MSA	MSA	UP	MSA	LP	MSA / LSA	ND	LSA
Relative density of known sites	+	+	Δ	−	Δ	+	+	Δ	-	+
Flake production from platform cores	+	+	+	ND	Δ	+	+	Δ	ND	Δ
Elongated blank production from platform cores	Δ	Δ	Δ	ND	Δ	Δ	+	+	ND	+
Elongated blank production from volumetric cores	Δ	Δ	+	ND	+	Δ	+	+	ND	+
Bipolar-on-anvil core reduction	-	−	-	ND	-	Δ	Δ	−	ND	-
Levallois core reduction	+	+	+	ND	-	+	Δ	-	ND	-
Technological points	+	+	-	ND	-	+	Δ	+	ND	Δ
Retouched or shaped points	Δ	+	Δ	ND	Δ	+	-	Δ	ND	-
Backed pieces (all dimensions)	-	−	-	ND	Δ	Δ	+	Δ	ND	Δ

These elements may be absent (-), sporadically present/rare (Δ), present/numerous (+), or no data is available (ND).

Table 2 – Table comparing the presence of typo-technological elements discussed in the text between the Nile Valley (NV) and the Horn of Africa (HoA).

Tabl. 2 – *Tableau comparant la présence des éléments typo-technologiques discutés dans le texte entre la vallée du Nil (NV) et la Corne de l'Afrique (HoA).*

planimetric, both Levallois and non-Levallois, with some occurrences of volumetric blade production and bipolar-on-anvil core reduction. Each site has distinct technological characteristics, in which Levallois is not clearly dominant. The production of elongated blanks is more significant than in preceding periods but is still mainly conditioned by planimetric conceptions of core reduction. Backed pieces seem to be present for the first time in the Horn in two MIS 3 sites, though in very small quantities and quite varied forms, and are not necessarily associated with blade industries (Mochena Borago). Retouched and shaped points remain predominant.

In the Nile Valley, the rare data available for MIS 4 and the beginning of MIS 3 in Egypt cover sites that demonstrate a very specific function of raw material extraction, and where technological manifestations of Levallois conceptions verging on volumetric blade production seem to have taken place (Taramsan, Safahan). It is in this respect that these industries are no longer considered as fully integrated into the technical world of the MSA but rather as precursors of a transition towards the UP. Indeed, one of the key sites from this period, NK4, is fully assigned to the UP by the presence of a volumetric approach to core reduction, despite some characteristics reminiscent of a planimetric approach more typical of the MSA, notably in the management of convexities. Similarly, Phase VI at Taramsa is attributed to the Upper Palaeolithic, despite certain characteristics that recall the MSA. The attribution of NK4 or Taramsa (Phase VI) to the UP is based almost exclusively on technological arguments, as the function of these sites (the extraction of raw materials) has led to a very low representation and uncharacteristic toolkits, except for the adzes of NK4. By contrast, in Sudan, the only site dated to the beginning of MIS 3, Affad 23 (~ 55 kya; Osypinska et al*.*, 2020; Osypinski, 2020; Osypinski et al., 2021), is considered as fully MSA, with a very clear use of Levallois methods.

4.2.3. End of MIS 3-MIS 2 pre-LGM (~ 35-25 kya)

Sites in the Horn of Africa that can securely be related to the very end of MIS 3 are DW1, DW4, B1s3 and B4 in the Ziway-Shala basin. These sites have provided blade industries produced following a planimetric approach to core reduction, most often through a bi-directional Levallois method, and the products of which show carefully faceted platforms (fig. 4). Since cores are all cores-on-flakes and therefore quite flat, the management of the lateral convexities was achieved by *débordant* removals, often highly inclined, having laterally taken away the intersection plane between the two surfaces. This type of management cannot be mistaken for a volumetric conception of core reduction, and moreover, no backed pieces have been recovered from these sites. In contrast, the site of Aga Dima S2, also in the Ziway-Shala basin and dated to the very beginning of MIS 2 has provided an assemblage characterised by similar types of productions, although this time with the introduction of strongly curved geometries on some of the cores. Alongside a volumetric management of the cores, the site has produced a toolkit composed of points associated with backed pieces of diverse morpho-dimensional characteristics, as well as burins.

In the Nile Valley, only a few sites have been dated to the end of MIS 3 and the beginning of MIS 2. With minimum ages around 25 kya, the Shuwikhatian-Edfouan industry, represented principally by three sites, belongs to this period, namely Shuwikhat 1, El Abadiya 1 and E71K9. Volumetric blade schemes are dominant here, though they include additional characteristics that recall planimetric conceptions and Levallois core reduction methods (management of convexities and preparation of striking platforms). These assemblages have produced a few backed pieces, but in relatively small quantities, and their manufacture is described as quite irregular.

4.2.4. The second part of MIS 2 (~ 25-15 kya)

In the Horn of Africa, only the site of Sodicho, whose material is currently in the process of being published, can be attributed to this period (Hensel et al., 2021). It is therefore necessary to jump forward several millennia to the beginning of MIS 1 in order to identify occupations again, at least in the Ziway-Shala basin and perhaps at Besaka (Habte, 2020). These latter areas have produced industries that are, this time, fully LSA with volumetric blade-bladelet productions, backed pieces and burins, with no Levallois core reduction, but which also occasionally provide a few flake cores (notably at Besaka). This is followed during the Holocene by highly diversified LSA technologies accompanied by equally disparate subsistence modes.

On the contrary, numerous sites attributed to the LP are documented and divided into multiple industries in the Nile Valley (table 1). These sites are characterised by highly diverse productions, generally blade-bladelet productions, with debitage methods that are both volumetric and planimetric. Volumetric blade productions are occasionally associated with Levallois core reduction methods (Kubbaniyan) or with methods that seem to derive from the Levallois (Halfan), whose descent from former production systems is not evident due to the poor chronological resolution. Backed pieces are abundant and tend to dominate the toolkit. They exhibit a significant variability and are often not highly standardised, even if the retouch type appears to be more regular than for MIS 3 sites. It is possible that the micro-burin technique is represented, though with a very limited or even purely accidental usage (Leplongeon, 2017; Leplongeon and Goring-Morris, 2018). The evolution of these industries is unknown given the poor archaeological data from the end of MIS 2 and the beginning of MIS 1 in the Nile Valley (with the possible exception of Jebel Sahaba; see discussions in Vermeersch and Van Neer, 2015; Crèvecœur et al., 2021; Leplongeon, 2021).

In the end, while stark contrasts remain in the archaeological records of these two regions, the above synthesis of data allows us to go beyond the incompatibility of comparisons between them, and instead to propose avenues of convergences between their cultural trajectories as well as to sketch more precisely the technological and chronological evidences defining their divergences.

4.3. Similarities between the two regions: parallel but asynchronous processes?

Beyond the marked differences in the archaeological records of the two regions characterised by gaps during which few or no sites are known, it is possible to identify parallel processes, at least regarding the development of industries with technical principles typical of the LSA or of the UP-LP.

At the beginning of the Upper Pleistocene, the MSA of the two regions can be characterised by a dominance of Levallois conceptions, which are resolutely central to the lithic productions and exhibit a wide range of variability. This diversity of Levallois productions leads to a mosaic representation of industries with distinct characteristics, centering around a common conception of the geometry of core reduction (opposed hierarchized surfaces, removals parallel to the intersection plane, and the importance of the preparation of the surfaces).

The conceptions of core reduction in the two regions become increasingly varied as Levallois methods decrease in importance at most sites. Industries with elongated blanks become more common, and from the end of MIS 4 the Nile Valley sees a move towards resolutely laminar and volumetric industries. The strong contrasts between industries within each of these regions reinforces the image of a mosaic of technical practices. The practices in some regions demonstrate important changes from a conceptual point of view regarding the production modes as well as in the toolkit, with the introduction of the concept of backing during MIS 3. This change however does not represent a stark technical rupture since, in both regions, the first volumetric blade industries also retain some characteristics that seem to have been inherited from the Levallois (ADS2, Shuwikhat 1).

This common trend of local developments leading to the replacement of the Levallois which was dominated by volumetric conceptions in both regions, follows a gradual though asynchronous pattern in both regions (MIS 4-3 in the Nile Valley, end of MIS 3-beginning of MIS 2 in the Horn). The fact that these changes were gradual has contributed to the adoption of different terminologies in the respective regions, depending on whether the interpretations emphasised the evidence for continuity (maintaining the assignment of the industries to the MSA in the Horn) or evidence that marks a break with previous technical traditions (attribution of the industries to the UP in the Nile Valley). It is possible that gradual trajectories towards new conceptions of core reduction and of the toolkit as a whole are rooted in the diversification of industries marking the end of the MSA, which is itself perhaps linked to the climatic conditions of the Last Glacial period. This diversification may indeed be seen as reflecting a strong adaptive dynamic in which technical systems had to rapidly be reinvented while remaining flexible in order to deal with increasingly unstable environmental situations. One can envision that the climate-related pressures that occurred asynchronously and in different ways in each region also led to techno-cultural changes taking place at different moments.

This asynchrony in the trajectories of change, despite some convergence in their processes, is again encountered at the time of the emergence of the LSA and the LP, during or after the LGM in both regions. However, the more pronounced discrepancies, and even the more significant break between the very end of the MSA and the early LSA sites, are exacerbated in the Horn of Africa due to the absence of archaeological data for the LGM period, corresponding to a hiatus of nearly 10,000 years. In the Horn, just after the LGM, Ethiopian sites of the Late Glacial – final Pleistocene – demonstrate the emergence of clearly laminar industries, with backed pieces and burins, and without any Levallois (Ménard et al., this volume). These were once grouped under the term of “Ethiopian Blade Tradition” (Clark and Williams, 1978) and are considered discontinuous with the varied industries of the Holocene LSA that follows (Ménard and Bon, 2015).

The Nile Valley during MIS 2 shows the development of original industries with a significant variability for a restricted chronological period and in a limited area. The question of their continuity with previous industries – the MSA in particular, based on the presence of Levallois conceptions during MIS 2 – remains open and difficult to resolve given the small number of known sites for the end of MIS 3. However, the evidence of profound conceptual changes towards blade and volumetric core reduction processes as early as MIS 4 in the Nile Valley do not allow us to reject the hypothesis of a sporadic reinvention of Levallois methods or at least methods recalling the Levallois during MIS 2 (Halfan). Several authors have suggested exterior influences on the development of the variability observed in MIS 2 in the Nile Valley through contacts with Northwestern Africa (Phillips, 1972 and 1973; Close, 1978 and 2002) or the Levant (Schmidt, 1996). In this respect, a recent genetic study based on ancient DNA from individuals from Taforalt (~ 15 kya), Morocco, indicates the presence of genetic interactions between the populations of northern Africa and those of the Levant at the end of the Pleistocene as well as a Western, Central, and Southern African ancestry for individuals from Taforalt (Van de Loosdrecht et al., 2018). These results suggest interactions along the Mediterranean at the end of the Pleistocene, while the role of the Nile Valley in these interactions remains to be clarified. Systematic comparisons of archaeological data between these regions are still rare (Leplongeon and Goring-Morris, 2018) and in the absence of ancient DNA from human remains in the Nile Valley, the question remains open. It is interesting to note that LSA sites documented at the beginning of the Holocene in the Horn of Africa (Ménard et al., 2014; Khalidi et al., 2020) also show the development of highly varied industries, close in both chronology and geography, and which present, as in the Nile Valley, highly contrasting modes of subsistence (also see Coudert, 2013).

It is tempting to draw parallels between the processes of change occurring in the two regions, even if they proceed according to significantly different timings. In each case, local developments within the MSA towards volumetric blade production, occasionally associated with a toolkit including backed pieces, are followed by distinctive changes marked by a growing diversification of industries. And it is only once this process was completed at the extreme end of the Pleistocene for the Horn – and perhaps as early as the beginning of MIS 2 in the Nile Valley – that we observe that the technical and behavioural universes of the MSA are definitively over. What comes out of this synthesis, is that despite each region presenting unique technical developments, there are similarities in the processes of change at the conceptual level regarding the lithic productions and through the lens of their evolution in the long-term. From this perspective, it is not so much a question of estimating whether ruptures occurred at exactly the same time, but rather whether they describe a similar dynamic of change. As a result, it appears that, without being able to assert the exact mechanisms of the influence of the “Big Dry” on the behaviour of prehistoric populations, it is nonetheless clear that in its broad chronological acceptance, this climatic phenomenon accompanied and undoubtedly amplified the restructuring of their technical worlds, as early as its beginning at the end of the MSA. And while these two regions have different archaeological records and signatures, it is clear from their comparison that their general trajectories can be brought closer to one another, not in the rhythm of change strictly speaking but in the direction of the processes of technological changes over time.

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Living the High Life? Prehistoric Occupation of High-Altitude Environments in Ethiopia

Une vie de haute volée ? L'utilisation des environnements de haute montagne en Éthiopie

Ralf Vogelsang

Abstract: On the one hand, high-altitude mountain habitats are often regarded as unfavourable for sustained human occupation, due to the challenging environmental stress in these landscapes for the human body. On the other hand, tropical highlands in Africa are suggested as potential refugia during times of climate deterioration. However, archaeological surveys in these areas were virtually non-existent. Extensive archaeological research during the last decade in the high-altitude regions of Ethiopia has fundamentally changed our understanding of prehistoric occupations in these areas. It is now known that these ecozones had been part of the human habitat at least since the emergence of *Homo sapiens*. High altitude landscapes were used for short-term, task-specific trips of small groups. However, they have also been used for longer periods as regular settlement places. The advantages of high-altitude biomes are the relative abundance of water and compressed altitudinal ecozones offering a wide spectrum of natural resources. For these reasons, highlands have also been used as retreats during times of environmental stress. However, climatic deterioration was not the main trigger for the occupation of high-altitude regions. They were also used during favourable environmental conditions as part of larger settlement areas that also included lowland regions or were at least part of exchange networks.
Keywords: Ethiopia, high altitude environment, Early Stone Age, Middle Stone Age, Later Stone Age, refugium, landscape archaeology.

Résumé : Les habitats de haute montagne sont souvent considérés comme défavorables pour une installation permanente, à cause du stress subi par le corps humain dans ce type d'environnement. Cependant, les hautes terres tropicales africaines sont perçus comme des refuges potentiels pendant les périodes des détériorations climatiques. Par ailleurs, les prospections archéologiques dans ces régions sont quasiment inexistantes. Des recherches archéologiques extensives menées depuis une dizaine d'années dans les régions des hauts plateaux d'Éthiopie ont fondamentalement changé notre compréhension des occupations dans ces zones. On sait maintenant que ces domaines biogéographiques font partie des habitats humains au moins depuis l'apparition d'*Homo sapiens*. De petits groupes y faisaient des excursions de courte durée pour y pratiquer des activités spécifiques, mais, régulièrement, ils y effectuaient aussi des séjours de plus longue durée. Les avantages des biomes de haute altitude sont l'abondance relative d'eau et des étages biogéographiques compressés qui présentent une vaste gamme des ressources naturelles. Pour cette raison, les hautes terres étaient utilisées aussi comme lieux de repli pendant les périodes de stress environnemental. Cependant, elles ont été aussi utilisées pendant des périodes aux conditions environnementales plus favorables, uand elles faisaient partie soit de régions d'occupation plus vastes avec des plaines, soit de réseaux d'échanges..
Mots-clés : Éthiopie, environnement de haute altitude, Early Stone Age, Middle Stone Age, Later Stone Age, refuge, archéologie du paysage.

INTRODUCTION: THE AFRICAN HIGHLAND DICHOTOMY

There is an interesting discrepancy regarding the occupation of high-altitude regions. On the one hand, high altitude mountain habitats are challenging for human physiology and therefore regarded as unfavourable for sustained human occupation (fig. 1, B). The most prominent phenomenon is the prevalence of high-altitude hypoxia. Other stresses and strains are increased solar radiation, water loss and metabolic rates (West et al., 2007). On the other hand, orographic rainfall, reaching a maximum at an altitude between 2,000 m and 2,500 m (Camberlin, 2019) and the ability to capture atmospheric water from fog and low-level clouds (Los et al., 2019) are the cause of higher precipitation rates in the tropical highlands of Africa in comparison to the surrounding lowlands. Due to the catchment of runoff water and high storage capacities, mountains act as important water reservoirs (fig. 1, C and fig. 2, C). Therefore, these regions are considered as favourable areas and potential refugia during arid periods such as the Last Glacial Maximum (LGM; Basell, 2008; Brandt et al., 2012; Steward and Stringer, 2012).

This discrepancy and the general character of prehistoric human occupations of Ethiopian high-altitude regions are the topics of this paper. In doing so, we will look at three major questions:

- What is the earliest evidence for human exploitation of the Ethiopian high-altitude environments?
- Is climate a trigger for sustained occupation and were highlands used as a retreat (refugium) during arid periods?
- Are high altitude regions only used for specific tasks, such as hunting and collecting of raw materials, plants and honey or are they regular settlement areas?

Prior to that, a definition of our understanding of two key-terms is necessary.

High altitude regions (highlands): the term “high altitude regions” can be defined using different parameters. For the purpose of this paper, the impact of high altitude on the human body is the salient factor and therefore, the term is used from A. J. Murray (2016): “The defining feature of the high altitude environments is sustained hypobaric hypoxia.” Native lowlanders experience altitude oxygen starvation from an elevation of 2,500 m above sea level (m a.s.l.) onwards but altitude sickness and mild tissue hypoxia are already common at around 2,000 m a.s.l. (Dietz and Hackett, 2013). This is also in round terms the lower limit for our classification of archaeological sites as a high-altitude site[(1)].

Refugia: we use the term in its initial conception for “regions where elements of the modern flora and fauna might have survived glacial periods with greatly reduced numbers and distribution” (Bennet and Provan, 2008, p. 2450). Broadly synchronous to glacial periods at high latitudes and comparable in their effects on species distribution and abundance are arid to hyper-arid environmental conditions in tropical regions. Classical refugia are areas around the margins of an ecological region. One particular response to climatic change, which is of special importance for this paper, is altitudinal shifts in mountainous regions (Bennet and Provan, 2008, p. 2451).

The hypothesis of a Late Pleistocene human refugium in the south-west Ethiopian highlands was first formulated by S. Brandt and colleagues (2007) and discussed for the Greater East African Region by L. S. Basell (2008). Other related research examines the role of refugia in the human expansion out-of-Africa from an evolutionary biogeographical perspective (Stewart and Stringer, 2012).

1. WHEN DID HOMININS FIRST OCCUPY TROPICAL HIGHLANDS?

Due to the challenges of highlands for the human physiology, it is parsimonious to assume that humans would only be pushed into such conditions by decreasing terrestrial resources in the lowlands following rapid population increase or climate crisis. In general, the colonization of highlands is regarded as a recent phenomenon (e.g. Aldenderfer, 2014) and high-altitude ecosystems are perceived as natural environments, unaffected by human influence. Even recent global change synopses (Ellis et al., 2010) state low level and late human transformation for tropical highlands. This general assumption had first been contradicted by evidence from the site Gadeb (De La Torre, 2011) that is now supported by recent discoveries from Mount Dendi.

1.1 Stone Age occupation of Mount Dendi

Approximately 100 km west of Addis Ababa on the west central Ethiopian plateau rises Mount Dendi, a silicic volcanic complex with a maximum altitude of 3,270 m a.s.l (fig. 1, A1 and fig. 3, C). A notable feature of the almost elliptical caldera is the presence of two lakes formed within the central depression (fig. 3, A and B). A large number of springs in the steep slopes of the caldera drain into the lakes. The current aquatic abundance is recharged by the smaller “Belg” rains from February to April and the heavier “Keremt” rainy season from June to September with an annual mean precipitation of about 1,400 mm (Degefu et al., 2014).

An archaeological survey associated with coring activities in the crater lakes by the University of Cologne’s CRC 806 research group in April 2012 (Wagner et al., 2018), led to the first discovery of Stone Age artefacts in the Dendi caldera and initiated further surveys in 2012 and 2015. The survey routes covered the western half of the caldera and the surrounding slopes, resulting in 82 archaeological sites ranging typologically from Early to Later Stone Age (fig. 3, B). In addition, three obsidian outcrops have been located, which have been exploited for the production of the prehistoric stone

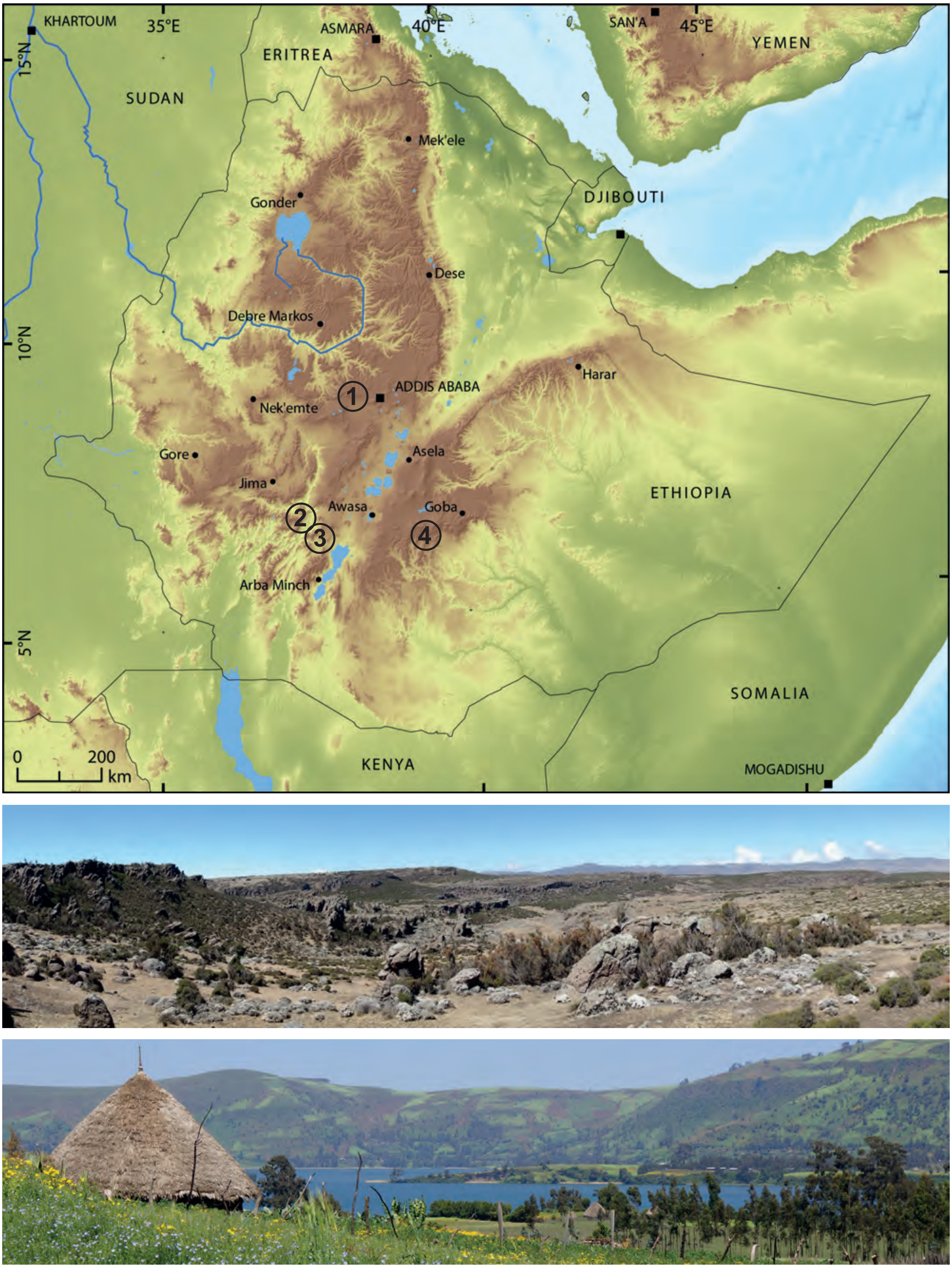


Fig. 1 – Regional map with sites listed in text: Mount Dendi (A1), Mount Sodicho (A2), Mount Damota (A3), Bale Mountains (A4); the harsh environment of the Sanetti Plateau/Bale Mountains (B; ~ 4,000 m a.s.l.); flowering meadows at the shores of the Dendi lakes (C; ~ 3,000 m a.s.l.).

Fig. 1 *– Carte de la région avec les sites mentionnés dans le texte : mont Dendi (A1), mont Sodicho (A2), mont Damota (A3), montagnes du Bale (A4) ; l'environnement rude du plateau Sanetti, montagnes du Bale (B ; ~ 4 000 m d'altitude) ; prairies fleuries sur les rives des lacs de Dendi (C ; ~ 3 000 m d'altitude).*

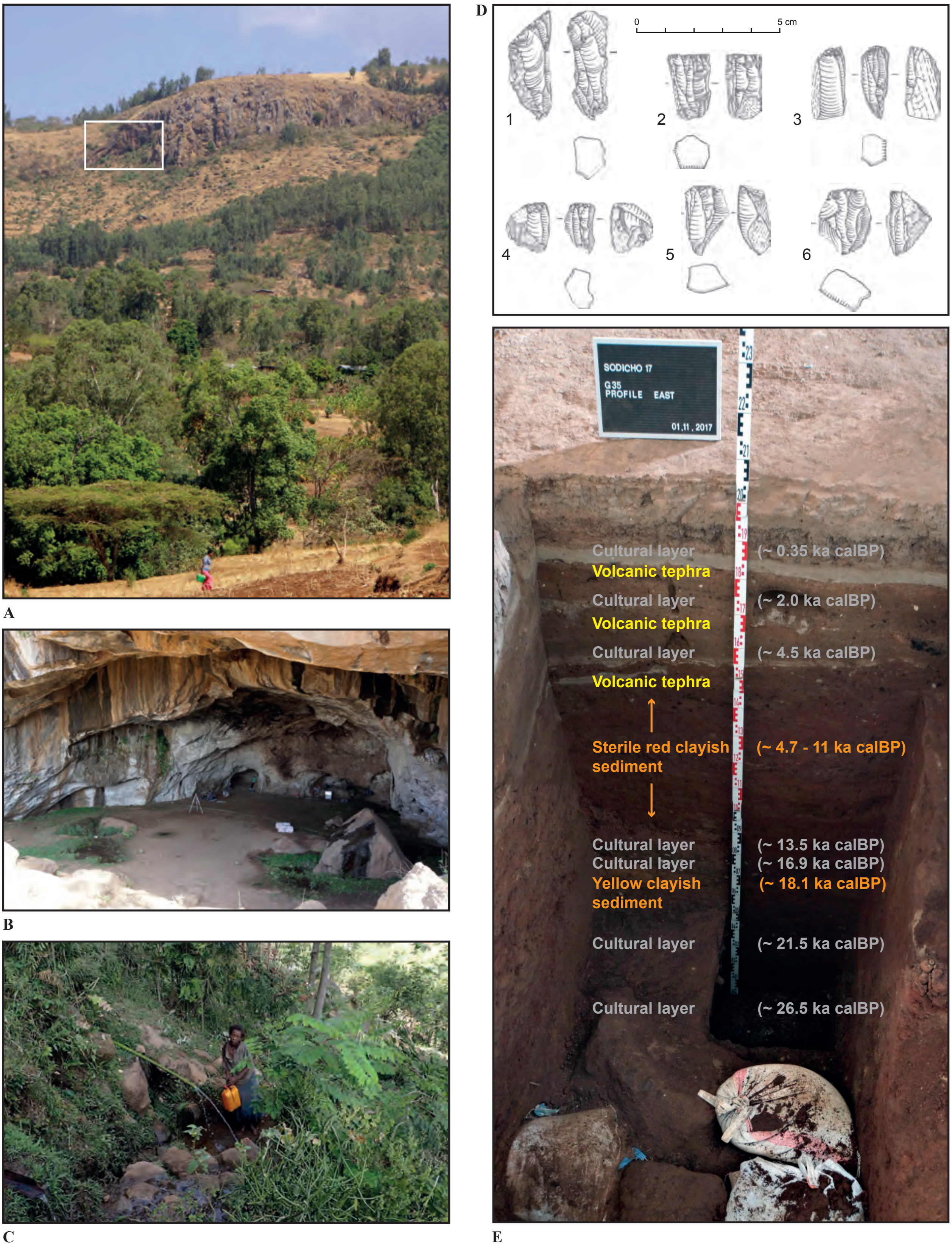


Fig. 2 – Mount Sodicho: The rock shelter Sodicho (A; white rectangle); interior of the rock-shelter with excavation trench (B); one of the many springs of Mount Sodicho (C); bladelett cores from the Late Pleistocene layers (D); profile G35 east with a sequence of cultural layers, volcanic tephra and clayish sediments (E).

***Fig. 2** – Mont Sodicho : l'abri Sodicho (A ; rectangle blanc) ; intérieur de l'abri avec la coupe du secteur fouillé (B) ; une des nombreuses sources du mont Sodicho (C) ; nucléus à lamelles provenant des couches du Pléistocène supérieur (D) ; coupe G35 est avec une séquence de couches anthropiques, de tephra volcanique et de sédiments argileux (E).*

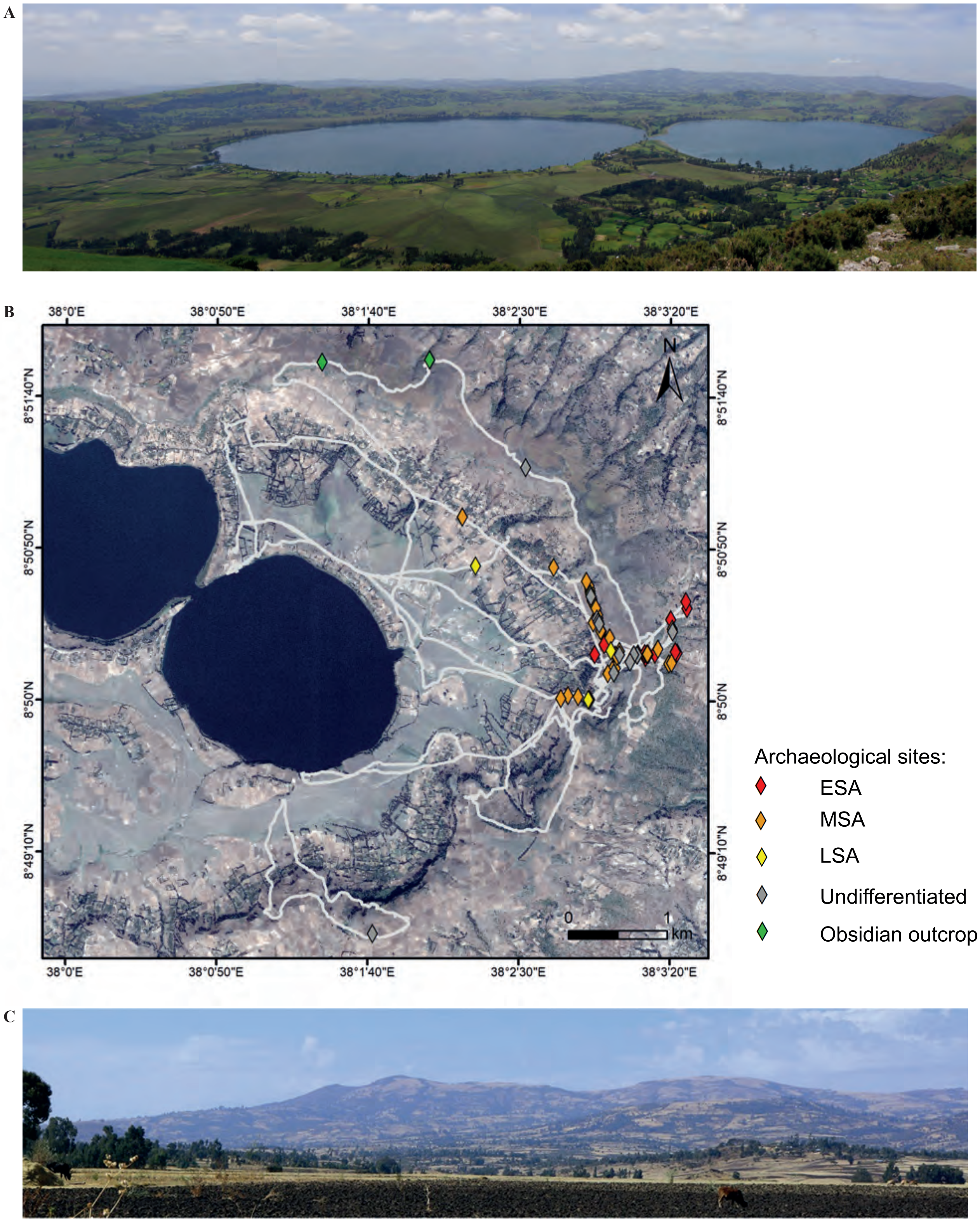


Fig. 3 – Mount Dendi: View of the two crater lakes within the caldera (A); map showing the survey routes and the location of archaeological sites (B); view of Mount Dendi, looking west (C).

Fig. 3 *– Mont Dendi : vue des deux lacs de cratère à l'intérieur de la caldeira (A) ; carte montrant les itinéraires de prospection et l'emplacement des sites archéologiques (B) ; vue du mont Dendi, vers l'ouest (C).*

artefacts (pers. comm. B. Nash). Obsidian is nearly the exclusively used raw material to produce stone artefacts during all Prehistoric periods.

1.1.1 The Later Stone Age occupation of Mount Dendi

The Later Stone Age (LSA) is the period of the most recent prehistoric occupation but is only represented by three surface sites. Although diagnostic LSA single finds have been hard to detect because they are generally small in size, the absence of larger scatters of artefacts from this period suggests only ephemeral human presence on the mountain. However, a test excavation in the small rock-shelter DEN12-A01 (fig. 4, A) proves repeated habitation in a high-altitude region from the Early Holocene until historical times in the uppermost layer A1 (fig. 4, B and D; Schepers et al., 2020). The basal, and up to now undated, horizon D has a probable *terminus post quem* of 10200 cal. BP. This is the age of a 2 m-thick tephra layer revealed in a sediment record from the Dendi lakes (Wagner et al., 2018). Evidence of this massive eruption is missing in the rock shelter sediments, suggesting a later deposition of the preserved layers. The oldest date comes from horizon C (7360 years cal. BP) and is of special interest, because there is no published contemporaneous archaeological assemblage from the Ethiopian Rift-Valley or the southwest Ethiopian highlands (Foerster et al*.,* 2015). The date verifies the settlement of the shelter in between two drier spells of the AHP. Starting around 6000 years ago increasing aridification leads to the end of the African Humid Period (AHP). Two dates of 4720 and 5390 cal. BP classify horizon B in this phase. LSA horizon A2 has an age of about 900 years cal. BP, that also dates the earliest appearance of pottery at the site and is separated by a hiatus of 3000 years from the underlying occupations. Charcoal dates around 1800 years cal. BP from a fluvial channel indicate erosional activities around that time that might have destroyed archaeological evidence from the intermediate period.

The surface and the basal archaeological assemblages (A1 and D) are characterized by the virtual absence of formal tools but a high number of flakes and bladelets with edge damage that might be the result of use-wear. Typical for the other three archaeological horizons is a restricted spectrum of tool types with an emphasis on micro-points and segments (fig. 4, C), which were used as projectile insets and are indicative of hunting equipment (e.g. Clark, 1977; Lombard and Pargeter, 2008; Lombard, 2015). The restricted tool-spectrum points to short-term stays of small groups of hunters, as also suggested by the presence of only wild species among faunal remains. Hunting trips might have been combined with other activities, such as collecting honey and plants or the sourcing of obsidian from the raw material outcrops on top of the mountain. In this way, foragers may have exploited a wider spectrum of resources than the archaeological record suggests.

The correlation of the settlement phases with the general climatic model for south-western Ethiopia verifies the human presence at Mount Dendi during the phase of aridification at the end of the AHP (fig. 4, D). Climatic evidence from two cores from the Dendi crater lakes shows that the effect of this climatic deterioration seems to be less distinct on the local scale (Wagner et al., 2018). This is an interesting advantage of location and might explain the occupation of highlands if it is a general effect that could be confirmed from other high-altitude regions.

1.1.2 The Middle Stone Age occupation of Mount Dendi

A total of 34 sites were classified as Middle Stone Age (MSA) based on stone tool typology especially different kinds of points (fig. 5, C1 to C3 and C5), and based on technological features, such as Levallois reduction strategy and blade production. Remarkable is the distribution of MSA sites in a row like pearls on a string along the 3,000 m contour line. If this connection reflects an old shoreline of the lake(s) has still to be clarified (fig. 5, A).

The characteristic tool category "points" can be subgrouped into bifacially retouched points (n = 10), unifacially retouched points (n = 9), edge-retouched points (n = 3) and unretouched Levallois-points (n = 5). Except for the edge-retouched points, the functionality of all other points as projectile armatures is suggested by a simple ballistics measure, the Tip Cross-Sectional Area (TCSA; see Shea, 2006, p. 224, fig. 1). The values for the facially retouched points and the Levallois-points are within the range of spearheads (Thomas, 1978; Sisk and Shea, 2011). A use as hunting equipment may be supported by the numerous single finds of points that might be evidence of unsuccessful throws. Comparable to the LSA period, the area seems to have been predominantly used for hunting expeditions. However, some larger clusters of MSA finds with a heterogenous spectrum of tool types, indicating diverse activities, might be the result of longer settlement events.

1.1.3. The Early Stone Age occupation of Mount Dendi

The occurrence of large bifacially retouched tools, such as different forms of handaxes (fig. 5, E), but also cleavers, scrapers and bifacial knifes resulted in the classification of 21 sites to the Early Stone Age (ESA) period. ESA sites are especially abundant in areas affected by gully erosion (fig. 5, B and D). Of special importance is the site DEN12-A02 with large bifaces partly in stratigraphical context that is located at an altitude of 3,000 m a.s.l. (Vogelsang et al*.,* 2018). Road construction created three artificial terraces that cut the artefact bearing deposits (fig. 6, A). The provenience of the ESA stone tools from the wall of the middle terrace could be verified by the excavation of a test-trench that yielded several flakes and one handaxe (fig. 6, B and D). The spectrum of the standardised tool-types is heterogenous, with different forms

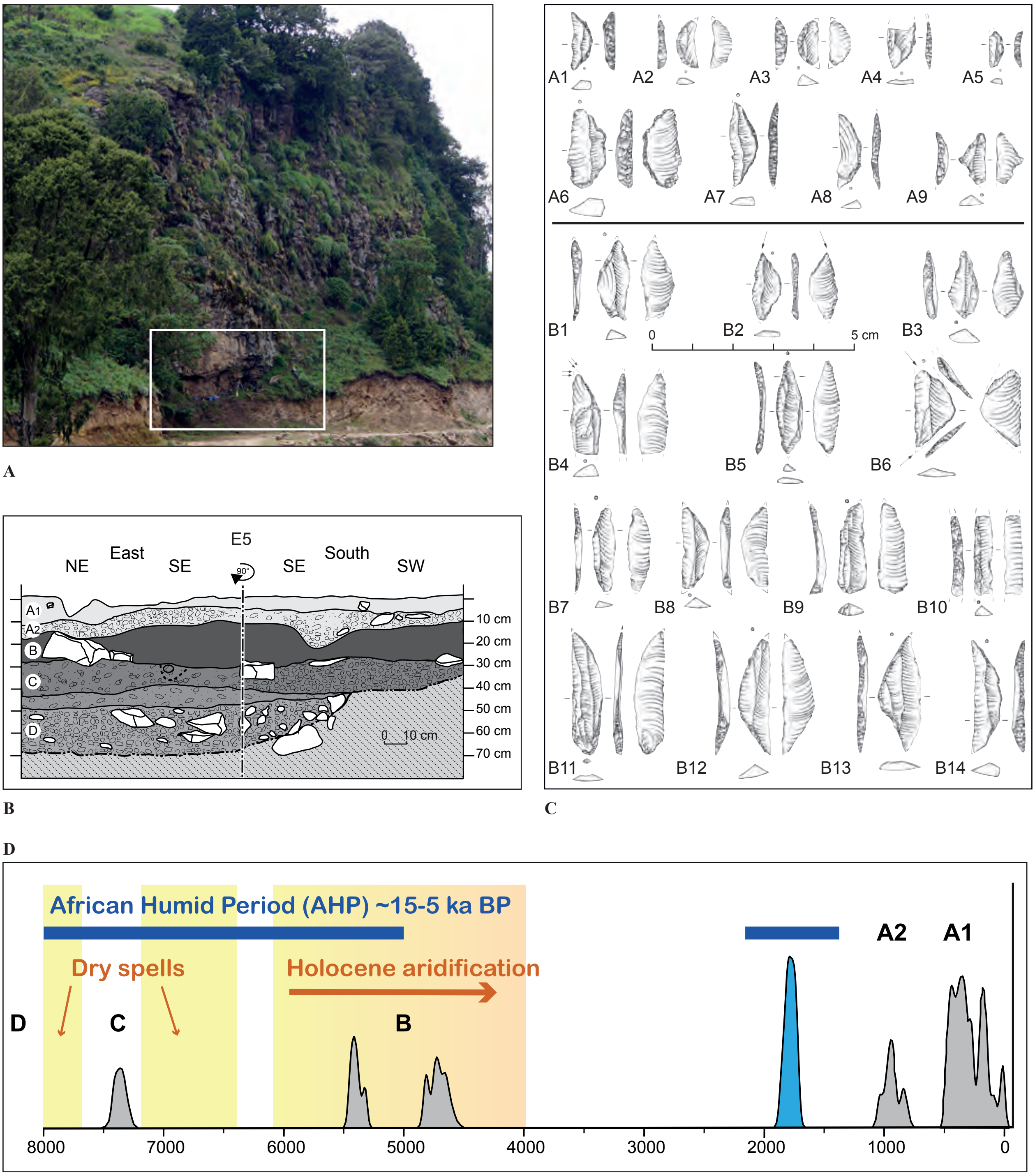


Fig. 4 – Mount Dendi: A) the rock shelter DEN12-A01 (white rectangle); B) section drawing with cultural layers A1 to D; C) backed microliths horizon A and B: micro-segments (A1, A2 and A4), micro-segment with crossed backing (A3), very small segment (A5), large segment (A6), long micro-double-points, unilaterally retouched (A7, A8, B5, B12 and B14), isosceles triangles (A9, B6 and B13), elongated trapeze, isosceles with straight truncation (B1, B11 and B8), segment with curved end (B2), alternately, bilaterally retouched micro-point (B3), long micro-points, unilaterally retouched (B4, B7 and B9), (broken) backed blade (B10); D) distribution of AMS-dates and their correlation with climatic phases (graph with CalPal 2016.2: Weninger and Jöris, 2008; climatic data: Foerster et al., 2015).

Fig. 4 *– Mont Dendi : A) l'abri DEN12-A01 (rectangle blanc) ; B) coupe avec les couches anthropiques A1 à D ; C) pièces microlithiques à dos couches A et B : micro-segments de cercles (A1, A2 et A4), micro-segment de cercle à dos croisé (A3), très petit segment de cercle (A5), grand segment de cercle (A6), micro double pointes longues, retouchées unilatéralement (A7, A8, B5, B12 et B14), triangles isocèles (A9, B6 et B13), trapèzes allongés, isocèles avec troncature droite (B1, B11 et B8), micro-segment de cercle avec extrémité recourbée (B2), micro-pointe retouchée de façon alterne (B3), micro-pointes longues, retouchées unilatéralement (B4, B7 et B9), lamelle à bord abattu [brisée] (B10) ; D) distribution des dates AMS et leur corrélation avec les phases climatiques (graphique réalisé avec CalPal 2016.2 : Weninger et Jöris, 2008 ; données climatiques : Foerster* et al.*, 2015).*

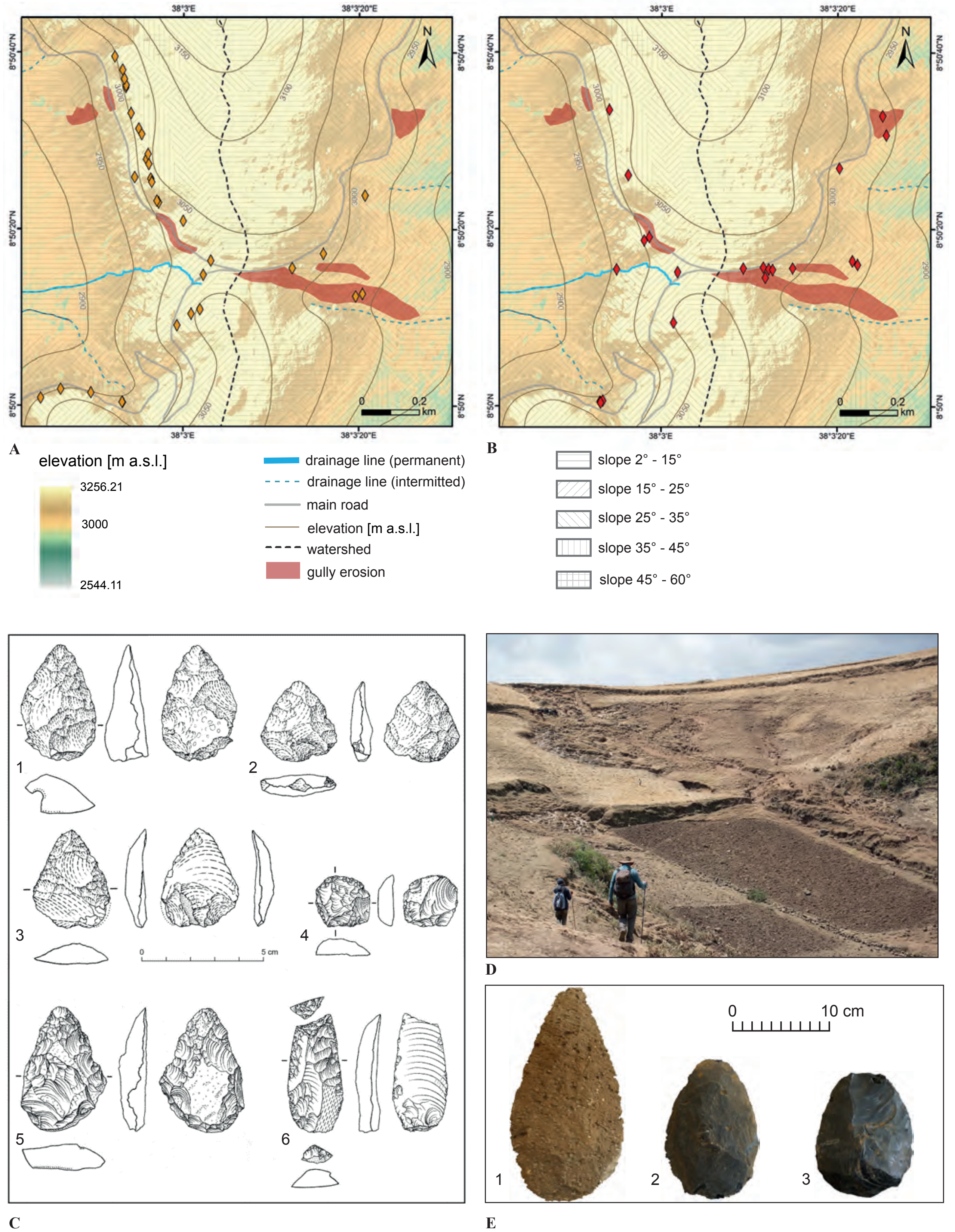


Fig. 5 – Mount Dendi: Distribution of MSA sites (A); distribution of ESA sites (B); MSA stone tools (C): bifacially retouched points (1 to 3 and 5), Levallois core (4), double side-scraper with steep end-retouch (6); area affected by gully erosion (D); handaxes from surface sites in different states of preservation (E).

***Fig. 5** – Mont Dendi : distribution des sites MSA (A) ; distribution des sites ESA (B) ; industrie lithique du MSA (C) : pointes à retouche bifaciale (1 à 3 et 5), nucléus Levallois (4), racloir double à troncature abrupte (6) ; zone affectée d'une érosion par ravinement (D) ; bifaces provenant de la surface, en différents états de conservation (E).*

of handaxes, a cleaver, two leaf-shaped scrapers and one backed knife (fig. 6, C). However, the similar operational sequence (*chaînes opératoires*) of all modified tools indicates a closed association of the finds. Facial shaping was first finished on one face and then on the other. In a last step, lateral thinning and edge retouch were performed for the preparation of the working edges (Vogelsang et al., 2018, fig. 4). The technological similarity of the production process suggests a close temporal connection of the assemblage. The diversity of tools speaks against an interpretation as a task specific site, but is more in favour of a settlement site. In addition, the heterogeneous tool-type spectrum gives a first indication for the chronological classification of the assemblage to the Late Acheulean. This is supported by the high level of knapping skills and the comparatively small size of the artefacts (Vogelsang et al., 2018, p. 306-309). The most approximating assemblage in Ethiopia is the site Mieso 31 (De La Torre et al., 2014) that is dated around 212 ka ago and marks the latest evidence of the ESA in Eastern Africa. The earliest securely dated site is Hugub Bed with an age of 600 and 500 ka (Gilbert et al., 2016). DEN12-A02 can roughly be dated in the range between these two limits, which makes it the highest located Acheulean site worldwide and marks the beginning of the settlement of high-altitude regions. Consequently, hominins might have settled in high altitude regions already before the advance of *Homo sapiens sapiens*. This would question the concept of modern humans' superiority in a wide range of domains, such as subsistence strategies and hunting equipment in comparison to extinct hominins.

2. WERE HIGHLANDS USED AS A RETREAT (REFUGIUM) DURING ARID PERIODS?

Today, the south-west Ethiopian highlands are a region classified as humid with an annual precipitation of 1,189-1,711 mm, that is in some parts even higher (Berhanu et al., 2013, table 3, fig. 6). The south-west Ethiopian highlands refugium hypothesis is based on the assumption that the annual precipitation, which is the highest average amount in the Horn of Africa today and are significantly higher in this region than in the surrounding areas, had also been relatively higher during arid phases in the past. This supposition is supported by climate modelling (Willmes et al., 2017) and that would have made the highlands an ecologically favoured region into which humans could retreat. However, archaeological evidence for this hypothesis is only scarce and was up to now confined to the Holocene (Foerster et al., 2015). Contrarily, important Pleistocene archaeological sequences, such as the stratigraphies from Mochena Borago rock shelter (Brandt et al., 2012 and 2017) and Goda Buticha (Pleurdeau et al., 2014; Tribolo et al., 2017) document an occupational gap of about 20000 years roughly between 30000 and 9000 BP, which encompasses the hyper-arid phase of the LGM.

2.1. Sodicho rock shelter

First evidence of archaeological settlement layers closing this gap comes from Sodicho rock shelter. The site is located about 225 km southwest from the capital Addis Ababa at the margins of the southern Ethiopian plateau to the western central and southern main Ethiopian Rift (fig. 1, A2).

2.1.1 Topography and research history

Sodicho rock shelter is situated on the southern flanks of Mount Sodicho (max. altitude 2,025 m a.s.l.), a volcano belonging to the Wagebeta Caldera Complex, which is one of the major trachytic volcanic complexes formed along the Rift's margins during the Plio-Pleistocene (Corti et al., 2013; Abbate et al., 2015). The steep cliff at this side of the volcano was most probably formed by a lateral blast of the crater wall (pers. comm. O. Bödeker). At an elevation of 1,910 m a.s.l., the shelter is located only a few meters below the edge of the plateau (fig. 2, A) and offers an excellent view over the surrounding landscape (Hensel et al., 2019, p. 208). Mount Damota and the Omo River Valley can be seen from the opening of the shelter under good visibility conditions. The mountain is flanked by two streams that drain into the Omo River about 11 km to the southwest. The site is located only about 40 km north-west from Mount Damota with the important archaeological key-site Mochena Borago.

In 2015, two one square-metre test-trenches were excavated in the north-western part of the shelter. Trench E41 was situated in one of the chamber-like caves in the rear-wall of the shelter, but excavations where soon constricted by rocks, which are most probably part of the bedrock. Therefore, in the subsequent three years excavations focused on trench F35 that was expanded by three square-metres (F34, G34, G35) and reached a maximum depth of 2.1 metres below surface in quarter-square G35/SE without reaching bedrock (fig. 2, B).

2.1.2 Settlement phases

The stratigraphy can be divided in two large sediment packages containing archaeological layers, which are divided by a 60 cm thick sterile deposit of red clayish sediment (fig. 2, E). Despite few potsherds and bones from historical times, the main two settlement layers of the upper part date around 4500 and 2000 years cal. BP respectively and contain LSA lithic assemblages, characterized by microlithic backed tools. The main difference between the two assemblages is the emergence of pottery in the younger assemblage. The sterile layer of red clay is bracketed by radiocarbon ages of around 10900 cal. BP and 4700 cal. BP, which roughly corresponds to the AHP However, the nature and duration of deposition are still unclear, but it might indicate a period when parts of the highlands had been too moist for human occupation.

Repeated occupation of the shelter is testified between 27000 and 13500 cal. BP. Preliminary analysis of the lithic assemblages shows a surprising uniformity of the stone artefacts. All assemblages are dominated by the production of bladelets and the analysed sample completely lacks any retouched tools (fig. 6, D). Settlement phases dating around 13500, 16900 and 21500 cal. BP coincide with the arid or rather hyper-arid climatic phases of the Older Dryas, Heinrich-1-event and LGM This is the first evidence for the use of highlands as a refugium during times of severe environmental stress in the lowlands.

3. PREHISTORIC LAND USE PATTERNS AND SETTLEMENT SYSTEMS IN MOUNTAINOUS REGIONS

The example of Sodicho rock shelter testifies to the occupation during arid periods, but humans would not only be pushed into high altitude environmental conditions by decreasing land resources in the lowlands following ecological changes. Highlands seem to have been part of larger settlement systems also during periods of climatic favourable conditions. The Prehistoric occupation of Mount Damota is a good case-study to answer the question about the general advantages of including mountainous regions into a hunter-gatherer habitat.

3.1 Mount Damota and the Mochena Borago rock shelter

Mount Damota is located 320 km south of the capital Addis Ababa at the intersection of the southwest Ethiopian highlands with the main Ethiopian Rift Valley (fig. 1, A3). The dormant trachytic volcano rises steeply from its surrounding flanks and offers from its peak (2,908 m a.s.l.) striking views of the central and southern Ethiopian Rift Valley, the Gibe and Omo River valleys, Lake Abaya and the Wolaita/Hadiya highlands. The topography of Mount Damota is dominated by steep slopes and rocky gorges in the mountain ranges (Abbate et al., 2015) and by lower relief topography in the transitional zone descending to the Rift Valley floor. The orographic effect of increased mean annual rainfall also applies to Mount Damota and amounts to 2,000 mm p.a. (Viste and Sorteberg, 2013).

Mochena Borago rock shelter is situated on the southwestern flanks of Mount Damota at ~ 2,200 m a.s.l. The large shelter (almost 70 m wide, 12 m high and 20 m deep) is at the head of a steep ravine, into which a seasonally active waterfall flows over the shelter's mouth (fig. 7, A).

3.1.1 The archaeology of Mochena Borago rock shelter

Archaeological research by the Groupe pour l'Étude de la Protohistoire de la Corne de l'Afrique (Gepca) in the Wolaita region since 1995 involved extensive excavations of Mochena Borago rock shelter, directed by X. Gutherz, that focused on the Holocene occupation of the site, but also revealed Later Pleistocene deposits in a 1.5 m^2 test unit (Gutherz, 2000; Gutherz et al., 2002). Since 2006, the Southwest Ethiopian Archaeological Project (SWEAP) directed by S. Brandt and L. Hildebrand, and between 2009 and 2014, in co-operation with the University of Cologne's Collaborative Research Centre 806 (CRC 806), investigates the Pleistocene deposits of the site (Brandt et al., 2012).

Geomorphological analyses indicate a multiphase, polygenetic accumulation and erosion of sediments deposited through natural and anthropogenic processes (fig. 7, B). The sedimentological evidence points to multiple occupations of the shelter mainly during humid conditions. More than 60 radiocarbon dates on charcoal make Mochena Borago one of the best-dated archaeological sites in Africa (Brandt et al., 2017) and classify the Pleistocene layers to Marine Isotope Stage 3 (MIS 3). Layers older than the radiocarbon "dating barrier" (> 50000 years) most probably reach back to MIS 4. Only one of the two main excavation trenches is partly analysed up to now (Brandt et al., 2012). Remarkable is the continuity of technological and typological attributes of the lithic assemblages of the four occupational episodes, dating between ~ 49400 and 36600 cal. BP (Upper T-Group, S-Group and R-Group). Like all other assemblages presented in this paper, obsidian is the dominant raw-material for the production of stone artefacts. Less frequently used rocks, mainly rhyolite, are 7.5% more prominent only in the Lower T-Group assemblage that is older than 50000 years. The dominance of obsidian is not surprising, because it is an excellent material to produce stone tools (Rapp, 2009) and is available in the vicinity. The main source for the inhabitants of Mochena Borago rock shelter had been the rich obsidian sources at Baantu approx. 20 km south east of the shelter (Brandt et al., 2012), albeit it is an open question whether the intensity of the erosion processes, leading to the exposure of the raw-material had the same intensity during the Late Pleistocene compared with the Late Holocene (Hensel et al., 2019). Nevertheless, it seems highly unlikely that raw material availability was a limiting factor and the reason for the generally small size of the lithics in all assemblages. A further characteristic for the technological attributes of the lithic assemblages is the coexistence of different core reduction strategies, such as centripetal cores (Levallois- and radial cores; fig. 7, C5 and C6) and a heterogeneous spectrum of other flake- and blade cores (single-, double- and multiple platform cores, bipolar cores, irregular cores; fig. 7, C1 to C4). Blade and bladelet production is part of all assemblages and there is a proportional increase and improved technological capabilities over time, although the total blade proportions remain small (Parow-Souchon, 2013). Characteristic modes of secondary preparation are facial retouch and backing that are present in all assemblages. However, there is a clear change in proportion from a predominance of facial retouch in the older assemblages (Upper and Lower T-Group) to a predominance of backed pieces in the two younger stratigraphic units. Unifacial and bifacial points are representative tool types (fig. 7,

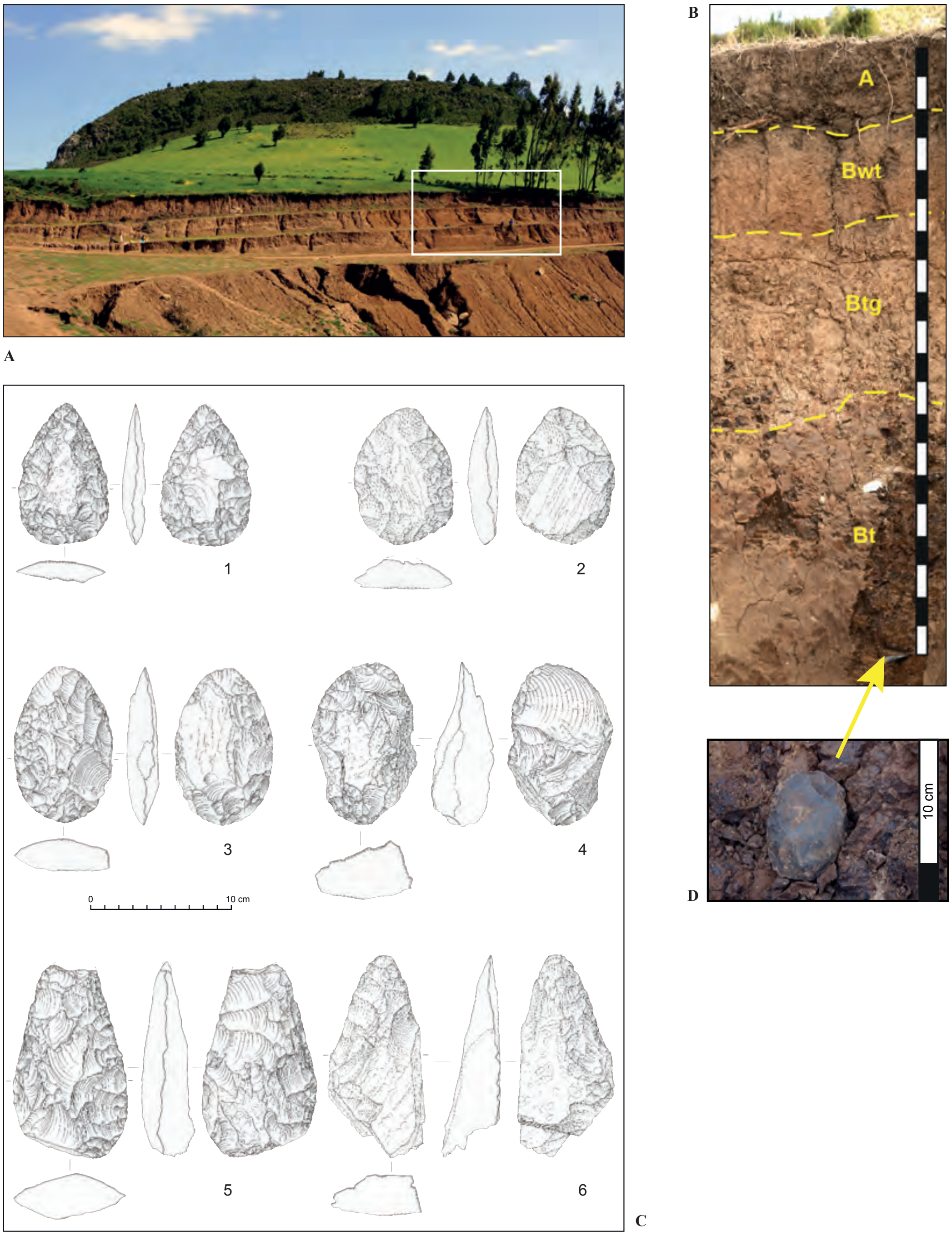
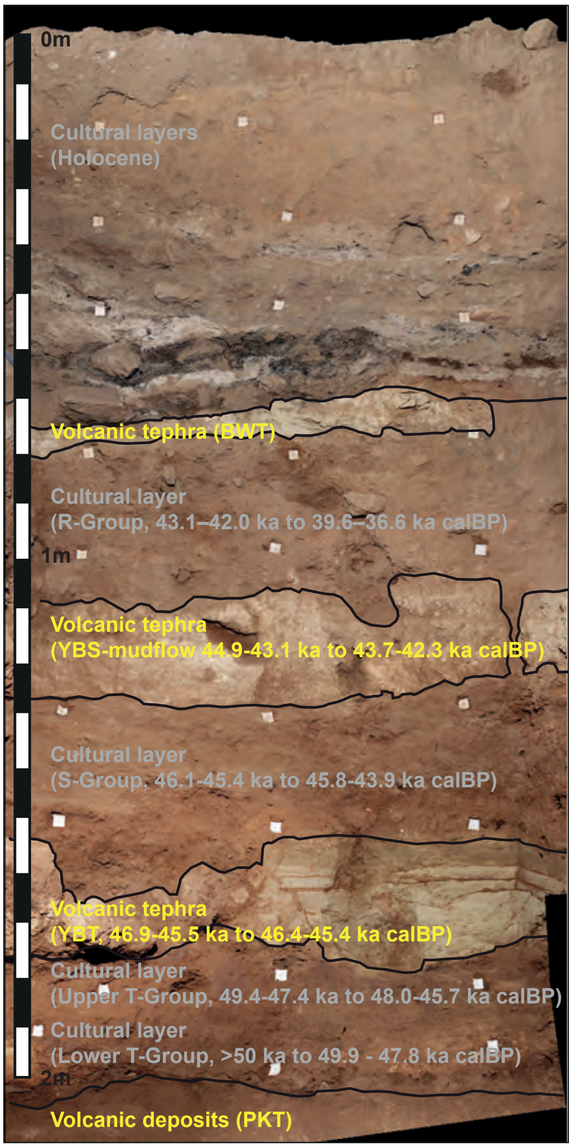


Fig. 6 – Mount Dendi: The Acheulean site DEN12-A02. View of the three artificial terraces and location of profile B (A; white rectangle, humans as scale); profile DEN12-A02 with four different soil horizons (B). The in situ handaxe (D) was found in the Bt horizon. The surface horizon A is a silty clay loam containing roots and showing a high total organic content (TOC; 4%). TOC and grain size decrease with depth. The lower horizons Bwt, Btg and Bt all classify as clays and have TOC values < 1%. These horizons show blocky soil structure and firm soil consistence. Furthermore, strong accumulation of siliceous clay with voids of manganese-oxides and iron hydroxides in the matrix are evident, also in characteristic micromorphological features such as intact coatings and nodules; DEN12-A02 bifacial tools (C): Flat cordate handaxe (1), bifacial scraper (2), ovate handaxe (3), cleaver-like biface (4), elongated handaxe (5), bifacial knife ("Keilmesser"; 6).

***Fig. 6** – Mont Dendi : le site acheuléen DEN12-A02. Vue des trois terrasses artificielles et de l'emplacement de la coupe B (A ; rectangle blanc, humains servant d'échelle) ; coupe DEN12-A02 avec quatre horizons de sol différents (B). Le biface in situ (D) a été trouvé dans l'horizon Bt. L'horizon de surface A est un loam argileux limoneux contenant des racines et montrant un contenu organique total élevé (TOC ; 4 %). Le TOC et la taille des grains diminuent avec la profondeur. Les horizons inférieurs Bwt, Btg et Bt sont tous classés comme des argiles et ont des valeurs de TOC < 1 %. Ces horizons montrent une structure de sol en blocs et une consistance de sol ferme. De plus, une forte accumulation d'argile siliceuse avec des vides d'oxydes de manganèse et d'hydroxydes de fer dans la matrice sont visibles, ainsi que des traits micromorphologiques caractéristiques, tels que des revêtements intacts et des nodules ; outils bifaciaux DEN12-A02 (C) : biface cordiforme (1), racloir à retouche bifaciale (2), biface ovalaire (3), biface en forme de hachereau (4), biface allongé (5), couteau bifacial (« Keilmesser » ; 6).*

A

B



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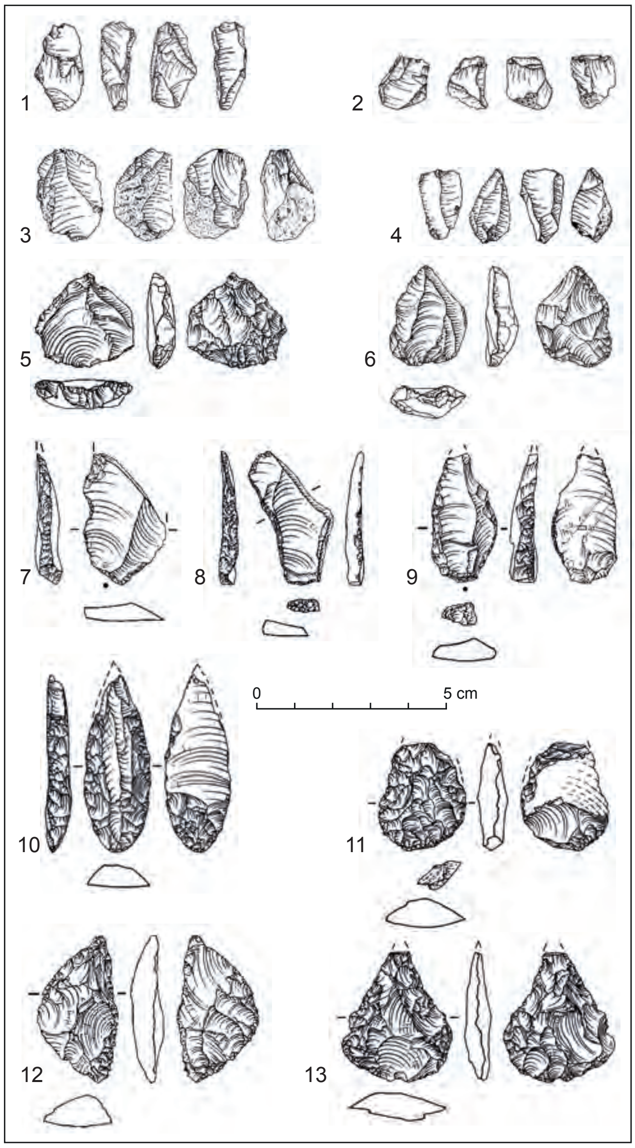


Fig. 7 – Mochena Borago: View of the rockshelter, with the “Block Excavation Area” (BXA) in the foreground (A); profile H9 West with a sequence of cultural layers and volcanic deposits (B); C) small flake and blade cores (1 to 4), Levallois cores (5 and 6), backed pieces (7 to 9), bifacially retouched tools (10 to 13).

***Fig. 7** – Mochena Borago : vue de l’abri, avec la « Block Excavation Area » (BXA) au premier plan (A) ; coupe H9 ouest avec une séquence de couches anthropiques et de dépôts volcaniques (B) ; C) petits nucléus à lamelles et à lames (1 à 4), nucléus Levallois (5 et 6), pièces à dos (7 à 9), outils à retouche bifaciale (10 à 13).*

C10 and C13), but not all facially retouched pieces can be classified as points. Especially in the T-Group assemblages, there is a broad spectrum of facially retouched tool types that needs further investigation (fig. 7, C11 and C12). The typological variety of backed pieces is also heterogeneous and unstandardized (fig. 7, C7 to C10). There are pieces with tips formed by backing that might have been used as perforators, small backed sidescrapers, flake fragments with basal or terminal truncation and backed flakes and blades with use-wear on the opposite edge, which suggest that hafting was practiced in SW Ethiopia since the early MIS 3.

3.1.2 Mount Damota settlement patterns

Accompanying the excavations in Mochena Borago, extensive pedestrian surveys covering a total distance of 130 km were conducted in the surrounding of the rock shelter. While Mochena Borago provides a stratified sequence with preservation of charcoal, bones and macrobotanical remains, open-air sites offer a complementary record of human behaviour. In general, open-air sites are more numerous than rock shelters and they represent distinct specific activities, such as settlement, hunting/butchering and raw material procurement. Whereas Mochena Borago's sequence provides crucial benchmarks for the chronological classification of the open-air sites, these, in turn, are the base for a landscape archaeological approach and permit the reconstruction of settlement- and land-use patterns.

The archaeological surveys on Mount Damota attempted to include all different landforms of the area, such as slopes, steep valleys and plateaus, in different altitudes from the foot of the mountain (~ 1,900 m a.s.l.) to the summit (2,900 m a.s.l). For this reason, survey routes followed not only currently used pathways that are often along ridges. Some routes also crossed the flanks of the mountain horizontally, thus covering steep slopes and gorges. Sixty-three archaeological sites were located and classified on the basis of characteristic tool-types to three rough chronological classes, namely MSA (fig. 8, A), LSA and historical period. Data on topographic features and archaeological site attributes aimed to assist reconstruction of settlement systems for different time periods. A detailed description of the methods and results, especially regarding the creation of settlement areas, is presented in Vogelsang and Wendt (2018). The quintessence of the analysis was an intensification of settlement activities from the MSA to the LSA and a different organization of the settlement clusters along the mountain slopes. The LSA sites form one large cluster with interconnected smaller sub-groups. In contrast, the reconstructed MSA settlement areas show a linear, vertical orientation, including different altitudinal belts in a close distance (fig. 8, B). This is interpreted as a land use model that offered short access to numerous elevations-bound ecozones. Small hunter-gatherer groups could exploit a wide spectrum of resources by taking advantage of the different altitudinal biotopes or move in annual cycles to exploit specific resources over a longer period (fig. 8, C). A historical example for the latter case were the Okiek (Huntingford, 1929), who lived in the forested highlands of the Mau escarpment in west central Kenya until deforestation and the change of the land tenure system by government intervention changed the demographics of the area (Blackburn, 1982; Kratz, 1999). The settlement area of an Okiek group consisted of one mountain ridge, on which they move to different forest zones according to three main honey seasons (Dale et al., 2004). The compression of numerous vertical ecozones within a small distance renders long distance annual migration unnecessary. In this respect, tropical highland zones in Africa, such as Mount Damota are an attractive environment even during periods of climatic favourable conditions.

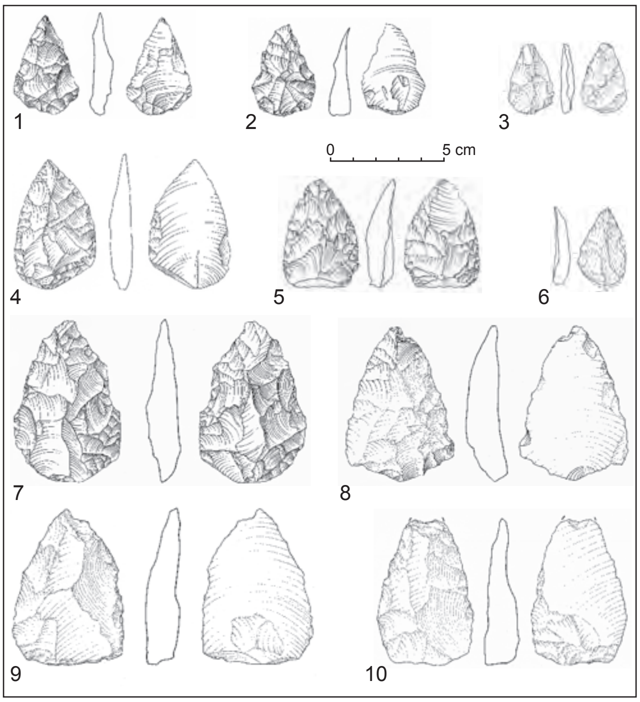
4. THE BALE MOUNTAINS AS AN EXAMPLE OF EARLY OCCUPATION OF ALPINE HIGHLANDS

The last section offers a short outlook on further approaches by ongoing fieldwork in the alpine environment of the Bale Mountains. The Ethio-German interdisciplinary Research Unit FOR2358, granted by the Deutsche Forschungsgemeinschaft, was established in 2016 to investigate the hypothesis of an early afro-alpine occupation. The afro-alpine region, also referred to as the African Mountain Archipelago, encompasses the high mountains of Ethiopia and tropical East Africa and is defined by its flora to the altitudinal zone above 3,500 meters (Hedberg, 1951). The Bale Mountains in south-eastern Ethiopia form the largest area of afro-alpine ecosystems in this region (fig. 1, B; fig. 9, A and B). The area was widely perceived as minimally disturbed with only minor and quite recent human impact (Umer et al., 2007; Yohannes et al., 2012) and is characterized by a large number of endemic species.

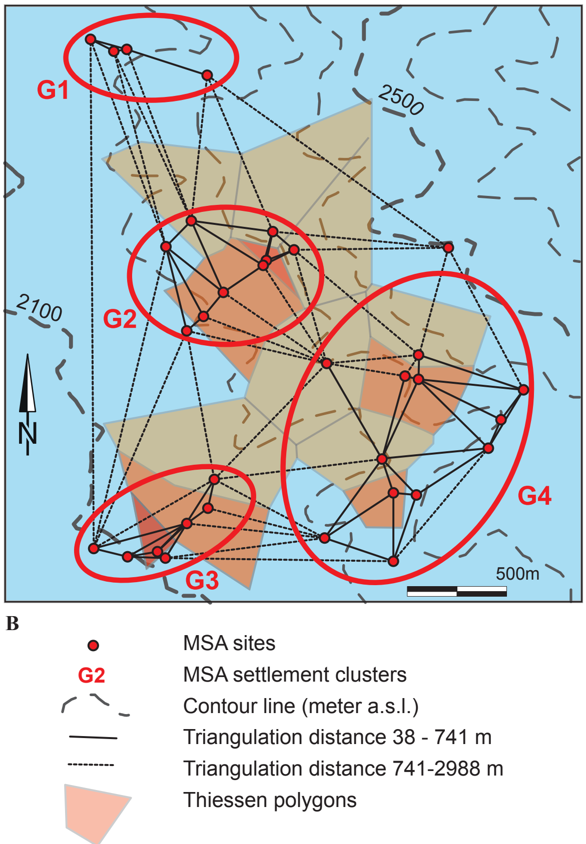
4.1 The Stone Age occupation of the Bale Mountains. First results

A first survey on the Bale Mountain plateau resulted in the location of 331 rock shelters (fig. 9, C), of which 56 were classified as potential archaeological sites (Reber et al., 2018). Up to now, 21 of these sites have been tested by small scale excavations of which three were extended to larger excavation trenches.

More than 37 radiocarbon dates from nine sites, located between altitudes of 3,430 and 4,123 m a.s.l., verify intensive settlement activities during the Holocene with a short gap between 7000 to 5000 years cal. BP. Up to now, there is again the hiatus between 30000 to 10000 cal. BP, which encompasses the period of the Big Dry. However, the sites Weyib and Simbero have an age of about 14000 years cal. BP and are two exceptions to this rule and may indicate that the missing evidence is based on the still preliminary research status. An early



A



B

C

Fig. 8 – Mount Damota: A) facially retouched points from MSA surface sites; B) MSA settlement cluster (G1-G4); C) ecological zones on and around Mount Damota: a = highland zone (dega; ~ 2,900-2,600 m a.s.l.), cool and moist with Afromontane vegetation (shrubs and grassland), b = mid-altitude zone (woyna dega, < 2,600-1,500 m a.s.l.), warmer and slightly drier, bamboo thickets and woodlands, c = lowland zone (kolla, below 1,500 m a.s.l.), hot and arid, open woodland and grassy savanna, d = Lake Abaya (1,169 m a.s.l.) hot, savanna forest and swamps.

***Fig. 8** – Mont Damota : A) pointes foliacées des sites de surface du MSA ; B) groupement de règlement du MSA (G1-G4) ; C) zones écologiques sur et autour du mont Damota : a = zone de hautes terres (dega ; ~ 2 900-2 600 m a.s.l.), fraîche et humide avec une végétation afro-montagnarde (arbustes et prairies), b = zone de moyenne altitude (woyna dega ; < 2 600-1 500 m a.s.l.), plus chaude et légèrement plus sèche, bosquets de bambous et forêts, c = zone de basse altitude (kolla ; en dessous de 1 500 m d'altitude), chaude et aride, forêts ouvertes et savane herbeuse, d = lac Abaya (1 169 m d'altitude), chaud, savane forestière et marécages.*

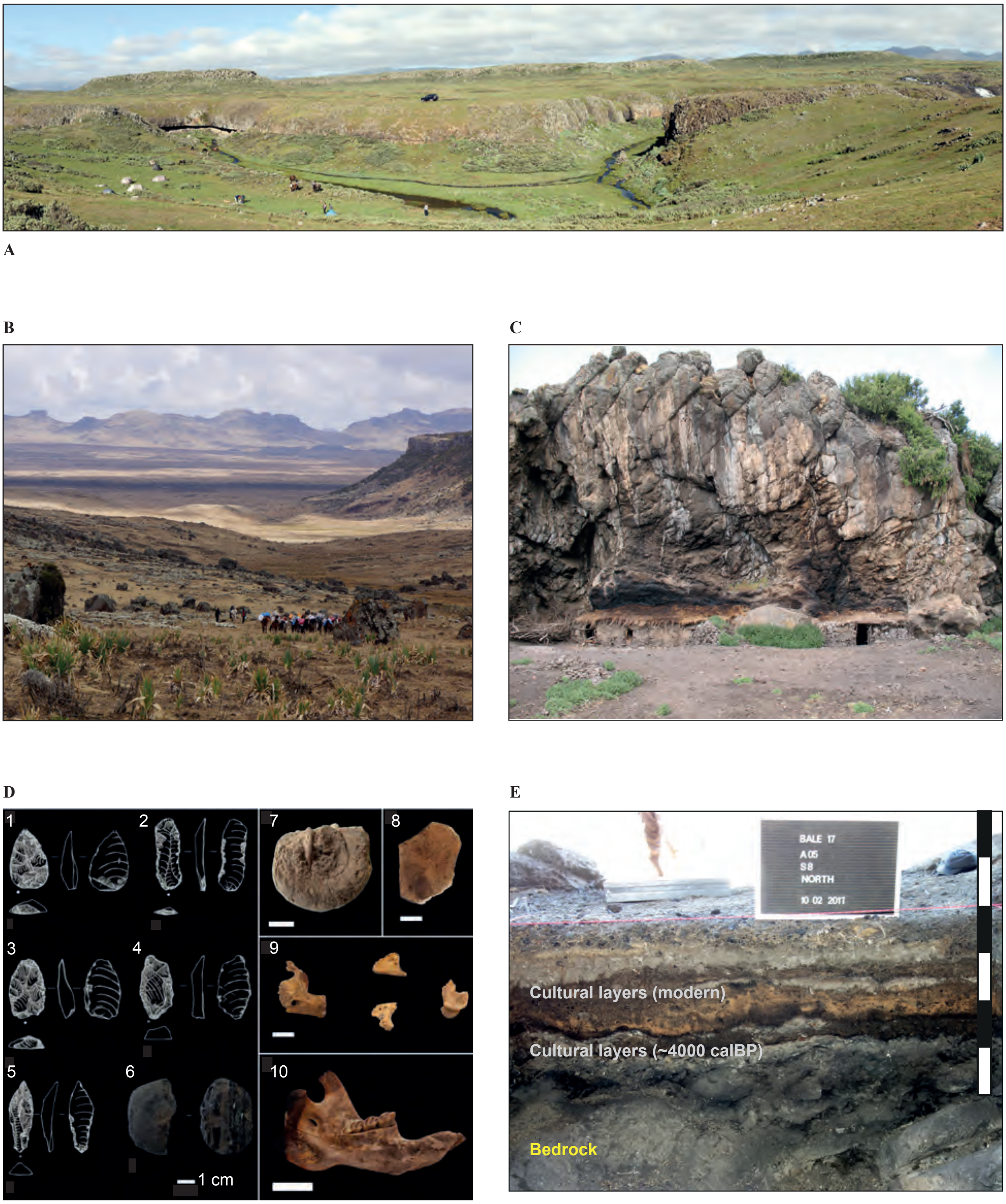


Fig. 9 – Bale Mountains: The Web Valley with the rock shelter Fincha Habera on the left and the waterfall on the right (A); the Sanetti Plateau (~ 4,000 m a.s.l.; A); seasonally inhabited rock shelter (C); selected finds from the MSA deposits (D, scale bars = 1 cm): unifacial points (1 and 3), laterally retouched blade with alternate retouch (2), scraper (4), point with basal thinning (5), photograph of a tested cortical nodule (6), spotted Hyena (*Crocuta crocuta*) coprolite with included rodent bone fragment (7), ostrich eggshell fragment (8), digested bovid phalanges (9), left mandible from a giant mole-rat (Tachyoryctes macrocephalus) that presents extremity burning marks (10); Holocene stratigraphy with typical thick accumulation of ash and charcoal (E).

***Fig. 9** – Montagnes du Bale : vallée de Web avec l'abri Fincha Habera à gauche et la cascade à droite (A) ; plateau de Sanetti (~ 4 000 m d'altitude ; B) ; abri habité de façon saisonnière (C) ; échantillon de mobilier provenant des dépôts MSA (D ; barres d'échelle = 1 cm) : pointes unifaciales (1 et 3), lame retouchée latéralement avec retouche alternante (2), grattoir (4), pointe avec aménagement basal (5), photographie d'un nodule cortical testé (6), coprolithe d'hyène tachetée (*Crocuta crocuta*) avec fragment d'os de rongeur inclus (7), fragment de coquille d'œuf d'autruche (8), phalanges de bovidés digérés (9), mandibule gauche d'un rat-taupe géant (Tachyoryctes macrocephalus) présentant des marques de brûlure aux extrémités (10) ; D) ; stratigraphie holocène avec une épaisse accumulation typique de cendres et de charbon de bois (E).*

occupation of the Bale Mountains is verified at the site Fincha Habera between 47000 to 31000 years cal. BP (Ossendorf et al., 2019).

The stone tool spectrum of the Holocene sites is characterized by backed microliths, such as segments and micro-points. A special feature of the region is the high number of borers that might indicate specific tasks, perhaps hide working. It seems plausible that the harsh and cold conditions of this high-altitude environment required warm clothing and perhaps dwelling structures made of hide (Chu, 2009). Another way of protecting against the cold was fire and exceptional massive accumulations of ash and charcoal are evidence of large fires in the inhabited rock shelters (fig. 9, E).

A remarkable site is the rock shelter Fincha Habera (fig. 9, A) that proves the Pleistocene occupation of the Bale Mountains (Ossendorf et al., 2019). All stages of the stone artefact reduction sequence, from acquisition, production of cores, blanks and tools to utilization and discard are present, which points to the use of the shelter as a settlement site. Characteristic tool types are small facially retouched points (fig. 9, D1, D3 and D5). The almost exclusive raw material for the production of stone artefacts is local obsidian. The main raw material source is the Wasama Ridge outcrop at an altitude of more than 4,200 meters a.s.l. and the passage to this source most probably passed along glaciers.

Surprising is the faunal spectrum of Fincha Habera with 93.5% of the identified bones belonging to the giant mole rat (*Tachyoryctes macrocephalus*). The high number of burnt bones and specific burn marks at the extremities indicate roasting of the animals and their consumption by humans (fig. 9, D10).

Despite the extreme environment and hunting specialization, the tool types from Fincha Habera are comparable to contemporaneous sites in the lowlands. Direct evidence of contact to these regions is an ostrich eggshell fragment (fig. 9, D8), because these birds never lived in such high altitudes (Stewart et al., 2020). It seems that the inhabitants of Fincha Habera used the Bale Mountains as one specific part of a larger settlement system.

Constant access to fresh water sources, such as meltwater from the Harcha and Wasama glaciers, might have been the initial impetus to occupy the alpine environment of the Bale Mountains. The focus on the endemic giant mole rat as a food source, which is available year-round, easy to catch and occurs in large numbers, comply with the higher metabolism and reduced physical ability in high altitudes. The availability of high-quality obsidian outcrops was an additional motivation to exploit these demanding ecozones.

CONCLUSION

Extensive archaeological research during the last decade in the high-altitude regions of Ethiopia has fundamentally changed our understanding of Prehistoric occupations in high altitude regions. We now know that despite the challenging environmental stress in high altitudes for the human body, these regions had been part of the human habitat at least since the emergence of modern *Homo sapiens*[2].

High altitude regions were used for specific tasks, such as hunting, collecting of raw-materials, plants and honey that might have been finished by expeditions of small groups during few days. However, they have also been used for longer periods as regular settlement areas. A major benefit of moving into high altitude regions is the relative abundance of water, which is one of the most limiting factors for human survival. The surroundings of all sites are characterized by numerous springs. Additional sources of water are in case of Mount Dendi the two crater lakes and in the Bale Mountains glacial melting water. A further advantage of mountainous regions are the altitudinal ecozones that permit the exploitation of a wide spectrum of natural resources in a small distance. The seasonal altitudinal shifting of ecozones extends the temporary availability of specific plants and the movement at a small scale in annual cycles renders long distance annual migration unnecessary.

Because of these advantages, highlands have also been used as retreats during times of environmental stress in the lowlands of Ethiopia. Although the species richness in plants and animals decreases under present climatic conditions between 1,000 m to 4,000 m altitude (Peters et al., 2019), the compressed altitudinal ecozones in combination are offering a broader spectrum in relation to the distances of logistical mobility (*senso* Binford, 1980) of foragers.

Thus, the occupation of high-altitude regions helped to overcome short periods of drought, but long-term climate changes might overstrain this settlement strategy. Climatic deterioration was not the main trigger for the occupation of high-altitude regions. Obviously, climate is an important limiting component, but human agency seems to be the more decisive factor. This also means that the occupants of high-altitude regions have not been marginalized people pushed into remote areas and living there in isolation. High altitude areas were most probably in all cases part of larger settlement areas that also included lowland regions or were at least part of larger exchange networks.

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NOTES

(1) In earlier publications, we spoke of tropical highlands. The term tropical was used according to the Köppen-Geiger climate classification that is based on five vegetation groups, precipitation and air temperature. Published over a hundred years ago (Köppen, 1900), it is still the most frequently used climate classification and has been updated in recent years (e.g. Kottek et al., 2006; Peel et al., 2007). Regarding M. C. Peel and colleagues (2007, p. 1638), the research area in the southwestern highlands belongs today to the Tropical Savanna climate. However, climate changed and in the paleoclimate simulation by C. Willmes and colleagues (2017), the region is part of the Warm Temperate Savanna zone during the Last Glacial Maximum. Therefore, the use of the term “tropical” is avoided in this text, because it may imply a diachronic analogy.

(2) The large bifacial tools from the site Dendi12-A02 might also have been made by *Homo heidelbergensis*, a possible antecessor of *Homo sapiens* (Rightmire, 1998; Stringer, 2016). In Ethiopia, the skull from Bodo, classified as *Homo heidelbergensis*, has an age of 600000 years (Clark et al., 1994). However, the correlation of cultural evolution, represented by archaeological groups defined by stone tool types and technology, with anatomical hominin evolution, namely distinct species, is problematic and the production of the DEN12-A02 assemblage by *Homo sapiens* is not completely out of question (e.g. Sahle et al., 2019).

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Interpersonal Violence in the Late Pleistocene
A Comprehensive Reanalysis of the Nile Valley Cemetery of Jebel Sahaba

Violences interpersonnelles durant le Pléistocène supérieur
Réévaluation du cimetière de Jebel Sahaba

Isabelle Crevecoeur, Marie-Hélène Dias-Meirinho,
Antoine Zazzo, Daniel Antoine, François Bon

Abstract: The Late Pleistocene and Early Holocene period are punctuated by major climatic changes whose effects on human populations remain poorly understood. In the Nile Valley, possible refuge areas during the periods of high climatic constraints, hyper-arid environmental conditions are documented until the onset of the Holocene.

Dated to the terminal phase of the Late Pleistocene, the Jebel Sahaba archaeological site 117 is the earliest cemetery in the Nile Valley. Excavated during the 1960s by the team of Pr. F. Wendorf, the 61 buried individuals of this funerary complex are well-known for exhibiting, in more than half of the cases, traces of interpersonal violence. The presence of cutmarks, traumatic lesions and embedded lithic artefacts in the human remains have been described since their first publication, and since then, this assemblage as served as possible evidence of organized warfare.

Here, we present an integrative approach to the reassessment of the Jebel Sahaba collections to discuss the cultural behavior of human groups in the Nile Valley during this period of fluctuating climatic and environmental conditions.

Between 2013 and 2019, we have conducted a thorough reassessment of the anthropological and archaeological evidence from the site in order to characterize the nature of the osseous lesions at a microscopic level, and to describe the archaeological assemblage. This analysis led to the identification of undocumented healed and unhealed lesions on new individual and/or previously identified victims, to the discovery of new lithic artefact embedded in the bones and the reappraisal of the nature of these lesions. In addition, the biological identities of all the individuals have been re-evaluated allowing for discussion of the demographic profile and burial selection of the Jebel Sahaba funerary assemblage.

We underline the projectile origin of most of the bone lesions and highlight the repetition of interpersonal violence acts at a lifetime scale given the number of individuals exhibiting healed and unhealed trauma. We reject the hypothesis that the Jebel Sahaba cemetery reflects a single warfare event; rather finding that the evidence supports the presence of sporadic and recurrent episodes of interpersonal violence in the Nile Valley, at the end of the Late Pleistocene.

Keywords: Warfare, projectile impact marks, indiscriminate violence, Sudan, Palaeolithic, funerary complex.

Résumé : La transition entre la fin du Pléistocène supérieur et le début de l'Holocène est rythmée par des changements climatiques importants dont l'impact sur les populations humaines reste mal connu. Dans la vallée du Nil, zones de refuge potentielle durant les périodes de fortes contraintes climatiques, des conditions environnementales hyper-arides sont documentées jusqu'au début de l'Holocène.

Daté de la fin du Pléistocène supérieur, le site archéologique de Jebel Sahaba 117 est le plus ancien cimetière de la vallée du Nil. Ce complexe funéraire a été fouillé au cours des années 1960 par l'équipe du Pr F. Wendorf. Les 61 individus enterrés recensés alors sont connus pour présenter des traces de violences interpersonnelles. La présence de stries sur les ossements, de lésions traumatiques et d'artefacts lithiques incrustés dans les restes humains a été mise en évidence dès leur première publication, ce qui a servi de support à l'hypothèse que cet assemblage témoigne de guerres préhistoriques organisées.

Nous présentons ici une approche intégrative à la réévaluation des collections de Jebel Sahaba pour discuter du comportement culturel des groupes humains dans la vallée du Nil pendant cette période de fluctuations climatiques et environnementales.

Entre 2013 et 2019, nous avons mené une réévaluation exhaustive des données anthropologiques et archéologiques du site afin de caractériser la nature des lésions osseuses à un niveau microscopique, et de décrire l'assemblage lithique associé à ce cimetière. Cette analyse a conduit à l'identification de lésions cicatrisées et non cicatrisées non documentées sur de nouveaux individus et/ou sur des victimes préalablement identifiées, à la découverte de nouveaux fragments lithiques incrustés dans des ossements et à la réévaluation de la nature de ces lésions. En outre, l'identité biologique de chaque individu a été révisée, ce qui a permis de discuter de la nature même du cimetière.

Nos résultats soulignent l'origine par voie de projectiles de la plupart des lésions osseuses et mettent en évidence la répétition de ces actes de violence interpersonnelle à l'échelle de la vie des individus, étant donné que plusieurs d'entre eux présentent des traumatismes guéris et cicatrisés. Nous rejetons l'hypothèse d'un cimetière lié à un événement unique de guerre, favorisant plutôt l'hypothèse de conflits sporadiques de faible ampleur dans la vallée du Nil, à la fin du Pléistocène supérieur.

Mots-clés : guerre, marque d'impact de projectile, violence interpersonnelle, Soudan, Paléolithique, complexe funéraire.

INTRODUCTION

The end of the Late Pleistocene and the beginning of the Holocene were marked by major climatic changes (Battarbee et al., 2004). Their impact on the inhabitants of the Nile Valley is still poorly understood and the analysis of sites from this period can provide unique insights into human responses to such environmental change. In Africa, geological evidence reveals that the generally dry conditions of the Last Glacial Maximum (LGM, ~ 23-18 kya; Gasse, 2000) were followed by the African Humid Period (~ 15-5.5 kya), which ended abruptly in the second half of the Holocene with the onset of more arid conditions (DeMenocal et al., 2000). In the Nile Valley, climatic conditions are depicted as hyper-arid during the second half of the Late Pleistocene (Paulissen and Vermeersch, 1987). Around 15-14 kya, the sudden overflow of lake Victoria into the White Nile establishes the present Nile-flow regime, causing regular and severe flooding of the Nile Valley all the way down to Egypt (Williams et al., 2006). Only after the Younger Dryas (~ 12.9-11.7 kya), do the monsoon conditions of the African Humid Period become more stable, creating more favorable conditions for the human occupation of the Nile Valley. There is little evidence for human occupations from the end of the Late Pleistocene to the beginning of the Holocene (~ 15-10.5 kya), with sites restricted to the floodplain of Upper Egypt and Nubia (Nicoll, 2004; Kuper and Kröpelin, 2006; Vermeersch and Van Neer, 2015). Of these, few have yielded complete human remains including the sites of Jebel Sahaba (site 117), Tushka (site 8905), Wadi Kubbaniya, and the site 6-B-36 from Wadi Halfa (Hewes et al., 1964; Wendorf 1968a; Wendorf and Schild, 1986).

Culturally, different lithic industries have been identified with sites associated with the end of the Late Pleistocene, among which the Fakhurian, the Kubbaniyan, the Idfuan, the Ballanan-Silsilian, the Afian, the Isnan and the Qadan (Wendorf, 1968a and 1968b; Lubell, 1974; Wendorf et al., 1989; Schild and Wendorf, 2010; Vermeersch, 2010; Leplongeon, 2021). Each of these occurs in restricted geographical areas along the Nile, mainly in Upper Egypt. They do not seem to be related to specific activities and are characterized by distinctive sets of lithic tools and/or technology that appear to be associated with distinct small hunting-fishing-gathering groups (Vermeersch, 2010). Each of these lithic groups is believed to represent a cultural tradition that reflects group identity within this restricted habitable area (Schild and Wendorf, 2010). The occurrence of large graveyards at the end of the Late Pleistocene reinforces the idea of strong social units within residential groups (Wendorf and Schild, 2004). In this context of supposed environmental pressure and geographical constrain, the identification of traces of interpersonal violence on the skeletal remains of at least half of the individuals buried in Jebel Sahaba have attracted much attention and generated debates regarding the emergence of violence and warfare during the Late Pleistocene (see Anderson, 1968; Keeley, 1996; Thorpe, 2003; Wendorf and Schild, 2004; Guilaine and Zammit, 2005).

Evidence of conflict is not uncommon in the Nile Valley. The oldest documented case appears to be from Wadi Kubbaniya, where the remains of a partial skeleton encased in cemented sediment provide early evidence of interpersonal violence (Wendorf and Schild, 1986). Two bladelets were found within the physical space of the skeleton, between the 11th and 12th ribs and the 2nd and 3rd lumbar vertebral bodies. A chip of flint was also found logged inside an area of partially healed trauma on the epicondylar ridge of the left humerus. A healed fracture of the right ulna also provides further evidence of earlier trauma (Angel and Kelley, 1986; Wendorf and Schild, 1986). Based on bone robustness and maturation, this individual was determined to be a young adult male (Angel and Kelley, 1986). Sediments and lithics suggest a date as early as 20 kya (Wendorf and Schild, 1986). Embedded lithic and healed fractures have also been documented on several individuals buried in the Wadi Halfa cemetery, associated with Qadan lithic industry (site 6-B-36; Hewes et al., 1964; Saxe, 1971; Greene and Armelagos, 1972). However, the most emblematic and widely cited example of early widespread violence is the cemetery of Jebel Sahaba. Early analyses of the skeletons by J. E. Anderson (1968) and B. Butler (1968) revealed evidence of interpersonal violence on the bones of at least half of the Jebel Sahaba individuals. In addition, abundant lithic artefacts that appear to be from the Qadan industry were discovered within the subsequently disappeared initial volumes of the bodies, where the soft tissues would have been, or directly embedded in the bones (Wendorf, 1968c).

The site of Jebel Sahaba (site 117), now submerged underneath the lake created by the Aswan High Dam, is located about 3 km north of the modern town of Wadi Halfa. While in use, the cemetery was located one kilometer east of the ancient shore of the Nile (Wendorf, 1968c). The site was discovered as part of the UNESCO-funded salvage campaigns of the sites that were to be flooded by the construction of the Aswan high dam (Wendorf, 1968c). R. Paepe and D. Perkins, part of the Columbia University Nubian Expedition, initially documented the site in 1962 (Solecki et al., 1963). The individuals associated with this first excavation are referred as JS C-1, JS C-2 and JS C-3 in the Jebel Sahaba collection (Wendorf, 1968a). In 1965, within the framework of the Southern Methodist University field season, F. Wendorf visited the site and further tested the areas immediately adjacent to the first excavation (Wendorf et al., 1966). The successful recovery of additional human remains led to a full-scale excavation and 49 skeletons (JS 1 to JS 49)

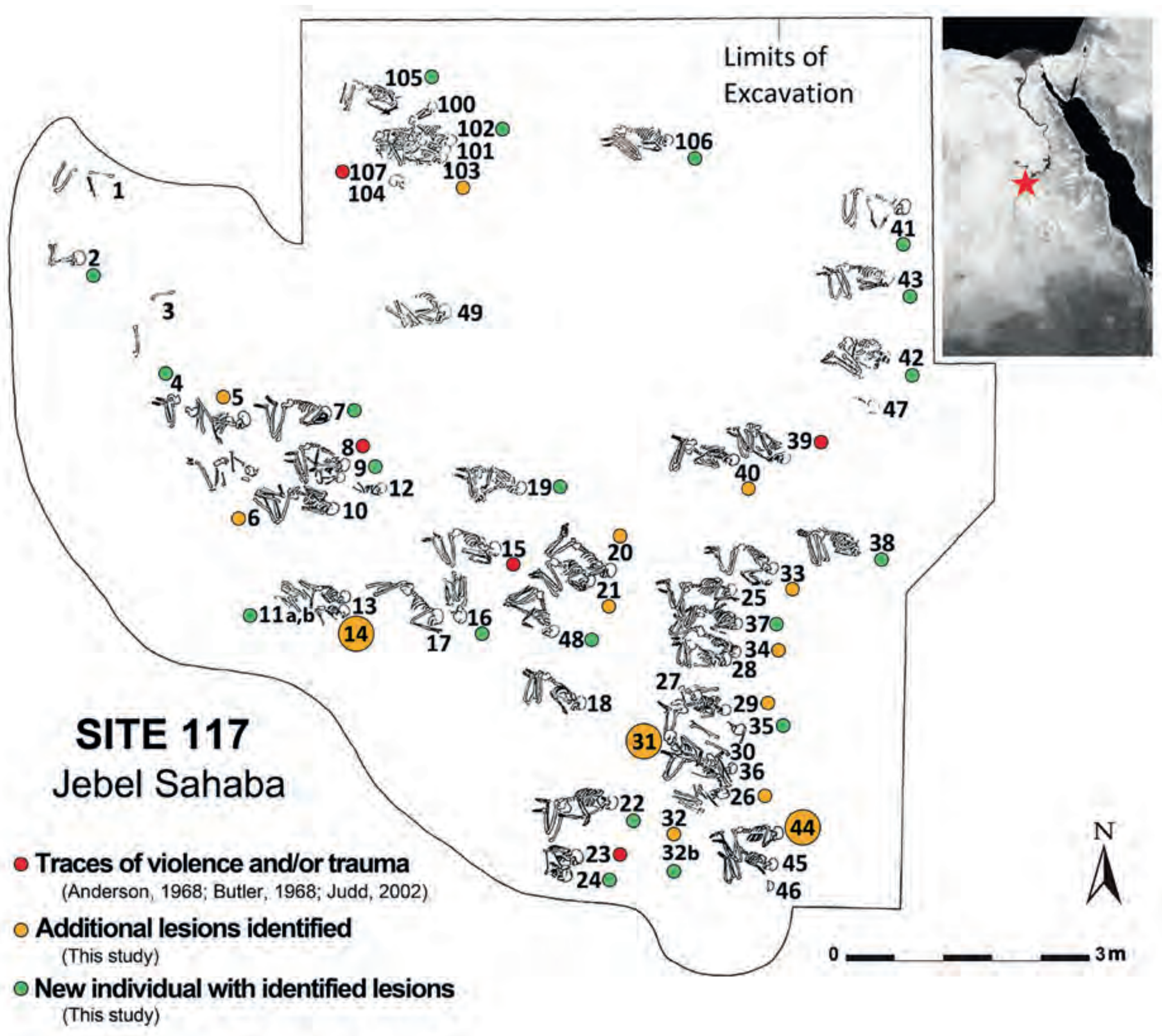

Fig. 1 – Location of the Jebel Sahaba cemetery, site 117, in the Nile Valley and map of the excavated area and burials (modified following Wendorf, 1968c). Red dots, individuals exhibiting signs of violence and/or traumatic lesions (Anderson, 1968; Butler, 1968; Judd, 2002); orange dots, additional newly identified lesions in the latter individuals; green dots, individuals newly identified as showing signs of violence and/or traumatic lesions; large dots, individuals discussed in detail in the text.

***Fig. 1** – Localisation du cimetière de Jebel Sahaba, site 117, dans la vallée du Nil, et plan de la zone fouillée avec les sépultures (d'après Wendorf, 1968c). Points rouges, individus présentant des signes de violence et/ou des lésions traumatiques (Anderson, 1968 ; Butler, 1968 ; Judd, 2002) ; points orange, lésions supplémentaires nouvellement identifiées chez ces derniers individus ; points verts, individus nouvellement identifiés comme présentant des signes de violence et/ou des lésions traumatiques ; points élargis, individus discutés en détail dans le texte.*

were uncovered in 1965, with an additional six excavated in 1966 (JS 100 to JS 107; Wendorf, 1968c; here: fig. 1).

The northern part of the cemetery was stripped by erosion, revealing disturbed and heavily cemented human remains. The rest of the cemetery consisted of well-preserved skeletons buried in oval pits cut into a weakly cemented sediment and covered by thin sandstone slabs (Wendorf, 1968c). Most were primary individual burials, with some double and multiple interments, as well as secondary deposits caused by later burials (Wendorf and Schild, 2004). In total, 61 skeletons were recovered, with most individuals carefully buried in contracted position on their left side, with the head toward the east, facing south. In most cases, the hands were positioned close to the face and the lower limb was flexed with the feet close to the pelvis (Wendorf, 1968a). Although no occupation deposits were found in the vicinity of the cemetery, more than 100 lithic artefacts were found inside or around the burials. They demonstrate strong resemblances with the Qadan lithic industry, particularly specific tool types such as crescent-like backed pieces described as "lunate" (see Wendorf, 1968c). Since all/most of these artefacts were found in the initial volume of the cadaver once occupied by the now decayed soft tissues or embedded in the bones, they cannot be considered as grave goods, nor can the Jebel Sahaba individuals be referred to as belonging to the Qadan population (Wendorf, 1968c). However, this lithic assemblage provides valuable information on the function of certain type of Qadan lithic artefacts and the chronology of the cemetery. Most pieces are unretouched flakes and chips that would, in different context, be identified as debitage artefacts rather than tools. In the case of Jebel Sahaba, their association to weaponry appears indisputable and may stem from an opportunistic or planned use of the cutting edge, suggesting highly flexible cultural behaviors (Wendorf, 1968c; Becker and Wendorf, 1993). The Qadan sequence is documented in Upper Egypt and Lower Nubia from the end of the Late Pleistocene (~ 18 kya) until the Holocene (Wendorf, 1968c; Schild and Wendorf, 2010). The antiquity of the site was confirmed using 10 direct radiocarbon dates carried out on five individuals from Jebel Sahaba (table 1; Wendorf and Schild, 2004; Antoine et al., 2013; Zazzo, 2014).

The oldest date, 13740 ± 600 BP (Pta-116; 14979-18568 cal. BP), is based on the analysis of bone collagen from the femur of JS 43 in 1988 (Wendorf and Schild, 2004). Due to the poor collagen preservation at the site, the original date had been challenged (e.g. Grine, 2016) or ignored (e.g. Lahr et al., 2016; Kissel and Kim, 2019) by some; and an additional nine dates were recently performed using bone, enamel and dentine bioapatite on four other individuals (JS 15, JS 22, JS 42 and JS 103; Antoine et al., 2013; Zazzo, 2014). The bioapatite results ranged from 7251 to 11660 BP, with the dates derived from the enamel being systematically younger (7251-9687 BP) than the ones obtained from bone and dentine apatite of the same individuals (10032-11660 BP; table 1). There is a higher risk of contamination when dating the mineral fraction of bones and teeth due to possible isotopic exchanges between carbonate in bioapatite and dis-

Prep #	Sample #	Sample ID	Anatomical part	Fraction dated	14C age	Error	Target #	Calibrated range (cal BP, 95.4%)		Ref.
Muse103	DS-1	skeleton 15	lower right M3	enamel apatite	7251	31	UBA-20124	8170	7981	1
Muse111	DS-9	skeleton 15	lower right M3	dentine+root apatite	11660	52	UBA-20132	13727	13362	1
Muse110	DS-2	skeleton 15	long bone fgmt	bone apatite	11049	43	UBA-20125	13090	12843	1
Muse104	DS-3	skeleton 22	upper left M3	enamel apatite	8512	40	UBA-20126	9544	9467	1
Muse99	DS-4	skeleton 22	pelvis fgmt	bone apatite	11133	50	UBA-20127	13160	12911	1
Muse105	DS-5	skeleton 42	lower right M3	enamel apatite	9043	45	UBA-20128	10285	9967	1
Muse100	DS-6	skeleton 42	pelvis fgmt	bone apatite	11093	49	UBA-20129	13104	12850	1
-	-	skeleton 43	-	bone collagen	13740	600	Pta-116	18568	14979	2
Muse102	DS-7	skeleton 103	upper right M2	enamel apatite	9687	55	UBA-20130	11229	10792	1
Muse101	DS-8	skeleton 103	pelvis fgmt	bone apatite	10032	46	UBA-20131	11802	11319	1

Table 1 – Results of the direct radiocarbone dates of the Jebel Sahaba individuals (1: Zazzo, 2014; 2: Wendorf and Schild, 2004). Calibration software: Oxcal version 4.4.2 (Bronk Ramsey, 2009). Calibration curve: IntCal 2020 (Reimer et al., 2020).

***Tableau 1** – Résultats des datations directes au radiocarbone des individus de Jebel Sahaba (1 : Zazzo, 2014 ;2 : Wendorf et Schild, 2004). Logiciel de calibration : Oxcal version 4.4.2 (Bronk Ramsey, 2009). Courbe de calibration : IntCal 2020 (Reimer* et al., *2020).*

solved inorganic carbon from the environment during fossilization, especially when a precipitation of secondary carbonates occurs (Zazzo and Saliège, 2011). For Jebel Sahaba, this phenomenon is well documented, with calcified crust deposits over the grave pits, as well as on some skeletal remains (Wendorf, 1968c). Contamination usually results in the dates being too young (Zazzo and Saliège, 2011). Consequently, the dentine date (UBA-20132 11660 BP, 13362-13727 cal. BP) provides the best apatite age estimate for the site and indirectly confirms the validity of the bone collagen date performed in the 1980s (Zazzo, 2014). Broadly dated between 13400 and 18600 cal. BP, the Jebel Sahaba cemetery is the earliest known funerary complex from the Nile Valley.

Since its discovery and original publication by F. Wendorf (1968a), the Jebel Sahaba cemetery has been used as possible evidence of organized warfare triggered by territorial disputes (Keeley, 1996; Kelly, 2000; Thorpe, 2003; Guilaine and Zammit, 2005; Daković, 2014). Many elements of the original findings, particularly the timing, nature and extent of the violence, but also the lithic association, have been challenged since (e.g. Jurmain, 2001; Ferguson, 2013; Kissel and Kim, 2019; Usaï, 2020). However, no integrative study of the traces of violence left on the human remains of the site has been undertaken to reassess this Prehistoric site (Thorpe, 2003). Several questions remain unanswered that would benefit from the latest interpretative anthropological forensic methods. Was the Jebel Sahaba cemetery the result of a single event, of sporadic episodes of interpersonal violence, or was it used as a place for the burial of specific individuals? Some traces or cutmarks on the bones seem to be the result of projectile penetration while other are described as deliberate cutting. Are they the result of specific funerary treatments or actual traces of violence? Finally, what can a reassessment of the lithic assemblage contribute to our understanding of the site?

A systematic macroscopic and microscopic reanalysis of the human remains curated at the British Museum was used to fully reevaluate and characterize the nature of the osseous lesions. Combined with a reevaluation of the lithic assemblage described by F. Wendorf in association with the burials, as from the surface around the skeletons, the new results offer a unique synthetic perspective on human behaviors at the end of the Late Pleistocene.

1. MATERIAL AND METHODS

In 2001, F. Wendorf donated all of the archives, artefacts and skeletal remains from his 1965-1966 Nile Valley excavations to the British Museum (Judd, 2007; Antoine and Ambers, 2014). M. Judd's preliminary osteological analysis noted discrepancies between field notes, photographs and associated skeletal remains, including the absence of three individuals, JS 1, JS 3 and JS 30, as well as some of the bones with embedded lithic artefacts described by J. E. Anderson (1968; Judd, 2007). As they were not a part of the British Museum donation, their whereabouts remain uncertain and they were therefore not included in this reanalysis. Judd's survey of the skeletal remains also noted the presence of bones or teeth from additional individuals. Our reanalysis also found supernumerary bones and teeth. Jebel Sahaba can now be regarded as including the remains of at least 64 individuals, three of whom are missing from the British Museum collection.

The analysis involved a full reevaluation of the age and sex using the latest anthropological methods. In some individuals, assessments were limited by the state of preservation of the skeletal remains. Biological sex was based on the morphology and dimensions of the pelvis (Brůžek, 2002; Murail et al., 2005; Brůžek et al., 2017). When the pelvis was not sufficiently complete, the cranium and mandible were also used (after Buikstra and Uberlaker, 1994) to assign sex preceded by the letter "p" for "probable" (i.e. pM = probable Male). Due to the requirements of child birth, the pelvis is a more reliable indicator of biological sex and the dimorphic traits of the skull can vary between populations. Moreover, the individuals from Jebel Sahaba are characterized by a robust phenotype which adds complexity to the interpretation of their cranial features (Anderson, 1968; Greene and Armelagos, 1972). Hence, when cranial morphology was the only method available, a question mark was added to denote the limitation of the approach (i.e. pM? = possible Male). Finally, when the cranium and the pelvis were absent, individuals are classified as undetermined (UND). The age-at-death of the immature individuals is predominantly based on the stage of dental development following C. F. Moorrees et al. (1963a and 1963b). In the rare occasions where the teeth were not present or preserved, the state of skeletal growth and development were used (after Maresh, 1970; Fazekas and Kosa, 1978; Scheuer and Black, 2000). In adults, A. Schmitt (2005)'s method was employed to score the remodeling of the iliac sacro-pelvic surface (ISPS), allowing for a conservative diagnosis of mature individuals whose population senescence characteristics are unknown. Given the strong dependence of the senescence processes on population, environmental and behavioral factors (Brůžek et al., 2005), when the ISPS was not preserved, we chose to cautiously assign the mature individuals into the following broad age groups based on the level of dental wear ([> 20 years] = individual with dental wear below category 4; [> 30 years] = individual with dental wear above Molnar's category 3; Molnar, 1971). In the rare instances for which dental remains were absent, mature individuals were designated as adults [> 20 years] if no sign of articular remodeling or entheseal changes where observable. In all the other cases, the individual was assigned to the age group [> 30]. In order to discuss potential demographic characteristics of the Jebel Sahaba cemetery, we grouped the individuals in six conventional age cohorts ([0-< 1], [1-4], [5-9], [10-14], [15-19] and [20-29 years]) that allow for comparisons with theoretical mortality values of a population with a life expectancy at birth of between 25 and 35 years (Ledermann, 1969).

Immature individuals falling into two cohorts based on age-at-death estimate standard deviations were assigned to the most probable one according to P. Sellier (1996).

Extensive and detailed microscopic analyses of all areas exhibiting taphonomic and/or anthropogenic traces were conducted using a digital microscope (Dino-Lite Premier) with a 5 Megapixels resolution, a polarizer and a 50x - 250x magnification range. Following the recommendations of M. J. Smith et al. (2007), each potential lesion was checked for embedded lithic fragments and described. Non-anthropogenic traces, mainly related to gnawing and termite activity, were differentiated using macroscopic and microscopic criteria (fig. 2; see Shipman and Rose, 1983; Backwell et al., 2012; Fernández-Jalvo and Andrews, 2016). Although trampling marks were unlikely, the Jebel Sahaba individuals having been buried in pits filled with sediment and covered by sandstone slabs, the diagnostic criteria from M. Domínguez-Rodrigo et al. (2009) were used to exclude such taphonomic changes.

Projectile Impacts Marks (PIMs) were characterized using projectile bone damage identification criteria derived from experimental archaeological research

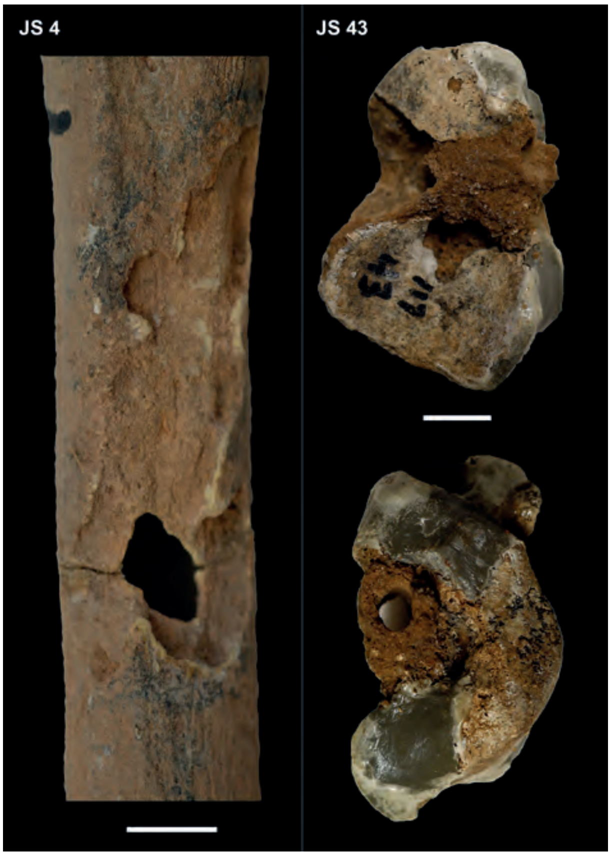

Fig. 2 – Examples of taphonomic bone alteration and residue caused by termite activity. Left, right humerus from JS 4 showing borehole and sub-cortical galleries; right, right talus from JS 43 with surface residue.

***Fig. 2** – Exemples d'altérations osseuses taphonomiques et de résidus causés par l'activité des termites. À gauche, humérus droit de JS 4, illustrant les perforations et les galeries sous-corticales ; à droite, talus droit de JS 43 avec résidu de surface.*

(Morel, 2000; Pétillon and Letourneux, 2003; Smith et al., 2007; Castel, 2008; O'Driscoll and Thompson, 2014; Duches et al., 2016). Although based on the hunting of small and large ungulates, these experimental studies provide a clear system of projectile trauma classification that is often lacking in analyses of interpersonal violence (Smith et al., 2007). Although embedded lithic or bone artefact fragments are the most direct diagnostic features used to identify projectile impact marks, a growing number of studies are now available to support the classification and interpretation of cutmarks and other puncture or perforation wounds (Smith et al., 2007; O'Driscoll and Thompson, 2014; Duches et al., 2016). The terminology and classification used in this study are characterized by the level of hard tissue projectile penetration defined by C. A. O'Driscoll and J. C. Thompson (2014). The term "drag" denotes cut-like marks with internal parallel longitudinal microstriations at the bottom of the groove and on its borders (fig. 3 and fig. 4). They are characterized by straight and continuous trajectories similar to slicing cutmarks (Duches et al., 2016). However, they differ from the latter in that they are deeper, with a wide and flat groove floor, and an abrupt angle between its floor and lateral borders (Duches et al., 2016). They also display a range of specific secondary traits such as cracking, flaking, scraping and bisecting marks (O'Driscoll and Thompson, 2014; Duches et al., 2016). Bisecting marks are related to bouncing and the movement of the projectile when it comes into contact with bone (O'Driscoll and Thompson, 2014). The shoulder effects found in slicing cutmarks are less pronounced in PIMs, most probably due to the rapidity and singularity of the impact (Shipman and Rose, 1983; Duches et al., 2016; Fernández-Jalvo and Andrews, 2016). Finally, the anatomical location of the PIMs can also be used to differentiate them from slicing cutmarks (Morel, 2000; O'Driscoll and Thompson, 2014). When the cause of the cut could not be ascertained, the generic term of cutmark is used (Potts and Shipman, 1981). A projectile embedded in bone is defined as a "puncture" by C. A. O'Driscoll and J. C. Thompson (2014) and this type of impact can be associated with the crushing, beveling, flaking and splitting of bone (fig. 5 and fig. 6). When the projectile fully penetrates the bone, the term "perforation" is favored (Castel, 2008).

In a number of cases, the cause of the lesion could not be identified due to poor preservation and uncharacteristic changes, and the term "trauma" is used. This category also covers all the healed or unhealed bone fractures, blunt force trauma and perforations with no PIM signs. The term "fracture" is defined as a partial or complete break in the continuity of a bone (Lovell, 1997). Finally, the term "lesion" refers to an injury whose nature or interpersonal origin could not be determined (fig. 7). The presences of bone callus or abscesses were also recorded. Signs of new bone formation or remodeling linked to healing processes were carefully noted and classified as "healed", implying a delay of at least three weeks between the injury and death (Lovell, 1997).

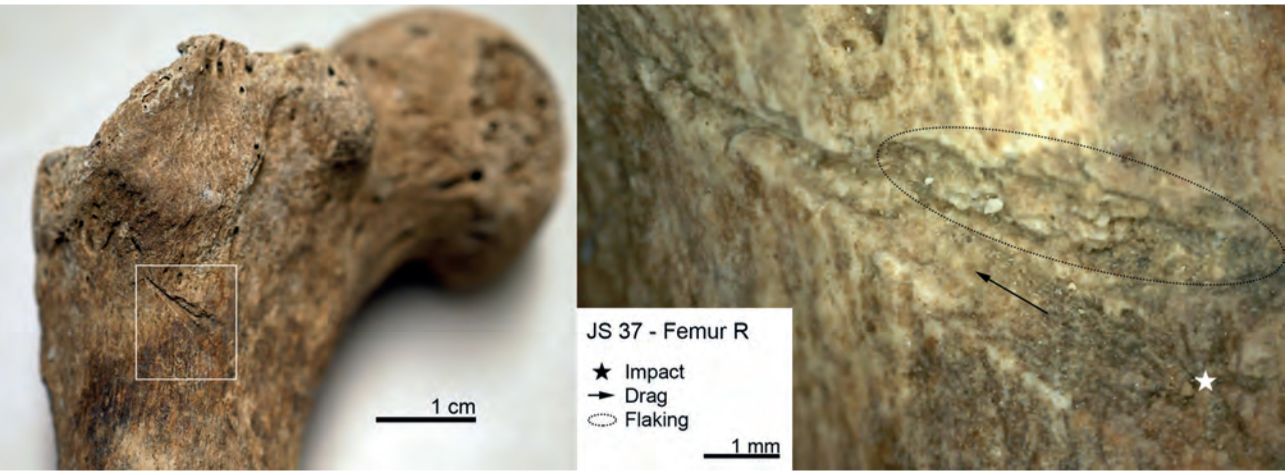

Fig. 3 – Illustration of the drag type of projectile impact marks (PIM) seen on the Jebel Sahaba individuals.
Left, macroscopic view of the drag; right, composite microscopic image of the drag illustrating the flaking.
Fig. 3 *– Illustration des types de marques d'impact de projectile (MIP) identifiés sur les individus de Jebel Sahaba.*
À gauche, vue macroscopique d'une éraflure ; à droite, image microscopique composite de l'éraflure avec un écaillage osseux.

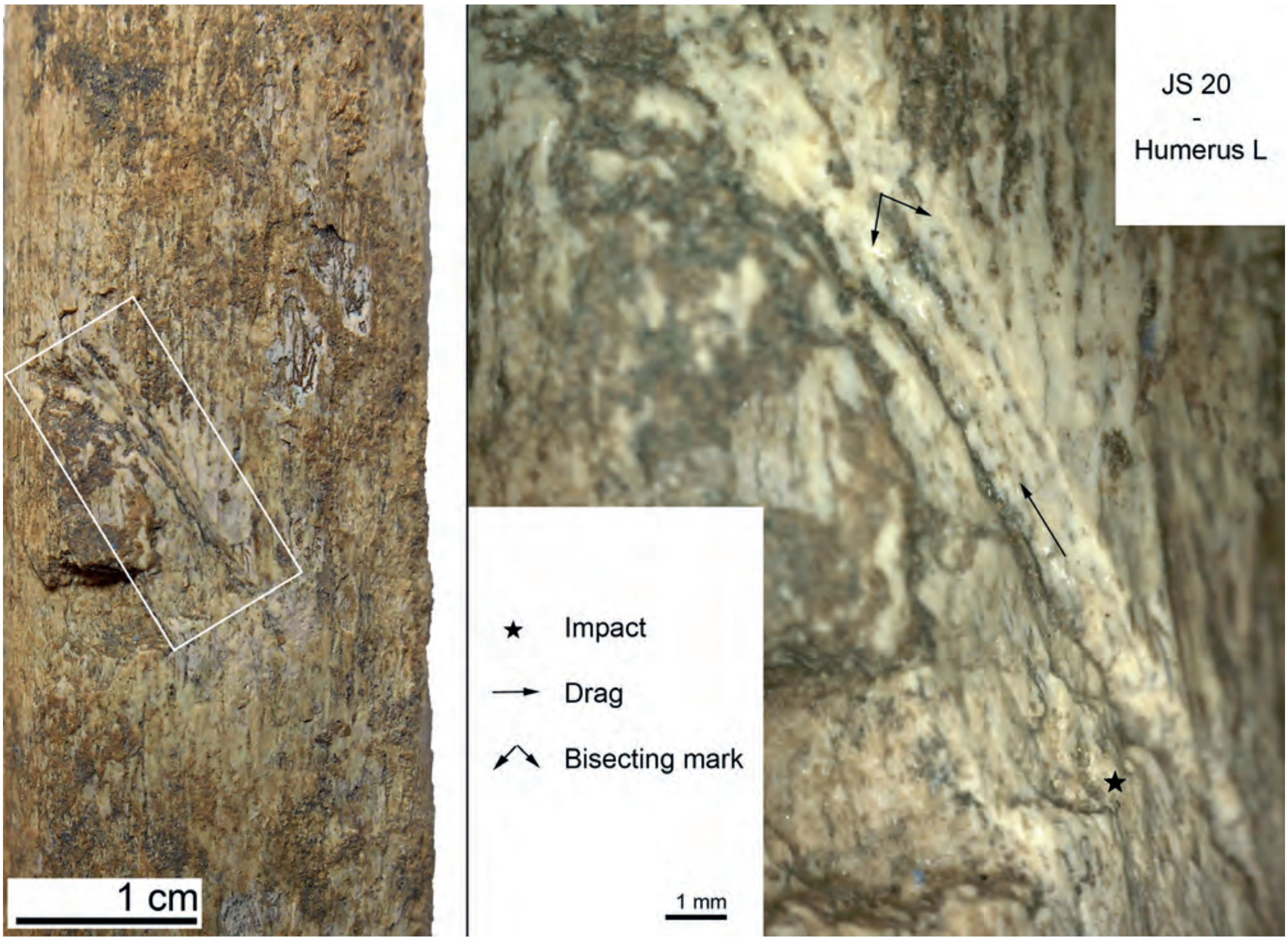

Fig. 4 – Illustration of the drag type of projectile impact marks (PIM) seen on the Jebel Sahaba individuals.
Left, macroscopic view of the drag; right, composite microscopic image of the drag illustrating bisecting marks.
Fig. 4 *– Illustration des types de marques d'impact de projectile (MIP) identifiés sur les individus de Jebel Sahaba.*
À gauche, vue macroscopique d'une éraflure ; à droite, image microscopique composite de l'éraflure avec les marques de bissection.

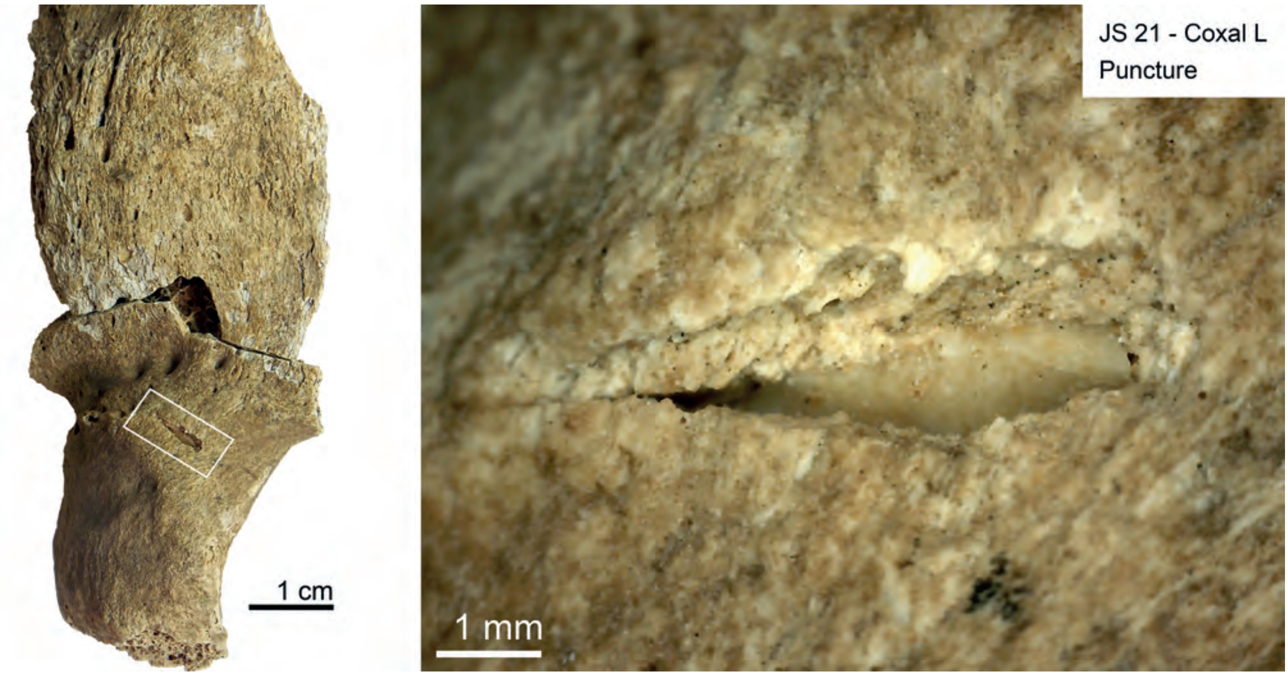

Fig. 5 – Illustration of the puncture type of projectile impact marks (PIM) seen on the Jebel Sahaba individuals.
Left, macroscopic view of the puncture with embedded artefact; right, microscopic image of the puncture.
Fig. 5 *– Illustration des types de marques d'impact de projectile (MIP) identifiés sur les individus de Jebel Sahaba.*
À gauche, vue macroscopique d'un percement avec fragment lithique fiché ; à droite, image microscopique du percement.

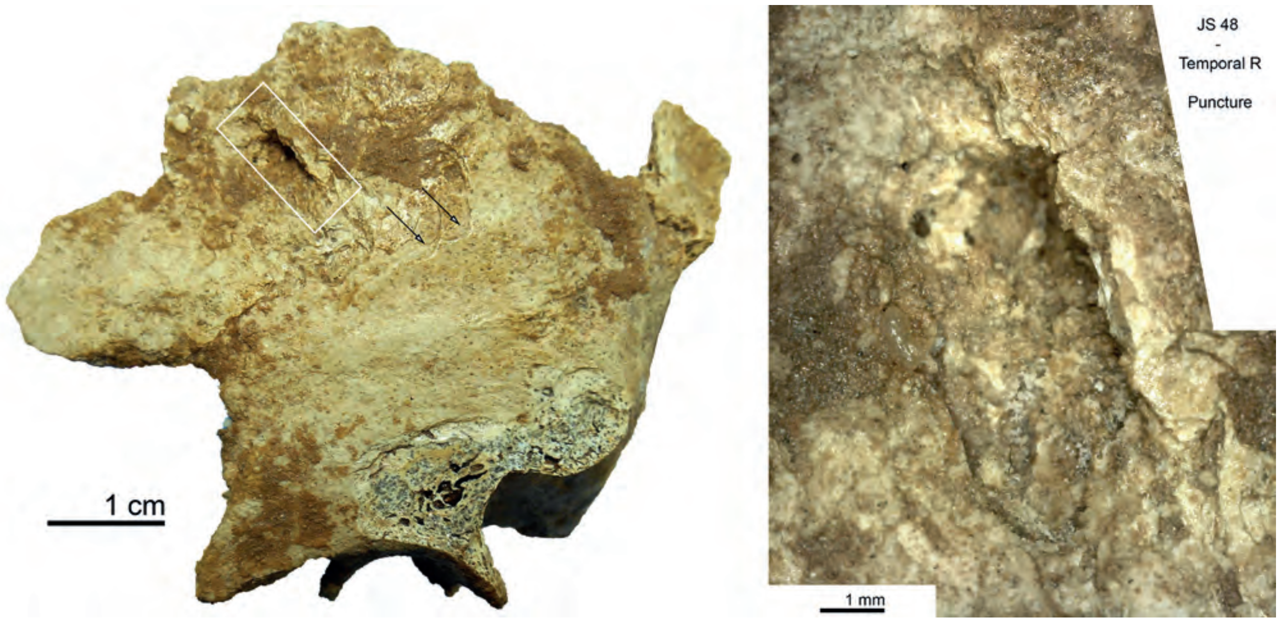

Fig. 6 – Illustration of the puncture type of projectile impact marks (PIM) seen on the Jebel Sahaba individuals.
Left, macroscopic view of the puncture; right, composite microscopic image of puncture illustrating crushing fractures associated to the extraction of the projectile.
Fig. 6 *– Illustration des types de marques d'impact de projectile (MIP) identifiés sur les individus de Jebel Sahaba.*
À gauche, vue macroscopique du percement ; à droite, image composite microscopique du percement illustrant les fractures d'écrasement associées à l'extraction du projectile.

Fig. 7 – Illustration of healed lesions recorded on the Jebel Sahaba individuals. Upper left quadrant, ovoid healed injury on the frontal bone; upper right quadrant, healed fracture of the distal extremity of the hand's second proximal phalanx; bottom, healed parry fracture of the ulna. Black bar = 1 cm.

***Fig. 7** – Illustration des lésions cicatrisées documentées sur les individus de Jebel Sahaba. En haut à gauche, blessure ovoïde cicatrisée sur l'os frontal ; en haut à droite, fracture cicatrisée de l'extrémité distale de la deuxième phalange proximale de la main ; en bas, fracture cicatrisée de la diaphyse de l'ulna. Barre noire = 1 cm.*

2. RESULTS

The individuals examined and the occurrence of healed and unhealed traumas and lesions are listed in the table S1. New analyses confirmed most of the lesions originally described by J. E. Anderson (1968) and B. Butler (1968), as well as the identification of a substantial number of additional traumas and lesions in new and previously identified individuals (fig. 1).

2.1 Reassessment of the evidence of interpersonal violence

Using new methods and interpretation models, a total of 106 previously unidentified lesions were observed, including 52 that can now be interpreted as PIMs. These have transformed our understanding of the site by revealing that a further 21 individuals had clear signs of interpersonal trauma in addition to the 20 described by F. Wendorf (1968c) and J. E. Anderson (1968; here: fig. 1).

Of the 61 individuals studied, 41 (67.2 %) exhibit at least one type of healed or unhealed lesion (lesions of unknown origin, traumas or projectile impact marks; table 2). This includes three-quarters of the adults (74.4%; n = 32), with only half of the non-adults affected (50%; n = 9). The difference, however, is not statistically significant: P (χ^2) > 0.05. Our analyses also show that out of these 61 individuals, 27.9% (n = 17; value corrected from Crevecoeur et al., 2021) exhibited signs of perimortem traumas (unhealed traumas and/or PIMS), and 62.3% (n = 38) displayed healed and/or unhealed traumas.

Both sexes have the same percentage of healed and unhealed lesions. Among the adults with traces of injury, 36.6% (n = 15) display signs of both healed and unhealed lesions, with males (n = 8) and females (n = 8) similarly affected. Only one non-adult has both healed and unhealed lesions. Interestingly, this individual is an

	Total (n = 61)		Female (n = 19)		Male (n = 20)		Indeterminate (n = 6)		Mature (n = 43)		Immature (n = 18)	
	n	%	n	%	n	%	n	%	n	%	n	%
No lesion	20	32,8	5	26,3	5	25,0	1	16,7	11	25,6	9	50,0
Lesions	41	67,2	14	73,7	15	75,0	5	83,3	32	74,4	9	50,0
Healed lesions	37*	90.2*	14	100,0	15	100,0	5	100,0	32	100,0	5	55,6
Unhealed lesions	20*	48.7*	8	57,1	8	53,3	0	0,0	15	46,9	5	55,6
H&U lesions	16	39,0	8	57,1	8	53,3	0	0,0	15	46,9	1	11,1
1. Traumas & PIMs	38	92,7	14	100,0	15	100,0	3	60,0	30	93,8	8	88,9
Healed Traumas & PIMs	31*	81.6*	11	78,6	15	100,0	3	100,0	27	90,0	4	50,0
Unhealed Traumas & PIMs	17*	44.7*	7	50,0	6	40,0	0	0,0	12	40,0	5	62,5
H&U Traumas & PIMs	10	26,3	4	28,6	6	40,0	0	0,0	9	30,0	1	12,5
2. Fractures	22	36,1	9	47,4	11	55,0	2	33,3	21	48,8	1	5,6
3. PIMs	25	61,0	10	71,4	10	66,7	1	20,0	19	59,4	6	66,7
Healed PIMs	11*	44.0*	4	40,0	6	60,0	1	100,0	10	52,6	1	16,7
Unhealed PIMs	17*	68.0*	7	70,0	6	60,0	0	0,0	12	63,2	5	83,3
H&U PIMs	3	12,0	1	10,0	2	20,0	0	0,0	3	15,8	0	0,0
4. Embedded lithic	11	26,8	3	21,4	6	40,0	0	0,0	9	28,1	2	22,2
Healed PIMs	4	36,4	0	0,0	4	66,7	0	0,0	4	44,4	0	0,0
Unhealed PIMs	8	72,7	3	100,0	3	50,0	0	0,0	6	66,7	2	100,0
H&U PIMs	1	9,1	0	0,0	1	16,7	0	0,0	1	11,1	0	0,0

Table 2 – Number of individuals exhibiting at least one type of lesion grouped by age-at-death or sexual diagnosis. The percentage in the two first lines are calculated on the minimal number of individuals for each category, while the percentage in the numbered lines are computed based on the recorded number of individuals with lesions for each category. The percentage in the underlying lines represents the proportion of individuals with healed, unhealed and healed and unhealed lesion occurrence within the numbered line category. n = number; % = percentage; PIM = projectile impact marks; H&U = healed and unhealed; * = number corrected from Crevecoeur et al, 2021.

***Tableau 2** – Nombre d'individus présentant au moins un type de lésion, regroupés par sexe ou par âge au décès. Le pourcentage dans les deux premières lignes est calculé sur le nombre minimum d'individus pour chaque catégorie, tandis que le pourcentage dans les lignes numérotées est calculé sur la base du nombre d'individus présentant des lésions pour chaque catégorie. Le pourcentage dans les lignes sous-jacentes représente la proportion d'individus présentant des lésions cicatrisées, non cicatrisées, et cicatrisées et non cicatrisées dans la catégorie des lignes numérotées. n = nombre ; % = pourcentage ; PIM = marques d'impact de projectile ; H&U = cicatrisé et non cicatrisé ; * = nombre corrigé par rapport à Crevecoeur* et al.*, 2021.*

adolescent belonging to the oldest immature age cohort [15-19] (table 3). Most individuals with lesions (92.7%; n = 38) had some that were traumatic in origin, and over half of these individuals had a projectile impact (61.0%; n = 25). This percentage is similar in adults and non-adults, and between males and females. Embedded lithic fragments were recorded in the PIMs of 11 individuals (26.8%; n = 11), and with a higher proportion in males (n = 6).

The location of the lesions also reveals some patterning to the traumas or PIMs (table 4). First, the number of healed fractures are mainly concentrated on the upper limb and the shoulder girdle (84.8%; n = 28). Fifty percent of these upper limb fracture involve the hands, with both the proximal phalanges and the metacarpals affected, and one-third are located on the forearm. Of the latter, defensive parry fractures of the ulna are the most common (table 4 and fig. 7; Lovell, 1997). A significant difference – P(χ^2) > 0.05 – between males and females was observed, with parry fractures of left and right sides, without favoring a side, mostly found on female individuals (88.9%; n = 8). Although not significant, hand bone fractures are more frequent in male individuals (58%; n = 7).

Projectile impact marks are most commonly observed on the lower limb and on the pelvic girdle compared to other anatomical parts (44.3%; n = 70; table 4). Similarly, this anatomical region has the highest frequency of puncture PIMs and embedded lithic artefacts (respectively 50.0%; n = 12; and 55.0%; n = 11). The sex of the individual does not appear to have influenced the frequency of these marks on different parts of the body. Drag marks are present on both upper and lower part of the body, with lower limbs marks mostly found on the femur (94.1%; n = 16) and equally distributed across males and females, as well as well as the left and right sides. In the upper limbs, the clavicles and humeri exhibit the highest number of projectile marks (n = 11). The direction of the strike reveals no differences between males and females, with both displaying a similar number of projectile marks

	Total (n=18)		Demographic age-at-death classes									
			[0-<1] (n=2)		[1-4] (n=5)		[5-9] (n=6)		[10-14] (n=3)		[15-19] (n=2)	
	n	%	n	%	n	%	n	%	n	%	n	%
No lesion	9	50,0	2	100,0	3	60,0	4	66,7	0	0,0	0	0,0
Lesions	9	50,0	0	0,0	2	40,0	2	33,3	3	100,0	2	100,0
Healed lesions	5	66,7	0	0,0	0	0,0	1	50,0	2	66,7	2	100,0
Unhealed lesions	5	44,4	0	0,0	2	100,0	1	50,0	1	33,3	1	50,0
H&U lesions	1	11,1	0	0,0	0	0,0	0	0,0	0	0,0	1	50,0
Traumas & PIMs	8	88,9	0	0,0	2	100,0	2	100,0	3	100,0	1	50,0
PIMs	6	66,7	0	0,0	2	100,0	1	50,0	2	66,7	1	50,0
Fractures	1	5,6	0	0,0	0	0,0	0	0,0	0	0,0	1	50,0

Table 3 – Detail of the type and number of lesions for the immature individuals in relation to the demographic age-at-death class. The percentage in the two first lines are calculated on the minimal number of individuals for each category, while the percentage in the underlying lines are computed based on the recorded number of individuals with lesions for each category. n = number; % = percentage; PIM = projectile impact marks; H&U = healed and unhealed.

Tableau 3 *– Détail du type et du nombre de lésions pour les individus immatures en fonction de la classe démographique d'âge au décès. Le pourcentage dans les deux premières lignes est calculé sur le nombre minimum d'individus pour chaque catégorie, tandis que le pourcentage dans les lignes sous-jacentes est calculé sur la base du nombre enregistré d'individus présentant des lésions pour chaque catégorie. n = nombre ; % = pourcentage ; PIM = marques d'impact de projectile ; H&U = cicatrisé et non cicatrisé.*

	Traumas & PIMs								Total lesions
	Traumas		PIMs					Total	
	Fractures	Perforations/ BFT	Drags	Punctures	Perforations	Total	Embbeded lithic		
Number of Lesions	33	4	40	24	6	70	20	107	139
Number of individuals	22	4	17	14	3	25	11	38	41
% of individuals	36,1	6,6	27,9	23,0	4,9	41,0	18,0	62,3	67,2
Anatomical repartitition									
1. Cranium (%)	3,0	100,0	20,0	25,0	66,7	25,7	15,0	21,5	20,9
% Frontal	-	75,0	50,0	50,0	25,0	44,4	33,3	47,8	48,3
% Parietal	-	-	-	33,3	50,0	22,2	66,7	17,4	13,8
% Temporal	-	25,0	12,5	16,7	-	11,1	0,0	13,0	13,8
% Occipital	-	-	-	-	25,0	5,6	0,0	4,3	10,3
2. Upper limb & Shoulder girdle (%)	84,8	-	35,0	8,3	-	22,9	10,0	41,1	36,0
% Shoulder girdle	7,1	-	35,7	50,0	-	37,5	50,0	18,2	20,0
% Humerus	10,7	-	35,7	-	-	31,3	50,0	18,2	18,0
% Ulna	28,6	-	14,3	-	-	12,5	-	22,7	20,0
% Radius	3,6	-	14,3	-	-	12,5	-	6,8	10,0
% Forearm	32,1	-	28,6	-	-	25,0	-	29,5	30,0
% Hand bones	50,0	-	0,0	50,0	-	6,3	-	34,1	32,0
3. Trunk (%)	3,0	-	2,5	16,7	-	7,1	20,0	5,6	5,8
4. Lower limb and Pelvic girdle (%)	9,1	-	42,5	50,0	33,3	44,3	55,0	31,8	37,4
% Coxal	-	-	5,9	66,7	-	29,0	63,6	26,5	23,1
% Femur	-	-	94,1	25,0	-	61,3	27,3	55,9	53,8
% Tibia	-	-	-	-	-	-	-	-	3,8
% Fibula	33,3	-	-	8,3	-	3,2	9,1	5,9	5,8
% Foot bones	66,7	-	-	-	100,0	6,5	-	11,8	13,5

Table 4 – Number and type of lesions recorded on the Jebel Sahaba individuals. Percentage of each of these lesions in relation to the anatomical parts, and percentage of infliction to specific bones. PIM = projectile impact marks; BFT = blunt force trauma; % = percentage.

Tableau 4 *– Nombre et type de lésions enregistrées sur les individus de Jebel Sahaba. Pourcentage de chacune de ces lésions par rapport aux parties anatomiques, et pourcentage d'affliction pour des ossements spécifiques. PIM = marques d'impact de projectile ; BFT = traumatisme par objet contondant ; % = pourcentage.*

that had entered from the back or the front of the body. In the case of both sexes, several individuals (n = 6) were identified as exhibiting marks consistent with both posterior and anterior impacts. Finally, the analysis reveals that all types of traumas were observed on the cranium. Most of the perforations caused by blunt force traumas and/or projectile impacts are observed on the cranium of non-adults (87.5% of the perforations; n = 7).

Three cases best illustrate the complexity and range of lesions found in the Jebel Sahaba individuals regardless of their age-at-death, sex or burial type.

Case 1: the double burial of the children JS 13 and JS 14 was discovered approximately 25 cm below the surface without any slab covering. Individuals JS 13 was lying next to and facing the back of child JS 14. Both were placed on their left side, with their head oriented toward the east in a contracted position. Both individuals are under the age of 6 years old. JS 13 is estimated to have been approximately 5 years old (their dental remains demonstrate a development consistent with 4.7 years ± 1; Moorrees, 1963a). JS 14 is estimated as having been closer to 4 years old based on a post-cranial measurement (femoral length = 225 mm; Maresh, 1970). Five lithic artefacts were found in association with the two individuals (Wendorf, 1968c). According to F. Wendorf, a "distal truncated and retouched flake" (i.e. a backed asymmetrical mono-points with an oblique cutting edge; see our own typological classification below and examples) was found at the base of the skull of JS 13 and "a backed and straight oblique distal truncated flake" (i.e. backed symmetrical mono-points) was found in the infilling of the infra-cranium. With JS 14, a "partially backed flake" was located at the base of the skull and a "basal truncated and straight oblique distal truncated flake" was found at the back of the mouth (i.e. two other examples of backed symmetrical mono-points following our classification) and an unretouched microlith chip was discovered inside the skull.

No osseous lesion were visible on JS 13 but the cranium and post-cranium of JS 14 both have unhealed trauma caused by projectile impacts (fig. 8).

The majority of the lesions are located on the calvaria and none of them had previously been documented. The frontal bone exhibits a blunt force trauma at the level of the glabella based on the pattern of the fracture lines. Several drag marks and an oblong perforation are present on the left side of the frontal squama, as well as scraping drag marks close to the bregma. A puncture site with faulting and part of an embedded artifact is also visible approximately one centimeter above the left orbit (fig. 9). A perforation is also present on the right parietal and on the occipital. The frontal and occipital perforation exhibit internal bevelling consistent with projectile impacts (Smith et al., 2007). The edges of the parietal perforation are partly broken which complicates its characterization, but its traumatic nature is undeniable. A further set of marks is visible on the left femur, including two groups of drags on the antero-lateral border of the proximal part of the diaphysis. The first group has two subpar-

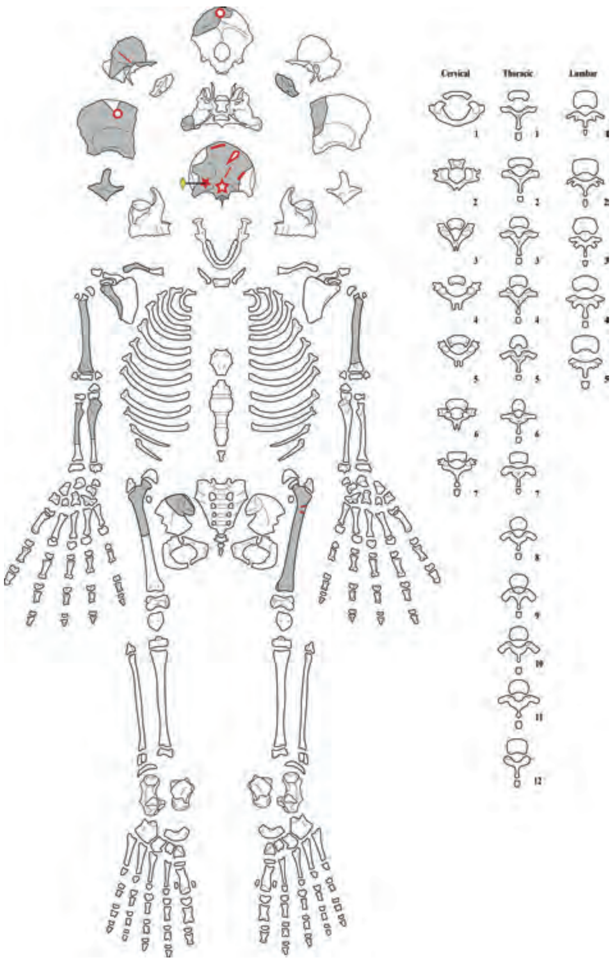

Fig. 8 – Location of the observed osseous lesions on JS 14. Grey parts represent preserved bones. Star, blunt force trauma; full star, unhealed puncture; open circle, perforations; yellow diamond, embedded artefact in a puncture; dash on the femur, drags traces of projectile impacts; line, cutmark.
***Fig. 8** – Localisation des lésions osseuses observées sur JS 14. Les parties grises représentent les os conservés. Étoile, traumatisme par objet contondant ; étoile pleine, percement non cicatrisé ; cercle, perforations ; losange jaune, artefact fiché dans un percement ; tiret sur le fémur, éraflures liées au passage d'un projectile ; ligne, trace de coupure.*

allel incisions with wide flat floors marked with parallel microstriations. Bone flaking is also present at the end of the trajectory. The second drag mark is located about one centimeter below the proximal one, and oriented slightly more anteriorly, with a bisecting pattern at its end. Based on these cutmark characteristics, the projectile most likely arrived from the medial side of the femoral diaphysis, in a downwards motion and towards the lateral side (fig. 10).

Case 2: skeleton JS 31 was buried approximately 30 cm below the surface and covered by sandstone slabs, with his right leg placed partially under JS 26 and over JS 36. The remains belong to a probable male most likely over 30 years old [> 30] based on the heavy dental wear as well as significant bone remodeling (osteoarthritis on the cervical vertebras, right elbow and left talus). The posi-

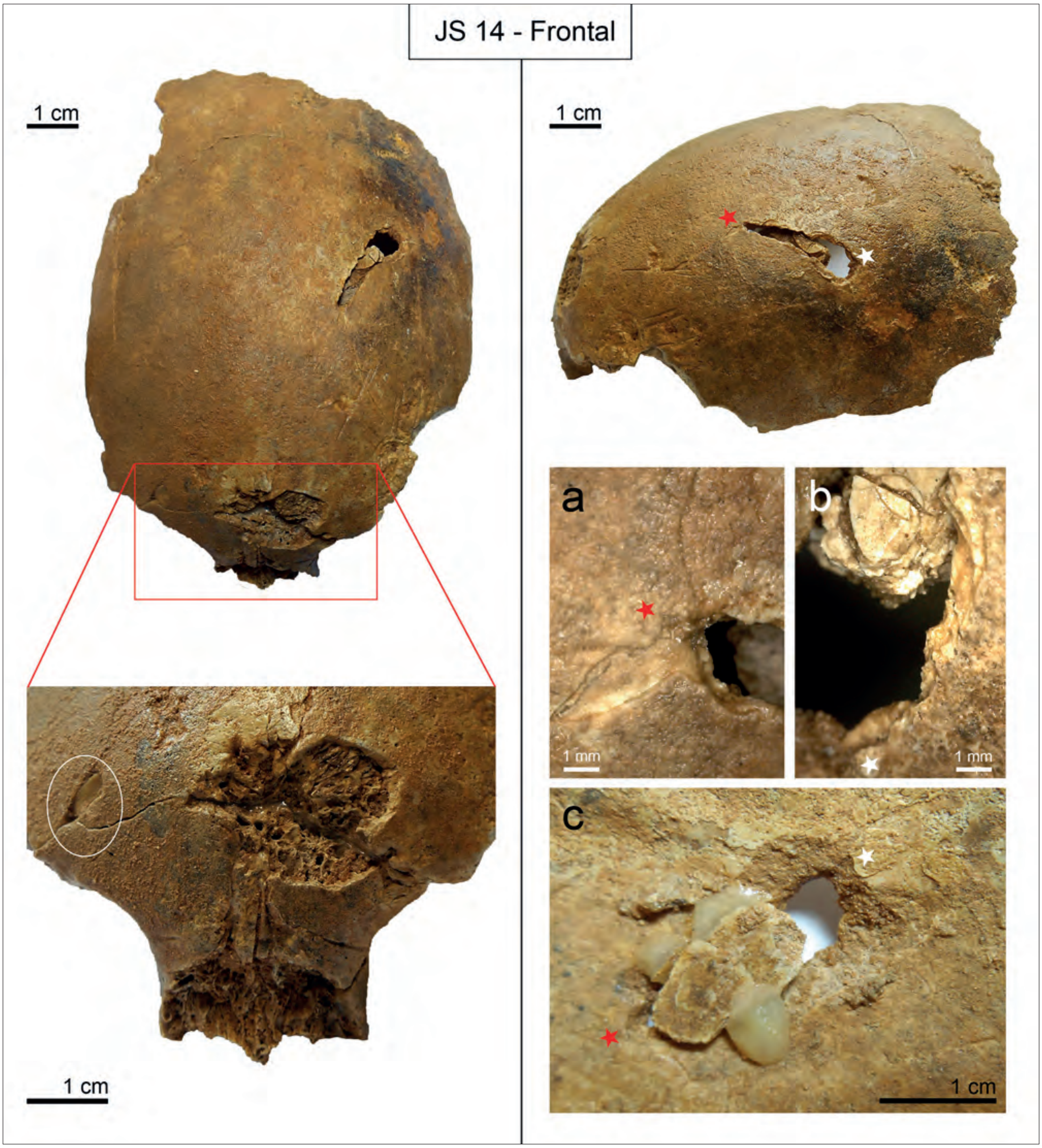

Fig. 9 – Lesions of the frontal bone on JS 14. Left, superior view of the frontal bone with, below, the magnification in frontal view of the red box showing the blunt force trauma and the embedded lithic (white oval) with hinge fractures; right, left lateral view of the frontal bone displaying the projectile perforation. Red and white stars are reference points for the magnified area; a, hinge fractures at the level of the entrance of the projectile; b, crushing fractures on the border of the perforation; c, endocranial view of the internal beveling. Note the miss-glued piece of bone associated to the perforation, part of the original conservation works.

***Fig. 9** – Lésions sur l'os frontal de JS 14. À gauche, vue supérieure de l'os frontal avec, en bas, le grossissement en vue frontale du rectangle rouge montrant le traumatisme par objet contondant, l'artéfact lithique fiché (ovale blanc) et les lignes de fractures ; à droite, vue latérale gauche de l'os frontal montrant une perforation oblongue associée à la pénétration d'un projectile. Les étoiles rouge et blanche sont des points de référence pour situer la zone agrandie ; a, lignes de fractures au niveau de l'entrée du projectile ; b, fractures par écrasement au bord de la perforation ; c, vue endocrânienne du biseau interne. Notez le morceau d'os mal collé associé à la perforation, lié aux travaux de conservation d'origine.*

Fig. 10 – Projectile impact marks on the left femur of JS 14. Left: Anterior view of the preserved part of the left femur; a, close up on the two sets of drag marks located on the antero-lateral side of the shaft; white star put as reference point for the magnified area; b, detailed view of the superior drag revealing the wide flat bottom of the groove and the parallel microstriations (magnification 245x).

***Fig. 10** – Marques d'impact de projectile sur le fémur gauche de JS 14. À gauche : vue antérieure de la partie conservée du fémur gauche ; a, gros plan sur les deux séries d'éraflures situées sur le côté antéro-latéral de la diaphyse ; l'étoile blanche est un point de référence pour situer la zone agrandie ; b, vue détaillée de l'éraflure supérieure révélant la morphologie de fond de sillon, large et plat, et les microstriations parallèles (grossissement 245x).*

tion of the body, laid on his back, with the head toward the northwest, the right upper limb extended alongside the torso and the left one across the stomach, differs from the associated group of multiple burials (JS 26, JS 27, JS 29, JS 30, JS 32 and JS 36; fig. 1).

Seventeen lithic artefacts found *in situ* were in direct association with his remains, with two embedded in the bone and 15 within the physical space of the body. Some were found inside the rib cage, close to the vertebral column, in the joint of the right scapula and humerus, next to the proximal end of the left humerus, and between the left tibia and the fibula, as well as on the right ilium (Wendorf, 1968c, p. 973-974). The artefacts are one "J-shaped geometric" (i.e. crescent-like backed piece in our own typological classification), retouched or unretouched microlith flakes and chips, "backed, convex backed and backed and basal truncated flakes" (each of them belonging to one of these three types illustrated below: crescent-like backed piece; backed symmetrical mono-points; backed asymmetrical mono-points with an oblique or transverse cutting edge). F. Wendorf also originally recorded the two embedded chips, with one initially interpreted as in a thoracic vertebra and the other in the right pubic symphysis. However, J. E. Anderson (1968) revised their identification as the lower cervical vertebra and left pubis, with the bone around both lithics showing severe reactive changes (in Anderson, 1968, fig. 15C; in Wendorf, 1968c, fig. 36). These two bones are, unfortunately, not part of the collection donated to the British Museum and their whereabouts are unknown. A previously unnoticed lithic artefact logged in the right femoral diaphysis was also identified during this reanalysis, bringing the total to three embedded lithics (fig. 11).

The lesions observed on JS 31 are located on the post-cranial skeleton. The reanalysis of the skeletal remains revealed previously unidentified healed and unhealed projectile impact marks, as well as healed lesions that are most likely the result of earlier interpersonal injuries. In addition to the embedded lithic artefacts in the now lost seventh cervical vertebra and the left pubic symphysis, several unhealed PIMs were identified including a puncture with crushing, faulting and flaking of the bone surface on the anterior surface of the left scapula. An incision was also observed on the subscapular fossa, about 2 cm below the scapular notch (fig. 12) and a deep V-shaped drag 2 cm in length is present halfway up the humerus on the posterior-medial side. Another long cutmark on the posterior-lateral face of the left ilium is harder to interpret and may not have been caused by a projectile. JS 31 also has a healed fracture of the distal extremity of the right first metacarpal. The right femur offers further evidence of healed lesions, with the presence of a bone callus on the lateral side of the proximal part of the shaft, and of a healed projectile wound on the anterior side at midshaft. Three previously unidentified embedded lithic chips are trapped in the healing bulge of the latter (fig. 13). The lesion on the proximal part of the diaphysis may relate to the healing of a partial fracture.

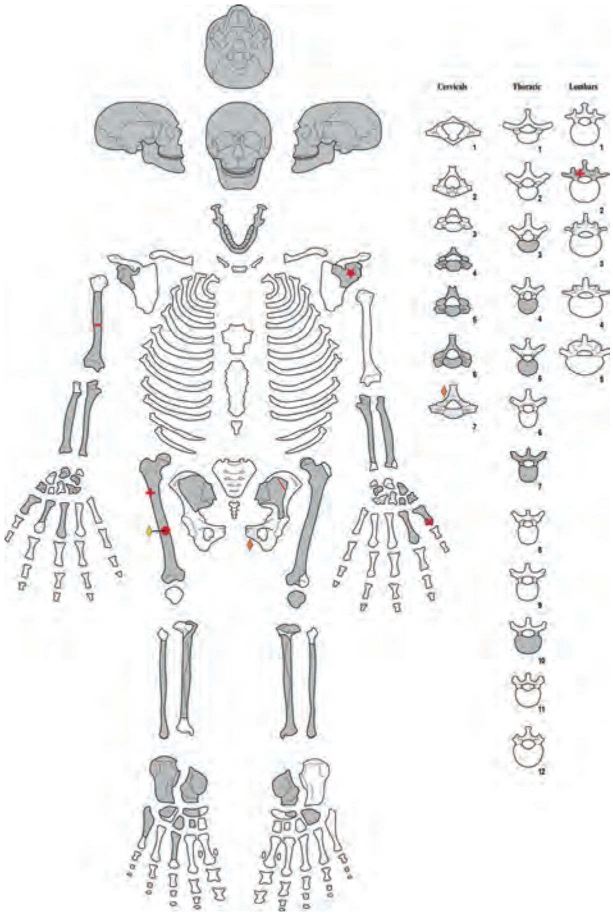

Fig. 11 – Location of the observed osseous lesions on JS 31. Grey parts represent preserved bones; striped areas are missing bones; full star, unhealed puncture; dash, drags traces of projectile impacts; line, cutmark; plus sign, healed lesions; time sign, healed fracture; full circle, healed puncture; yellow diamond, embedded artefact in a puncture; orange diamond, embedded artefact in lost bone.

***Fig. 11** – Localisation des lésions osseuses observées sur JS 31. Les parties grises représentent les os conservés ; les zones hachurées représentent des os ou fragments d'os manquants. Étoile pleine, percement non cicatrisé ; tiret, éraflures liées au passage d'un projectile ; ligne, trace de coupure ; signe plus, lésions cicatrisées ; signe multiplié, fracture cicatrisée ; cercle plein, percement cicatrisé ; losange jaune, artefact fiché dans un percement ; losange orange, artefact fiché dans un os perdu.*

Case 3: JS 44, a possible female individual that appears to have been older than 30 years, was buried about 35 cm below the surface and covered by sandstone slabs. The remains were found in close proximity to JS 45 and JS 46, both of whom were buried deeper than JS 44. Excavated by the Finnish expedition, it remains unclear if these individuals were interred at the same time. Like most of the Jebel Sahaba individuals, JS 44 was buried on her left side, in a contracted position with her head toward the east. Twenty-one lithic artefacts were found in close association with the skeleton, one of which was embedded in the fourth rib, close to the vertebra. The others are located close to the mandible, in the pelvis and rib cage, against the distal end of the right femur, and between lumbar ver-

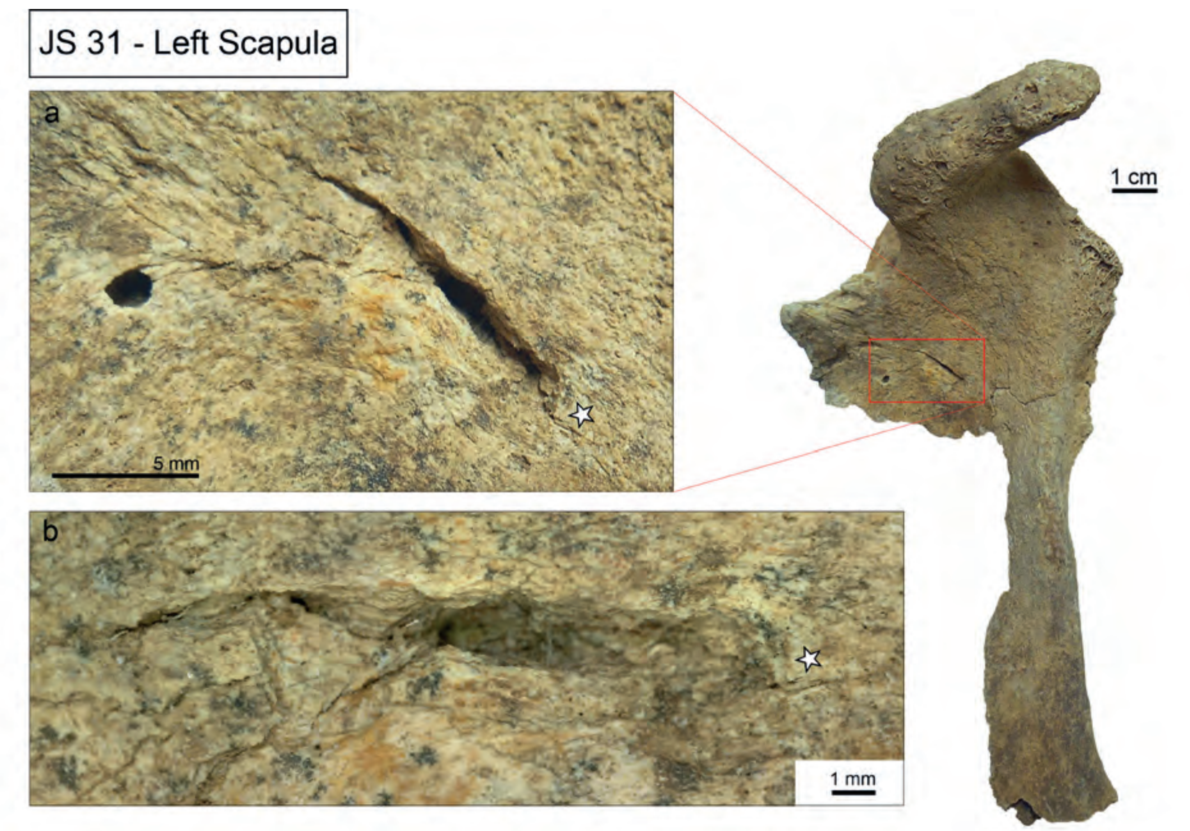

Fig. 12 – Projectile impact puncture on the left scapula of JS 31: a, red rectangle close up on the subscapular fossa showing the puncture associated with flaking and faulting; b, composite microscopic image of the puncture displaying the crushing of the bone in the lower border of the puncture (magnification 40x).

Fig. 12 *– Percement par impact de projectile de l'omoplate gauche de JS 31 : a, Rectangle rouge en gros plan sur la fosse sous-scapulaire montrant le percement avec un écaillage osseux et des lignes de fractures ; b, image microscopique composite du percement montrant l'écrasement de l'os dans le bord inférieur du percement (grossissement 40x).*

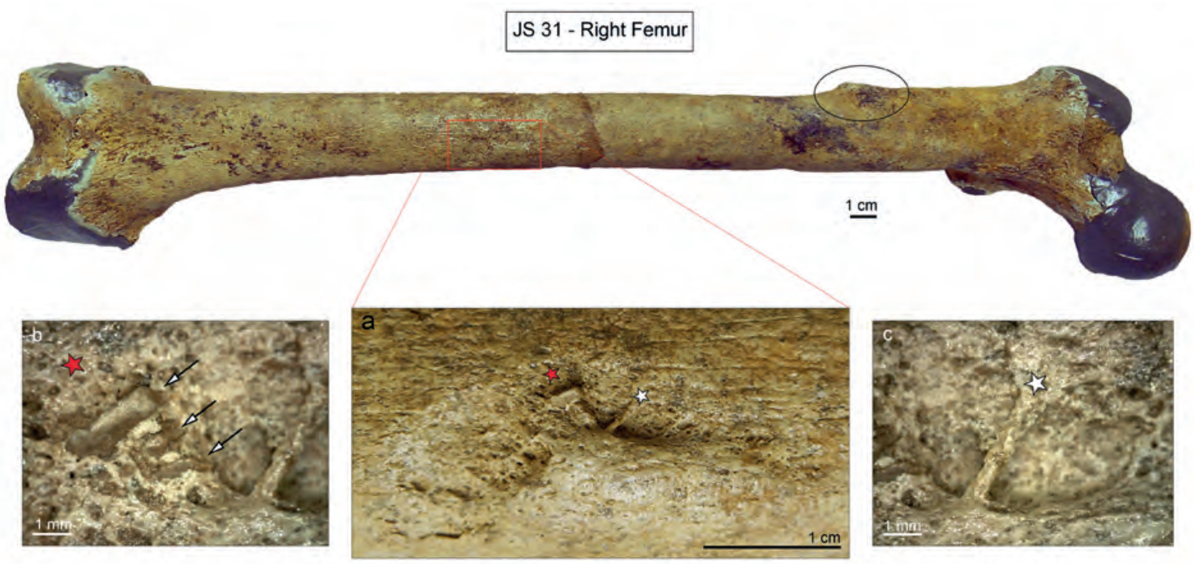

Fig. 13 – Healed lesions on the right femur of JS 31. Red rectangle, healed projectile lesion; black ellipse, bone callus; a, red rectangle close up of the healed projectile injury with red and white stars as reference points for the magnified area b and c; b, microscopic view of the three embedded lithic chips marked by arrows; c, microscopic view of a bony bridge separating two geometric marks indicating the presence of two lost lithic chips (magnification 50x).

Fig. 13 – Lésions *cicatrisées sur le fémur droit de JS 31. Rectangle rouge, lésion cicatrisée liée à un projectile ; ellipse noire, cal osseux ; a, gros plan du rectangle rouge illustrant la lésion cicatrisée liée à un projectile avec des étoiles rouge et blanche comme points de référence pour situer les zones agrandies b et c ; b, vue microscopique des trois éclats lithiques fichés dans l'os et marqués par des flèches ; c, vue microscopique d'un pont osseux séparant deux marques géométriques indiquant la présence de deux éclats lithiques perdus (grossissement 50x).*

tebras (Wendorf, 1968c, p. 978). According to F. Wendorf (1968c), the artefacts include two "J-shaped geometrics" (corresponding to two different categories in our own typological classification, i.e. a crescent-like backed piece and a backed symmetrical mono-points), unretouched flakes and chips, and "backed, convex backed, backed and straight oblique distal truncated, and straight basal truncated flakes" (each of them belonging to one of the same three types illustrated below: crescent-like backed piece; backed symmetrical mono-points; backed asymmetrical mono-points with an oblique or transverse cutting edge). F. Wendorf also noted two cases of chip and/or flake alignments during the excavation which were interpreted as evidence of composite projectile use (Wendorf, 1968c). The fourth rib with embedded "backed flake" is, unfortunately, also not present in the British Museum Wendorf collection, and could therefore not be reassessed.

As with JS 31, all the lesions observed on JS 44 are located in the post-cranial skeleton (fig. 14), with healed fractures present on the left clavicle, right ulna and radius, and one left rib. The fracture of the left clavicle shaft is located on the acromial end of the diaphysis, revealing a slight torsion and a displacement of the bone fragments. The right forearm healed fracture is oblique, with a displacement (translation and rotation) of the two broken pieces (fig. 15). The trauma broke the proximal part of the ulna's diaphysis and the distal part of the radius shaft. The clavicle and forearm fractures most probably occurred during the same event. Given the oblique nature in the forearm and acromial involvement in the clavicle, they might be the result of an indirect trauma, such as a bad fall, rather than a defensive parry fracture (see Lovell, 1997).

The other lesions, however, are clearly the result of projectile impacts. A triangular notch on the lateral face of the ilium, about 1 cm from the greater sciatic notch, has a lithic fragment embedded in the incision. The laminated aspect of the bone overlying the flake suggests there was an attempt to extract the projectile (fig. 16). The morphology of the mark also indicates the projectile travelled from the postero-medial to the antero-lateral side of the left pelvic bone, which suggest the projectile was travelling back to front. In addition to the now missing fourth rib, PIMs were also observed on right femur. Two parallel drags less 1 cm long and approximately 2 cm from each other are visible on the posterior side of the diaphysis. These two drags exhibit a flat bottom with parallel microstriations. The most distal one shows flaking marks on the proximal border (fig. 17). It is worth noting that the angle of penetration into the bone differs for both drags, the most proximal one being more tangential. These drag marks reflect a projectile trajectory that came from the disto-lateral to the proximo-medial part of the bone. An upward direction suggest that the individual was hit while running or that the projectile was drawn from a lower position. In addition, the spacing between these two drags and their morphology are consistent with penetration from a single composite projectile. This hypothesis is strengthened by F. Wendorf's field observation of *in situ* lithic alignments associated with JS 44.

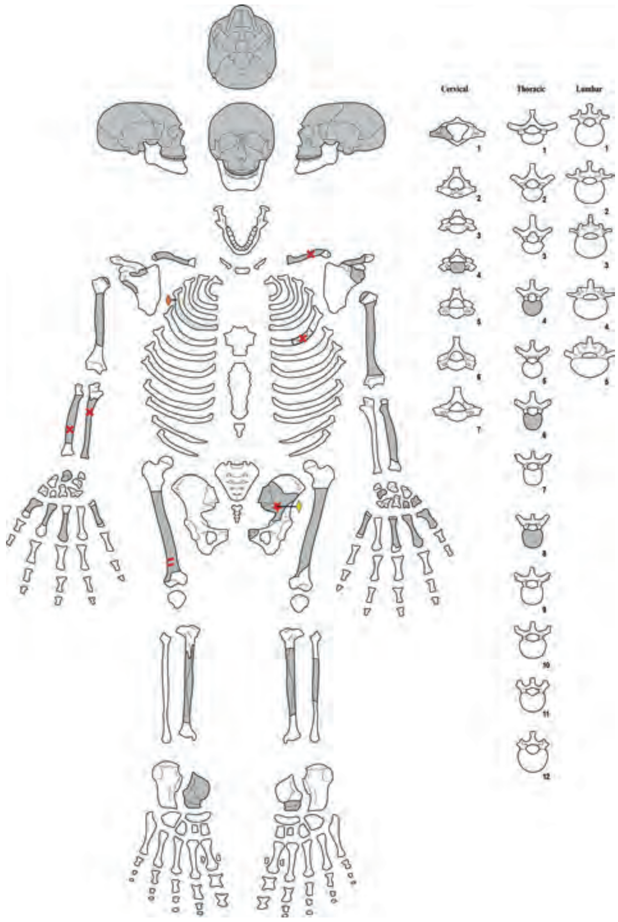

Fig. 14 – Location of the observed osseous lesions on JS 44. Grey parts represent preserved bones; striped area is a missing bone; crisscross area is a rib whose exact anatomical position is unknown. Full star, unhealed puncture; dash, drags traces of projectile impacts; time sign, healed fracture; yellow diamond, embedded artefact in a puncture; orange diamond, embedded artefact in lost bone.

***Fig. 14** – Localisation des lésions osseuses observées sur JS 44. Les parties grises représentent les os conservés ; la zone rayée représente un os manquant ; la zone quadrillée est un fragment de côte dont le rang n'est pas certain. Étoile pleine, percement non cicatrisé ; tiret, éraflure liée au passage d'un projectile ; signe multiplié, fracture cicatrisée ; losange jaune, artefact fiché dans un percement ; losange orange, artefact fiché dans un os perdu.*

2.2 Burial selection and mortality profile

In view of the high number of individuals with evidence of interpersonal violence, the frequency of projectile impact marks, and the presence of several double or multiple burials, the site's mortality profile was analyzed to investigate possible patterns in burial selection (see Sellier, 1996; Castex et al., 2009). Should the cemetery reflect a single "warfare" event, an unbalanced demographic profile (e.g. the overrepresentation of a certain sex or age class less likely to die otherwise) is probable (see Bridges, 1996). At Jebel Sahaba, the individuals that could be sexed (n = 39) revealed no bias, with 48.7% females and 51.3% males. The age distri-

Fig. 15 – Healed fractures on JS 44. From top to bottom, left clavicle superior view, right radius anterior view and right ulna anterior view.

Fig. 15 – *Fractures cicatrisées sur JS 44. De haut en bas, vue supérieure de la clavicule gauche, vue antérieure du radius droit et vue antérieure de l'ulna droit.*

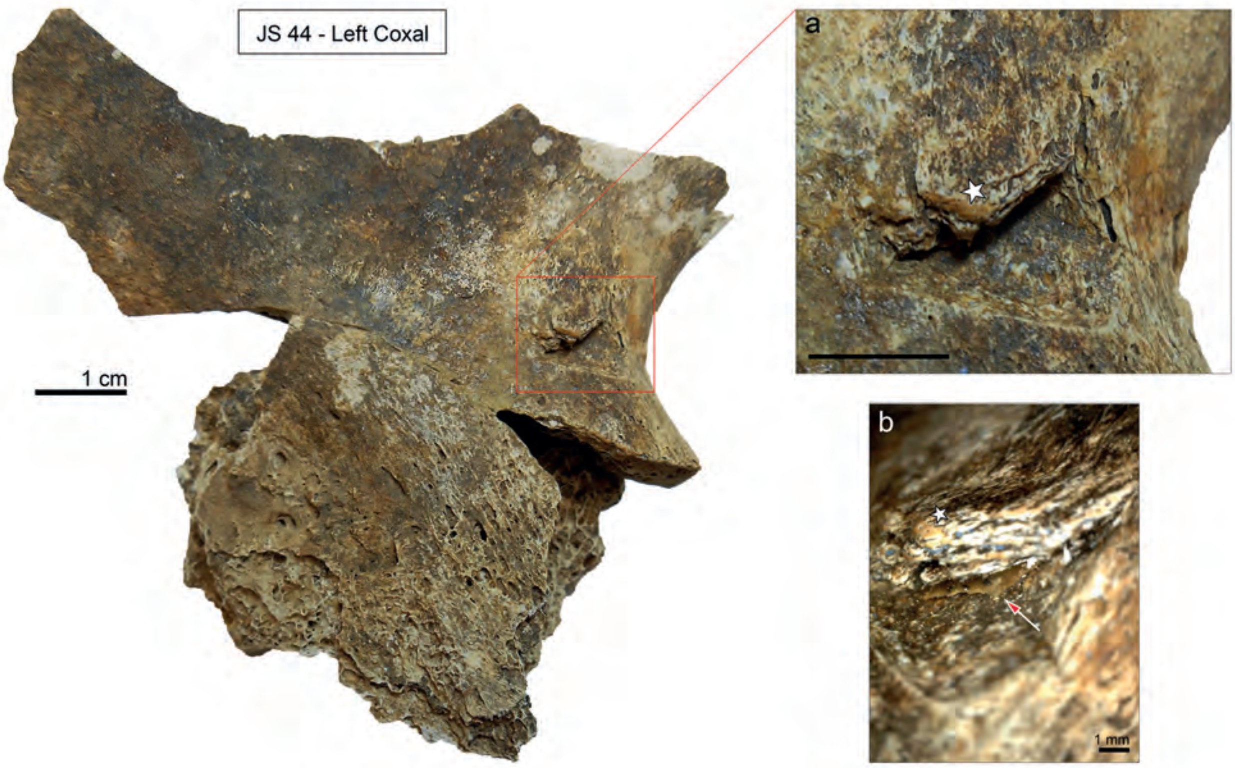

Fig. 16 – Lateral view of the left pelvis of JS 44 with a projectile impact puncture with an embedded lithic flake. a, red rectangle close up of the PMI with white star as reference point for the magnified area b; b, microscopic view of the puncture showing the laminated aspect of the superior border and the lithic artefact inside the puncture indicated by the red arrow (magnification 30x).

Fig. 16 – *Vue latérale du coxal gauche de JS 44 avec un percement lié à un impact de projectile contenant un éclat lithique toujours fiché dans l'os. a, Gros plan du rectangle rouge centré sur la MIP avec l'étoile blanche comme point de référence pour la zone agrandie b ; b, vue microscopique du percement montrant l'aspect feuilleté du bord supérieur, l'artefact lithique fiché dans le percement est indiqué par la flèche rouge (grossissement 30x).*

Fig. 17 – Parallel drags on JS 44 located on the posterior surface of the right femur diaphysis, at the level where the lateral supracondylar line, which delimitates the lateral part of the popliteal plane, meets to lateral side of the femoral diaphysis. a, red rectangle close up showing the two parallel drags and the direction of the projectile with the arrows; white star as reference point for the magnified area b; b, microscopic close up on the distal drag showing the flaking of the superior border at the origin of the drag; red star as reference point for the magnified area c (magnification 45x); c, composite microscopic view of the proximal part of the distal drag displaying the wide flat bottom of the groove and the parallel microstriations (magnification 235x).

***Fig. 17** – Éraflures parallèles présentes sur JS 44 au niveau de la face postérieure de la diaphyse fémorale droite, à l'endroit où la ligne supra-condylaire latérale, qui délimite la partie latérale du plan poplité, rejoint la face latérale de la diaphyse fémorale. A, gros plan du rectangle rouge montrant les deux traînées parallèles, la direction du projectile est indiqué par le sens des flèches, et l'étoile blanche marque le point de référence pour la zone agrandie b ; b, vue microscopique de l'éraflure distale montrant l'écaillage du bord supérieur à l'origine l'éraflure ; l'étoile rouge marque le point de référence pour la zone agrandie c (grossissement 45x) ; c, vue microscopique composite de la partie proximale de la traînée distale révélant la morphologie de fond de sillon, large et plat, et les microstriations parallèles (grossissement 235x).*

bution shows a clear underrepresentation of non-adults ([< 20] = 29.5%) compared to the theoretical percentage ([<20] = 54.5% ± 9.5%) for a population with a life expectancy at birth of between 25 and 35 years (Ledermann, 1969). However, this imbalance is mostly due to the lack of perinates, neonates and young children (age classes [0-1] and [1-4]) whose mortality quotient stands outside the lower limits of the theoretical values (fig. 18).

As with the young adults, the remaining non-adults do not exhibit any unusual distribution, and neither category is overrepresented at the site. Interestingly, the small proportion of very young children is not unusual in pre-Neolithic funeral assemblages and could relate to demographic factors, cultural behaviors such as the separate burial of young infants, or poor preservation (Saxe, 1971; Bocquet-Appel, 2002; Bocquet-Appel and Naji, 2006). In the case of Jebel Sahaba, differential preservation does not appear to have been a factor as a majority of the non-adults remains are well-preserved.

2.3 Reassessment of the lithic assemblage

With the exception of a few flakes and points, the surface artefacts (i.e. found into the fill surrounding the burials) differ in term of typology and raw material from the ones found inside the burials and within the physical space of the skeletons. According to F. Wendorf and R. Schild (2004), 116 pieces were found in direct association with 24 individuals. This number, however, differs from the number of listed artefacts in their tables (n = 112), as well as those described in the original publication (n = 118; Wendorf, 1968c). Their 2004 paper does not appear to include burials JS C-1, JS C-2 and JS C-3, excavated by the Columbia Expedition, and the lithic artefact found with JS 41 was not reported in F. Wendorf and R. Schild (2004) as its exact position in the deposit was noted as unknown in F. Wendorf (1968c).

Of F. Wendorf's 1968c publication, 118 artefacts, including seven embedded ones, were found directly associated with 27 individuals. Our reassessment has led to the identification of a further 13 pieces embedded in the bones. We counted the multiple fragments found in one PIM as one artefact (table S2). Based on these findings, a new total of 132 artefacts were found in direct association with 28 individuals. In addition to the lithic assemblage from the surface (n = 72), our reassessment included 115 pieces from the original collection. The three pieces from burials JS 25, JS 45 and JS 47 are not in the British Museum collection. A supplementary piece was, however, found associated to burial JS 26. This piece was mixed with the surface material, probably from the beginning, which could explain its absence in F. Wendorf's inventory (although the piece was drawn in Wendorf, 1968c, fig. 34dd). We also included five pieces found near burials JS 101 to JS 107. Although not directly in contact with the skeletons, their association to the individuals in this multiple burial is suggested by F. Wendorf (1968c, p. 988). We have taken into account these artefacts in our reas-

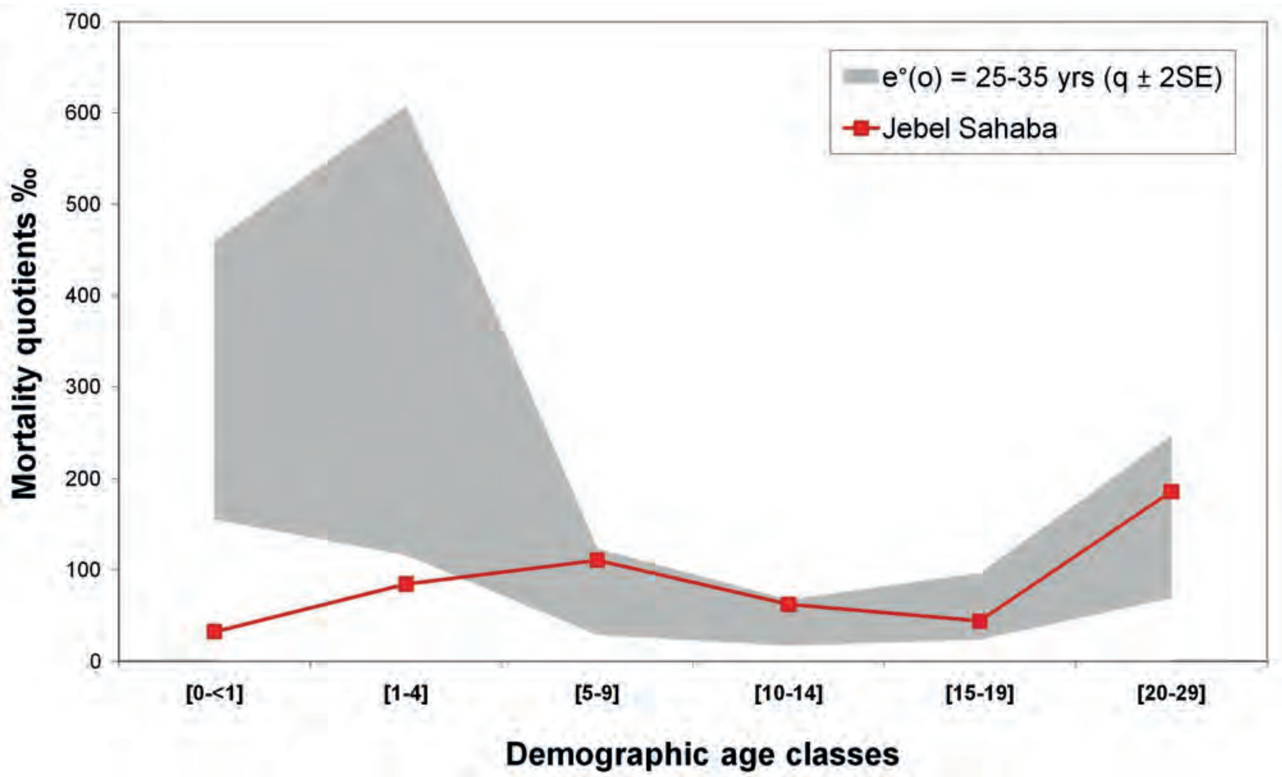

Fig. 18 – Mortality quotients by age class at Jebel Sahaba compared to the theoretical mortality rates of S. Ledermann (1969) for a population with a life expectancy at birth of between 25 and 35 years.

***Fig. 18** – Quotient de mortalité par classe d'âge à Jebel Sahaba comparé aux taux de mortalité théoriques de S. Ledermann (1969) pour une population préindustrielle ayant une espérance de vie à la naissance comprise entre 25 et 35 ans.*

sessment, but we remained cautious as to their association with the burials. Our reexamination confirms the diversity of shape of the artefacts with a tendency toward small size pieces. Despite a strong typological variability, most lithic artifacts found inside the burials can be identified as projectiles or armature elements, including the unretouched parts. This industry, however, is hard to characteristics and compare to other from the same period as it is based on an assemblage consisting of elements that mostly relate to a single function: the manufacture of weapons. However, technological and typological elements fit well with the definition of the Qadan industry (Shiner, 1968). The current reassessment also revealed strong similarities to the Tushka area B industry previously attributed to the Qadan (Albritton and Wendorf, 1968; Wendorf, 1968b; Becker and Wendorf, 1993). In Jebel Sahaba burials, as in Tushka area B, the lithic artefacts were mainly produced using a bipolar technique on anvil with small flint nodules or small pebbles. This kind of knapping generates flakes with very diverse morphologies. However, certain intentions are discernable, particularly a desire to obtain elongated flakes with asymmetrical sections. Another method, however less represented, enters into Levallois production *sensu lato*. On the other hand, no blades or bladelets productions are identified in this assemblage.

Our reassessment of the 115 lithic artefacts revealed 62 points (see below), 43 unretouched flakes and microchips, and seven undetermined pieces (fig. 19 and fig. 20). In addition, one Levallois core (fig. 19c), one scraper (fig. 19d) and one burin (fig. 19e) were noted. However, it should be underlined that the association of the Levallois core and the burin with the skeletons is described as less certain by F. Wendorf, compared to the others artefacts mentioned in associated with the burials. Among the points, three main morphologies can be distinguished: backed asymmetrical mono-points with an oblique or transverse distal cutting edge (n = 22; fig. 19, q to v), backed symmetrical mono-points (n = 16; fig. 19, f to l) and crescent-like backed pieces (n = 9; fig. 19, m to p). In addition, there are indeterminate points (n = 10; mostly fragments which could belong to one of the previous categories). There are also unretouched symmetrical mono-points (n = 5; fig. 19, a and b), some of which are the only ones that can be tentatively assigned to Levallois industry. On the other hand, we note the absence of elongated bi-points corresponding to “typical” lunate. The range in size is fairly diverse, with most points microlithic (around 2-2.5 cm long), while others are more robust (3 to 4 cm long). This is especially the case among the backed symmetrical mono-points and the unretouched symmetrical mono-points. Significantly, preliminary functional analysis shows that some artefacts bear impact fractures.

Morphological diversity co-occurs within burials. Of the 21 pieces found in association to burial JS 44, for example, six are micro- and three unretouched flakes, five are backed symmetrical mono-points, three backed mono-points with an oblique or transverse distal cutting edge, three crescent-like backed pieces and one is an indeterminate point.

Based on this reanalysis, almost half of the elements used as weapons are unretouched flakes and microflakes, that would have been missed in any other context (fig. 20), as noticed by F. Wendorf (1968c). Most appear to be laterally shafted composite elements used as part of projectiles. The points would have been mounted at the end of shafts, with crescents laterally shafted. Their diversity in both size and shape suggests the use of several types of weapons, particularly light arrows but also much heavier arrows or spears. Finally, the use of points with oblique or transverse distal cutting edges appears to indicate that one of the main lethal properties sought is to slash and cause blood loss. The fact that many were found inside the volume of the skeleton indicates their efficiency at penetrating the body. Those found are likely to be the ones that had detached themselves from their shaft and were not successfully removed prior to burial.

Finally, a remark is necessary regarding the artefacts within the fill of the surrounding burials. In a recent paper, D. Usaï (2020) uses their existence as a basis for questioning the association of all the artifacts discovered at Jebel Sahaba with the burials. Her hypothesis is that the excavation of the burials in older archaeological levels would have fortuitously mixed all these artefacts with the contents of the tombs. The counter-argument to this hypothesis is based on two categories of information: 1) the clear spatial correlation that exists between many of the lithic remains previously described and the numerous traces of impact that a majority of the bodies bears; 2) the fact that the remains found in direct association with the bodies form an assemblage that is completely different from the one collected from within the fill surrounding the burials. Within this latter assemblage, a large part of the pieces is composed of varieties of rock not represented in the lithic industry explicitly associated with the skeletons. These pieces are notably in silicified wood, quartz or quartzite (29 out of 71 pieces studied). Finally, a careful examination shows that only about 10% of these elements are similar to the artefacts explicitly associated with the skeletons, underlining that these assemblages are of different origins. Moreover, and contrary to what D. Usaï (2020) asserts, the number of pieces associated with the bodies in the burials that are not compatible with weapon remains is very small: a scraper (JS 29), a Levallois core (JS 41), and a burin (JS 110). Besides, the core is noted as “found in fill adjacent to skeleton, exact position unknown” (Wendorf, 1968, p. 977) and the burin is described as “found with or near burials” (Wendorf, 1968, p. 988). This leads us to conclude that there is no artefact, or very few, that could be seen as grave goods, but that most if not all of the artefacts found in direct association with the skeletons do indeed belong to the weapons used to wound them. The comparison we were able to make between the artefacts found in direct association with the burials and the assemblage of Tushka B, unanimously attributed to Qadan, allows us to maintain this cultural attribution not only for the lithic components but also for the burials that deliver its elements.

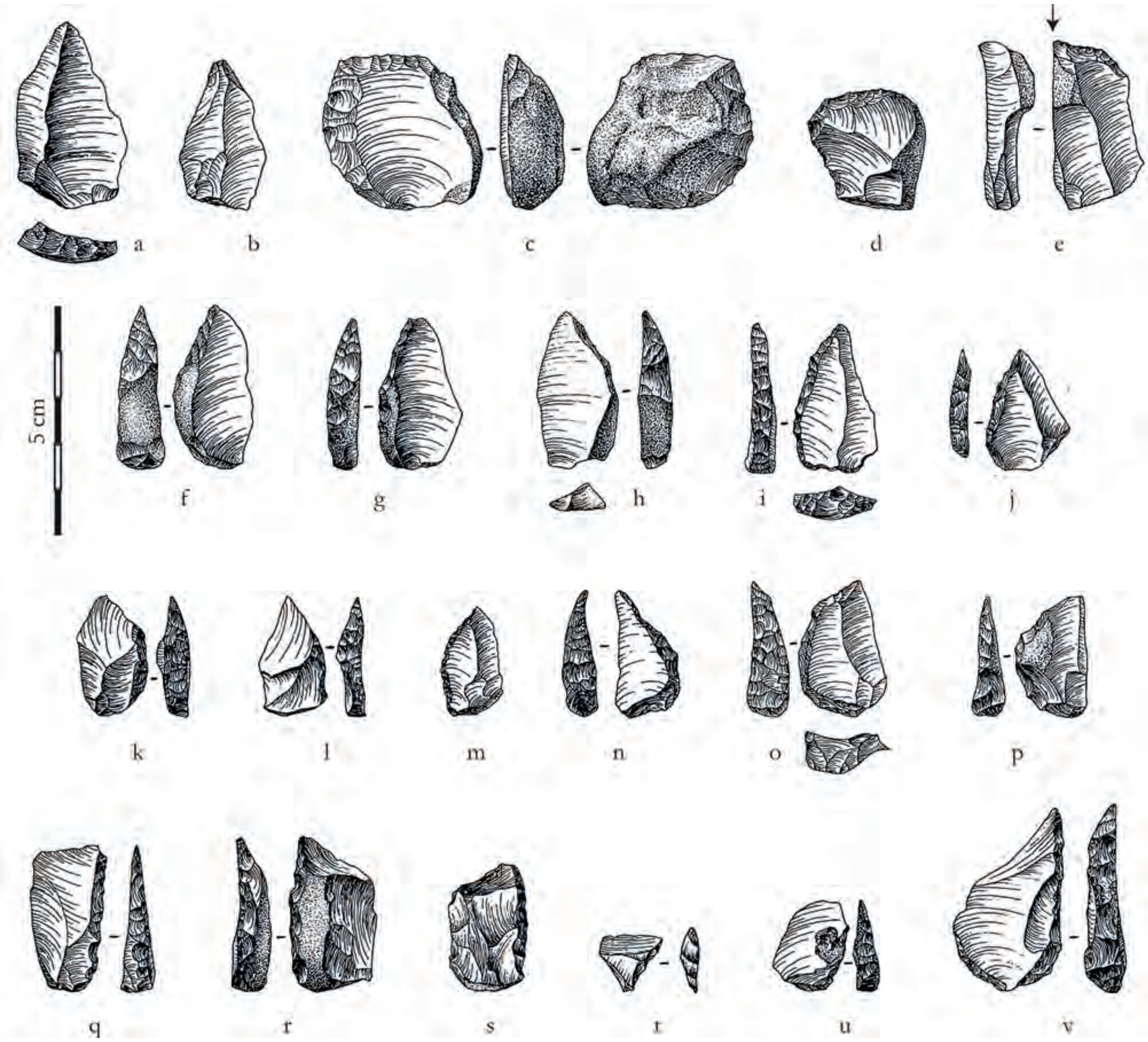

Fig. 19 – Jebel Sahaba, lithic industry sample (modified following Wendorf, 1968c): a-b, unretouched symmetrical mono-points (assimilated with caution to Levallois points); c, Levallois core; d, scraper; e, burin; f to l, backed symmetrical mono-points; m to p, crescent-like backed pieces; q to v, backed asymmetrical mono-points with an oblique or transverse distal cutting edge. Burials JS 14 (g-h); JS 21 (i, m, v); JS 29 (d); JS 31 (q-r); JS 33 (s); JS 34 (n); JS 35 (a, t); JS 41 (c); JS 44 (f, j to l, p, u); JS 103 (b), with or near JS 110 (e), JS-C1-3 (o).

***Fig. 19 :** Jebel Sahaba, échantillon de l'industrie lithique (d'après Wendorf, 1968c) : a-b, mono-pointes symétriques non retouchées (hypothétiques pointes Levallois) ; c, nucléus Levallois ; d, grattoir ; e, burin ; f à l, mono-pointes symétriques à dos ; m à p, pièces à dos assimilables à des géométriques de type de croissant ; q à v, mono-pointes asymétriques à dos avec un tranchant distal oblique ou transversal. Tombes JS 14 (g-h) ; JS 21 (i, m, v) ; JS 29 (d) ; JS 31 (q-r) ; JS 33 (s) ; JS 34 (n) ; JS 35 (a, t) ; JS 41 (c) ; JS 44 (f, j à l, p, u) ; JS 103 (b), avec ou près de JS 110 (e), JS-C1-3 (o).*

3. DISCUSSION

Since its discovery in the 1960's, the Jebel Sahaba cemetery has been regarded as the oldest evidence of organized warfare caused by environmental constrains (e.g. Thorpe, 2003; Guilaine and Zammit, 2005; Daković, 2014). However, the lesions observed on the Jebel Sahaba skeletons and the nature of the funerary complex had not been reassessed (or benefited from the use of modern anthropological methods) since F. Wendord's 1968a publication. It remained unclear if the site was the result of a single conflict, a specific burial place for individuals who died a violent death or evidence of sustained interpersonal violence in Late Pleistocene hunter-gatherer groups (Wendorf and Schild, 2004).

F. Wendorf (1968c) and J. E. Anderson (1968) had highlighted the projectile nature of several lesions, particularly those bearing embedded lithic artefacts. Here, macroscopic and microscopic methods were used to distinguish projectile injuries from slicing cutmarks and taphonomical modifications (see Shipman and Rose, 1983; Morel, 2000; Pétillon and Letourneux, 2003; Smith et al., 2007; Castel, 2008; Domínguez-Rodrigo et al. 2009; Backwell et al., 2012; O'Driscoll and Thompson, 2014; Duches et al., 2016; Fernández-Jalvo and Andrews, 2016). More than half of the injured individuals buried at Jebel Sahaba exhibit clear projectile impact marks (61.0%; n = 25), with most showing signs of trauma (92.7%; n = 38). Irrespective of age and sex, the majority have clear signs of interpersonal violence involving projectile weapons. The number of individuals with both healed and unhealed traumas also increases with age from adolescence (n = 1), to young adults (n = 2) and adults (n = 13). Importantly, the co-occurrence of ante-mortem and perimortem lesions on several Jebel Sahaba individuals had not previously been noted and indicates that acts of interpersonal violence occurred repeatedly within their lifetime.

As with experimental studies on ungulates (Castel, 2008; Duches et al., 2016), drag marks are the most frequent PIMs observed at Jebel Sahaba. In ungulates, these are usually followed by punctures, particularly on the appendicular skeleton (Castel, 2008; Duches et al., 2016), which was also the case at Jebel Sahaba. As underlined by M. J. Smith et al. (2007), microscopic fragments of the actual weapons also often end up embedded in the bones, either at impact or while attempting to remove the weapon. J.-C. Castel (2008) experimental work also reveals that 45.0% of ungulates PIMs include at least one small embedded lithic fragment. At Jebel Sahaba, artefacts were found in one third of the drag and puncture impact marks (31.3%; n = 20). Of these, the great majority were in puncture marks (70.8%; n = 17).

The PIMs patterns support the use of composite weapons made of shafted retouched and unretouched flakes, including light and heavy projectiles. This is corroborated by the alignment of flakes and chips within the physical space of the skeletons, the reassessment of the lithic assemblage and cases of parallel drags less than 2 cm apart consistent with ethnographical and experimental spear and arrow shaft diameters (Dias-Meirinho, 2011; Pétillon et al., 2011; Duches et al., 2016).

Identifying interpersonal violence on skeletal remains is not always straightforward and often depends on the type of trauma and the archaeological context (Walker, 2001; Jackes, 2004). Clear examples of fatal interpersonal blunt (e.g. Sima de Los Huesos SH17; Sala et al., 2015) and sharp force trauma (e.g. Shanidar 3; Trinkaus, 1983) go as far back as the Middle Paleolithic. The oldest Palaeolithic projectile trauma date to the Epigravettian period (~ 31-26 kya; Fu et al., 2016), with an example of an embedded point in the second thoracic vertebra of a child from Grimaldi (Henry-Gambier, 2001) and an incision on the first thoracic vertebra of Sunghir 1 caused by a projectile or a hand-held blade (Trinkaus and Buzhilova, 2012). Based on the available evidence, the number of projectile injuries appears to increase over time and cases of fatal trauma in Europe become more frequent during the Mesolithic (Estabrook, 2014). During this period, burial assemblages containing multiple individuals with perimortem trauma also begin to appear, with famous

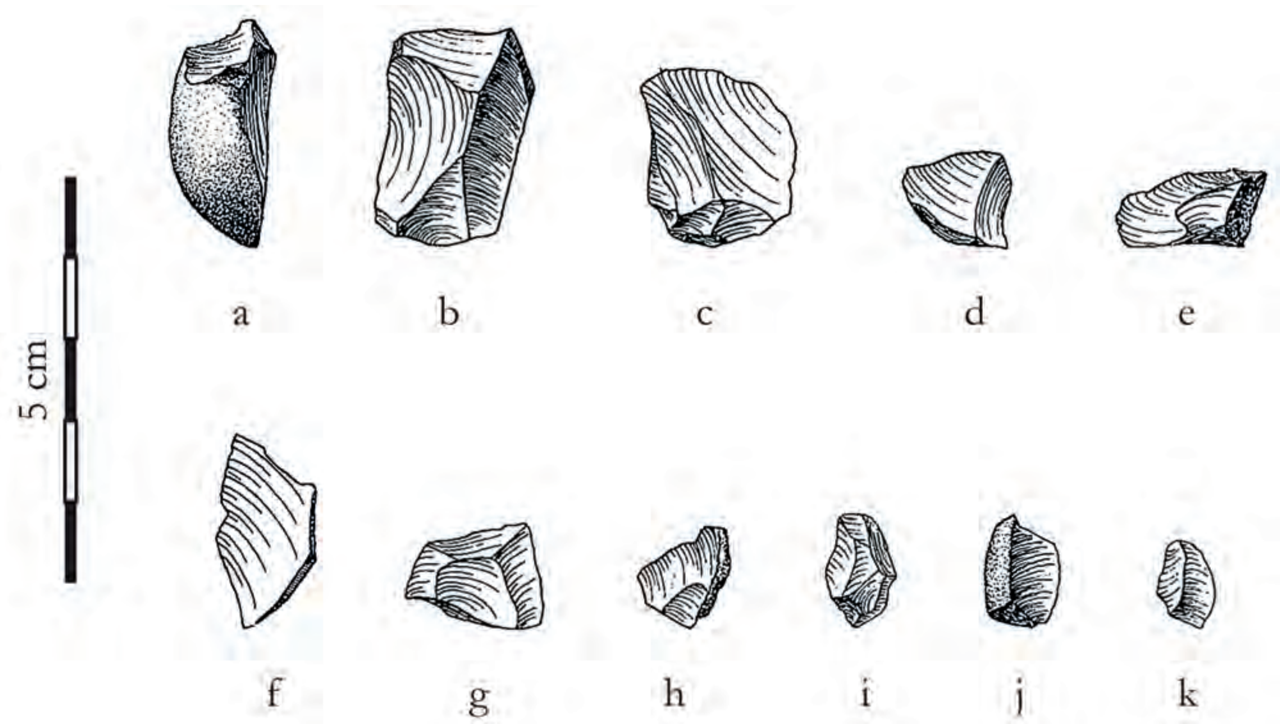

Fig. 20 – Unretouched flakes and microflakes (complete or fragmented; modified following Wendorf, 1968c) samples from Burials JS 21 (c), JS 23 (e), JS 29 (a), JS 31 (b), JS 33(d), JS 44 (f to k).

Fig. 20 *Échantillons d'éclats et de micro-éclats non retouchés (entiers ou fragmentés, d'après Wendorf, 1968c) des sépultures JS 21 (c), JS 23 (e), JS 29 (a), JS 31 (b), JS 33(d), JS 44 (f à k).*

examples at Ofnet in Germany (Frayer, 1997) and the Vasilyevka III burial ground in the Dnieper rapids region of the Ukraine (Lillie, 2004). These examples, however, differ from Jebel Sahaba. At Ofnet (circa 9 kya), females and children dominate the group and skull trauma is more frequently found in adult males (Frayer, 1997; Orschiedt, 2005). Although the interpersonal nature of the bludgeoning identified on six cranium is clear and was probably caused by warlike conflict, the deliberate grouping of 34 selected skulls and associated cervical vertebra, likely from decapitated individuals, with pierced red deer teeth in two multiple burials reflects a specific mortuary behavior (Orschiedt, 2005). The cemetery from Vasilyevka III (circa 12 kya), however, shares some similarities with Jebel Sahaba. Around 60 individuals in single, double or multiple burials were found mainly in flexed positions. Five adults were identified with single or multiple embedded microliths associated with composite projectiles (arrow and spear) including three females, one male and one undetermined individual (Lillie, 2004). In the case of Ofnet, although all individuals seem to have been subjected to a violent death, only 18% of them show clear signs of trauma on the bones selected for burial. Of the lesions observed at Jebel Sahaba, only 13.1% of the individuals have unhealed trauma to the cranium and cervical vertebrae. Similarly, at Vasilyevka III, only 8% of individuals have at least one embedded lithic compared to 18% at Jebel Sahaba. In all cases, detectable lesions and lithics only reveal part of the story.

The site of Nataruk provides the closest parallel of interpersonal violence to Jebel Sahaba (Lahr et al., 2016). Situated west of lake Turkana and dating to around 10.5-9.5 kya, the individuals found in Nataruk appear to exhibit signs of violent death through projectile impact marks (punctures and perforation), sharp and blunt force trauma, as well as fractures. Lesions mainly located on the skulls, cervical vertebras, lower limbs and hand are described (Lahr et al., 2016), although some researchers have made a case against this being a massacre site, arguing that the burials are not contemporaneous and that the cranial damage is inconsistent with blunt force trauma (Stojanowski et al., 2016). The Nataruk example also differs from Jebel Sahaba in that there is no clear pattern of deliberate burial, no signs of trauma on children and a lack of healed trauma in the adults.

Violent behavior in past and present hunter-gatherer societies appears to vary, in part reflecting the period, culture and the level of organization of mobile and semi-sedentary societies (e.g. Keeley, 1996; Kelly, 2000; Thorpe, 2003; Guilaine and Zammit, 2005; Allen and Jones, 2014). If semantic and ideological debates still surround the use of the term warfare for Prehistoric conflicts (Boulestin, 2020), ethno-archaeological examples suggest that the concept of warfare can encompass all form of antagonistic relationships from feuds, individual murders, ambush attacks, raids and trophy taking to bloody clashes and larger armed conflicts (cf. Keeley, 1996; Kelly, 2000; Guilaine and Zammit, 2005; Allen, 2014; Allen and Jones, 2014; Leblanc, 2014; Darmangeat, 2019). The level of warfare can vary, with some conflicts being all-encompassing, constant and deadly, while others are episodic events of various intensity that occur sporadically (Jones and Allen, 2014; Leblanc, 2014). Irrespective of time and space, some similarities are nevertheless observable. Many reported cases from Australia, Africa, North and South America reveal differences in the frequency and type of trauma between males and females, and acts of violence on non-adults are rare. Often, young males show higher levels of trauma, while females more frequently exhibit parry fractures (e.g. Standen and Arriaza, 2000; Chatters, 2014; Pilloud et al., 2014; Schwitalla et al., 2014; Gordón, 2015; Allen et al., 2016; Pfeiffer, 2016). Cranial injuries on the frontal and parietal bones are common, although the type of weapon used and the nature of the conflict clearly influences the nature, located and distribution of the lesions (e.g. Standen and Arriaza 2000; Chatters, 2014; Pardoe, 2014; Pilloud et al., 2014; Schwitalla et al., 2014; Allen et al., 2016). Comparisons with Jebel Sahaba, although tentative in view of the large timescale and regions involved, reveal some interesting differences. In other ethno-archaeological cases, healed traumas are the most common occurrence, while archaeological examples from Ofnet or Nataruk appear to display mostly perimortem lesions. At Jebel Sahaba, the co-occurrence of healed and unhealed lesions strongly supports sporadic, though recurrent, episodes of interpersonal violence between Nile Valley groups at the end of the Late Pleistocene. The projectile nature of at least half of the lesions suggests inter-group attacks, rather than intra-group or domestic conflicts, and the frequency of healed wounds confirms that these events were not always lethal and could occur several times during the life of an individual. A catastrophic single mass burial is highly unlikely and is not supported by the archaeological evidence or the demographic analysis. With the exception of a higher percentage of parry fractures in females, there appears to be no patterning in the distribution of trauma or PIMs by either age of sex. Based on the lesions, the projectile direction also reveals an equal number of posterior and anterior strikes that do not support face-to-face battles. Rather, the involvement of a range of ages and both sexes, with primary (n = 26), double (n = 4) and multiple (n = 4) burials, including some with evidence of disturbance due to the addition of later individuals (Wendorf, 1968c), indicates small episodes of recurring violent events such as raids or ambushes against this community. This appears to have taken place within a brief timespan given the homogeneity of burial location and practices.

Designated special burial locations for the victims of violence are documented in ethnological and historical records (Kamp, 1998; Jackes, 2004). At Jebel Sahaba, the percentage of individuals with traces of perimortem traumas and/or lithic artefacts found within the physical space of the skeleton is 54%. If multiple burials are treated as simultaneous deaths and individuals without detectable signs of a violent death, but buried in direct association with others that are included, the percentage is closer to 64%. The nearby and possibly contemporaneous burial sites at Tuskha (site 8905; Wendorf, 1968b) and Wadi Halfa (site 6-B-36; Hewes et al., 1964) do not seem to document comparable level of evidence for violence but a careful review of the data may suggest otherwise. In Tushka, 19 human skeletons from different periods were uncovered. Among them, 12 individuals buried in contracted position on their left side are thought to be dated between 15-11 kya based on geological and archaeological data, taphonomic observations and several radiocarbon dates (Albritton and Wendorf, 1968). Two double burials are present, the remaining individuals are in single burials, and no direct association of lithic artefact was noted during the excavation. Unfortunately, the surface of the cortical bone cannot be analyzed due to its poor state of preservation. The site of Wadi Halfa (6-B-36), also associated with Qadan lithic industry, displays some similarity with Jebel Sahaba, including burial practices (Saxe, 1971). Out of the 36 individuals buried at the site, seven have healed fractures of the ulna (three parry fractures), hand bones (two phalanges and one metacarpal) and lower limb (one fibula), as well as of healed trauma to the cranium (one frontal and one parietal; see Greene and Armelagos, 1972). An additional individual also shows evidence of an unhealed projectile trauma with an embedded stone point in a cervical vertebra (Greene and Armelagos, 1972). These lesions are only present on adult individuals regardless of the sex (4 males, 4 females). D. L. Greene and G. L. Armelagos (1972) also reported some new bone formation associated with longitudinal grooves on two humeri belonging to two of the individuals with signs of trauma. A. Saxe (1971) suggested that the differential mortality rates between males and females of adult age (defined here as the [25-30] age class) in the Wadi Halfa cemetery could indicate that males were engaging in warfare more than female individuals. The percentage of individuals with traumas at Wadi Halfa (22.2%; n = 8) is much lower than at Jebel Sahaba (62.3%; n = 38). However, some projectile impact marks may not have been recognized during the analysis of the human remains. The frequency of the more easily visible healed parry fractures is similar at both sites (8.3%, n = 3, for Wadi Halfa; and 9%, n = 6, for Jebel Sahaba). In both, fractures of the upper limb also dominate (84.8%, n = 28, for JS; and 85.7%, n = 6, for Wadi Halfa in ulnas and hand bones). Finally, there is little doubt that the individuals in the Jebel Sahaba cemetery were carefully buried by the members of their own community. Individual associations are likely to mirror their relationship during life with, for example, several examples of females and children in three out of the four double burials and one of the multiple burials (JS 100, JS 103) with the remains of two women and three children. If Jebel Sahaba was indeed a special burial place, this applied to all members of the community and followed expected demographic patterns. Therefore, it is most likely that the level of interpersonal violence observed in the site reflects broader inter-group behavioral relationships in the Nile Valley at the end of the Late Pleistocene rather than specific funerary practices.

Finally, the high level of interpersonal violence observed at the site may, in part, have been driven by the climatic changes associated with the beginning of the African Humid Period. The erratic and severe flooding of the Nile caused by an overflow of lake Victoria around 15-14 kya most certainly impacted settlements and the subsidence strategies of human populations all the way up to Egypt prior to the more stable monsoon conditions that emerged at the beginning of the Holocene (Williams et al., 2006). During the Last Glacial Maximal, few human remains have been recovered in the Nile Valley. This is mirrored by a drastic reduction in the archaeological, record with little evidence for the presence of humans along the lower Nile from Marine Isotopic Stage 4 (~ 71 kya) to the Last Glacial Maximum (Vermeersch and Van Neer, 2015). During this time period, the survival of small groups in the fewer sustainable areas in Upper Egypt and Lower Nubia is supported by the unusual phenotypic diversity, probably related to population fragmentation and isolation, found in the Late Pleistocene fossils of this region (e.g. Anderson, 1968; Greene and Armelagos, 1972; Irish, 2005; Crevecoeur, 2008; Pagani and Crevecoeur, 2019; Leplongeon, 2021). With variation of lithic industries noted at the end of the Late Pleistocene indicating different cultural traditions and the co-occurrence of large cemetery spaces suggesting some level of sedentism (Schild and Wendorf, 2010), severe territorial competition between the region's hunter-fisher-gatherer groups is likely to have occurred when faced with forced adaptation to such drastic environmental changes (e.g. Lillie, 2004; Jones and Allen, 2014; Schwitalla et al., 2014; Allen et al., 2016). Climate change is most likely to have been a driving force behind violent competition for resources over time.

4. CONCLUSIONS

For the first time since F. Wendorf's (1968a) original publication, a complete reassessment of the Jebel Sahaba cemetery, often considered to be the oldest evidence of organized warfare, was used to clarify the nature, extent and dating of the violence experienced by the individuals buried at the site. Using modern approaches and methods, the reappraisal undeniably supports the interpersonal nature of the lesions and confirms the projectile origin of most of the trauma. The reassessment of the lithic artefacts associated with each burial reveals that most were elements of composite projectile weapons. Our analyses also show that out of 61 individuals, 27.9% had signs of perimortem traumas and 62.3% displayed healed and/or unhealed traumas (excluding here undiagnosed lesions) regardless of the age-at-death or sex, including children as young as 4 years old. Although double and multiple burials with up to four individuals are present, probably indicating simultaneous deaths, several burials exhibit signs of later disturbance caused by subsequent interments. Furthermore, the data does not support a single catastrophic event. In addition, the demographic profile of the Jebel Sahaba cemetery is inconsistent with a mass burial. While acknowledging the possibility that the Jebel Sahaba cemetery may have been a specific place designated for the burial of victims of violence, the presence of numerous healed traumas and the reuse of the funerary space both support the occurrence of recurrent episodes of small-scale, sporadic interpersonal violence at the end of the Pleistocene. Most are likely to have been the result of skirmishes, raids or ambushes. Territorial and environmental pressures triggered by climate changes at the end of this period are most likely responsible for the frequent conflicts between culturally distinct Nile Valley semi-sedentary hunter-fisher-gatherers groups. New direct radiocarbon dates also confirm the antiquity of the site, and suggest that it is at least 13.4 kya old (or comprised between 13.4-18.2 kya), thus making Jebel Sahaba the oldest cemetery in the Nile Valley and one of the earliest sites displaying extensive interpersonal violence in the world.

The early inhabitants of the Nile Valley appear to have lived in an environment where violence was a regular part of both life and human behavior. Unlike many examples of early warfare and interpersonal violence (see review in Kissel and Kim, 2019), the violence at Jebel Sahaba differs in that it was clearly frequent, extensive and intense, with many skeletons displaying multiple lesions. It also appears to have been indiscriminate of age and sex, involving both younger children and women. The broader significance of what happened at Jebel Sahaba can be hard to contextualize in view of the vagaries of the archaeological record, with the cemetery only representing one side of the story. Our limited understanding of the Nile Valley social and cultural diversity during the Pleistocene also hinders more complex interpretations. As argued by M. Kissel and N. C. Kim (2019), outbreaks of interpersonal violence are unlikely to simply be reactive outcomes to environmental conditions or social signals, but must also be grounded in culturally constituted motivations for violence. It is also unclear how, if at all, the individuals buried at the site acted towards other groups and whether recurrent episodes of small scale sporadic violence can truly be viewed as warfare. What remains clear, however, is that Late Pleistocene groups were capable of repeated acts of extensive and indiscriminate violence towards most, if not all, members of a community.

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Individual	Biological identity				Healed				Unhealed			
	Sexual diagnosis	Mature/ Immature	Age-at-death estimates	Demographic class	Lesions	Traumas	PIMs	Embedded lithic	Lesions	Traumas	PIMs	Embedded lithic
JS 2	UND	IMM	[5-9]/[10-14]	[5-9]		x						
JS 4	UND	IMM	[15-19]/[20-30]	[15-19]	x							
JS 5	pM	MA	[20-49]	[> 30]	x	x			x			
JS 6	M	MA	[> 40]	[> 30]	x		x	x			x	
JS 7	pF?	MA	[> 30]	[> 30]		x						
JS 8	pF?	MA	[> 30]	[> 30]		x	x					
JS 9	UND	IMM	[1-4]/[5-9]	[1-4]							x	
JS 10	pM?	MA	[25-39]	[> 30]								
JS 11A	pM?	MA	[20-35]	[20-29]		x						
JS 11B	UND	MA	[> 30]	[> 30]	x							
JS 11C	UND	IMM	[0]/[0<1]	[0-<1]								
JS 12	UND	IMM	[5-9]	[5-9]								
JS 13	UND	IMM	[1-4]/[5-9]	[1-4]								
JS 14	UND	IMM	[1-4]	[1-4]						x	x	x
JS 15	pF?	MA	[20-35]	[20-29]	x		x					
JS 16	pF?	MA	[> 30]	[> 30]			x				x	
JS 17	pM?	MA	[20-35]	[20-29]								
JS 18	pM	MA	[> 50]	[> 30]								
JS 19	M	MA	[> 30]	[> 30]	x	x						
JS 20	pM?	MA	[> 30]	[> 30]		x			x		x	x
JS 21	pF	MA	[30-49]	[> 30]	x						x	x
JS 22	M	MA	[25-39]	[> 30]			x	x				
JS 23	pF?	MA	[> 30]	[> 30]	x						x	x
JS 24	UND	IMM	[5-9]	[5-9]							x	
JS 25	pF?	MA	[> 50]	[> 30]								
JS 26	F	MA	[20-49]	[> 30]		x					x	
JS 27	UND	IMM	[0-1]/[1-4]	[1-4]								
JS 28	pF	MA	[20-49]	[> 30]								
JS 29	M	MA	[20-49]	[> 30]		x					x	x
JS 31	pM	MA	[> 30]	[> 30]	x	x	x	x	x		x	x
JS 32	UND	MA	[25-35]	[20-29]		x	x					
JS 32b	UND	MA	[> 30]	[> 30]		x						
JS 33	pF?	MA	[25-35]	[20-29]		x					x	
JS 34	pF?	MA	[20-49]	[> 30]	x	x						
JS 35	UND	MA	[20-35]	[20-29]	x							
JS 36	pF?	MA	[> 30]	[> 30]								
JS 37	pF?	MA	[> 30]	[> 30]	x						x	
JS 37b	M	MA	[> 30]	[> 30]								
JS 38	M	MA	[> 30]	[> 30]	x	x	x					
JS 39	pM	MA	[> 30]	[> 30]	x	x						
JS 40	pM	MA	[15-19]/[20-25]	[20-29]	x	x						
JS 41	pF	MA	[> 30]	[> 30]	x	x			x			
JS 42	pM	MA	[20-29]	[20-29]	x	x					x	

Individual	Biological identity				Healed				Unhealed			
	Sexual dia-gnosis	Mature/ Immature	Age-at-death estimates	Demographic class	Lesions	Traumas	PIMs	Embedded lithic	Lesions	Traumas	PIMs	Embedded lithic
JS 43	UND	MA	[> 50]	[> 30]	x	x						
JS 44	pF?	MA	[> 30]	[> 30]		x					x	x
JS 45	pF?	MA	[> 30]	[> 30]								
JS 46	pM	MA	[> 30]	[> 30]								
JS 47	UND	IMM	[5-9]	[5-9]								
JS 48	pM	IMM	[15-19]	[15-19]		x					x	
JS 49	pF	MA	[> 30]	[> 30]								
JS C1	M	MA	[>50]	[> 30]			x	x	x			
JS C2	UND	IMM	[1-4]/[5-9]	[5-9]								
JS C3	UND	MA	[> 30]	[> 30]								
JS 100	UND	IMM	[1-4]/[5-9]	[5-9]								
JS 100 extra	UND	IMM	[0-<1]	[0-<1]								
JS 101A-B	UND	IMM	[1-4]	[1-4]								
JS 102	pF	MA	[> 30]	[> 30]	x	x	x					
JS 103	UND	IMM	[10-14]	[10-14]							x	x
JS 104-107	pF?	MA	[> 30]	[> 30]	x	x						
JS 105	UND	IMM	[10-14]/[15-19]	[10-14]	x	x						
JS 106	M	IMM	[10-14]/[15-19]	[10-14]			x					

Table S1 - Inventory of Jebel Sahaba individuals showing their biological identity (sexual diagnosis and age-at-death estimates) and the type of lesions recorded for each of them. Lesions are separated in two main columns for healed and unhealed injuries. Each column is subdivided by type of lesions – lesions (when the origin is unknown); traumas (for bone fracture, blunt force traumas and perforations whose projectile origin is not ascertained) and PIMs (for projectile impact marks). The presence of embedded lithic artefacts in association to PIMs is also listed. UND = undeterminate; M = male; pM = probable male; pM? = possible male; F = female; pF = probable female; pF? = possible female; MA = mature; IMM = immature.

***Tableau S1** – Inventaire des individus du Jebel Sahaba, montrant leur identité biologique (diagnostic sexuel et estimation de l'âge au décès) et le type de lésions enregistrées pour chacun d'eux. Les lésions sont séparées en deux colonnes principales pour les blessures cicatrisées et non cicatrisées. Chaque colonne est subdivisée par type de lésions : lésions (lorsque l'origine est inconnue) ; traumatismes (pour les fractures osseuses, les traumatismes par objet contondant et les perforations dont l'origine par projectile n'est pas déterminée) et les PIM (pour marques d'impact de projectile). La présence d'artefacts lithiques fichés dans les ossements en association avec des MIPs est également répertoriée. UND = indéterminé ; M = homme ; pM = probable homme ; pM ? = possible homme ; F = femme ; pF = probable femme ; pF? = possible femme ; MA = mature ; IMM = immature.*

Individual	Sex	Demographic age class	Presence of lesions	Burial	Grave pit		Artefact associated (Wendorf, 1968)		New embedded artefacts (this study)
					Depth	Cover	Volume of the body	Embedded	
JS 2	UND	[5-9]	x	Disturbed	At surface				
JS 4	UND	[15-19]	x	Disturbed	15 cm	Slabs			
JS 5	pM	[> 30]	x	Individual	10 cm	Slabs			
JS 6	M	[> 30]	x	Disturbed	10 cm	Slabs			1
JS 7	pF?	[> 30]	x	Individual	25 cm				
JS 8	pF?	[> 30]	x	Double	30 cm				
JS 9	UND	[1-4]	x	Double	30 cm				
JS 10	pM?	[> 30]		Individual	30 cm				
JS 11A	pM?	[20-29]	x	Disturbed	10 cm				
JS 11B	UND	[> 30]	x	Disturbed	10 cm				
JS 11C	UND	[0-<1]		Disturbed	10 cm				
JS 12	UND	[5-9]		Individual	10 cm				
JS 13	UND	[1-4]		Double	25 cm		2		
JS 14	UND	[1-4]	x	Double	25 cm		3		1
JS 15	pF?	[20-29]	x	Individual	35 cm				
JS 16	pF?	[> 30]	x	Individual	35 cm				
JS 17	pM?	[20-29]		Individual	35 cm		1		
JS 18	pM	[> 30]		Individual	30 cm	Slabs			
JS 19	M	[> 30]	x	Individual	40 cm	Slabs			
JS 20	pM?	[> 30]	x	Double	40 cm	Slabs	6		1
JS 21	pF	[> 30]	x	Double	40 cm	Slabs	17	2¤	6
JS 22	M	[> 30]	x	Individual	40 cm	Slabs			1
JS 23	pF?	[> 30]	x	Double	10-20 cm		2	1¤	
JS 24	UND	[5-9]	x	Double	40 cm		1		
JS 25	pF?	[> 30]		Multiple	45 cm	Slabs	1¤		
JS 26	F	[> 30]	x	Multiple	30 cm	Slabs	5 (+1*)		
JS 27	UND	[1-4]		Disturbed	20 cm	On slabs			
JS 28	pF	[> 30]		Multiple	20 cm		1		
JS 29	M	[> 30]	x	Multiple	40 cm	Slabs	7		
JS 31	pM	[> 30]	x	Individual	30 cm	Slabs	15	2¤	1
JS 32	UND	[20-29]	x	Disturbed	60 cm				
JS 32b	UND	[> 30]	x	Disturbed					
JS 33	pF?	[20-29]	x	Individual	60 cm	Slabs	8		
JS 34	pF?	[> 30]	x	Multiple	60 cm	Slabs	2		
JS 35	UND	[20-29]	x	Disturbed	50 cm	Slabs	6		
JS 36	pF?	[> 30]		Individual	40 cm	Slabs			
JS 37	pF?	[> 30]	x	Multiple	60 cm	Slabs	1		
JS 37b	M	[> 30]		Multiple					
JS 38	M	[> 30]	x	Individual	60 cm	Slabs	1		
JS 39	pM	[> 30]	x	Individual	70 cm	Slabs			
JS 40	pM	[20-29]	x	Individual	70 cm	Slabs			
JS 41	pF	[> 30]	x	Individual	40 cm	Slabs	1		
JS 42	pM	[20-29]	x	Individual	35 cm	Slabs	1		
JS 43	UND	[> 30]	x	Individual	35 cm	Slabs			

Individual	Sex	Demographic age class	Presence of lesions	Burial	Grave pit		Artefact associated (Wendorf, 1968)		New embedded artefacts (this study)
					Depth	**Cover**	**Volume of the body**	**Embedded**	
JS 44	pF?	[> 30]	x	Individual	35 cm	Slabs	20	1	1
JS 45	pF?	[> 30]		Individual	40 cm	Slabs	1¤		
JS 46	pM	[> 30]		Disturbed	40 cm	Slabs			
JS 47	UND	[5-9]		Individual	35 cm	On slabs	1¤		
JS 48	pM	[15-19]	x	Individual	50 cm				
JS 49	pF	[> 30]		Individual	45 cm	Slabs			
JS C1	M	[> 30]	x	Multiple	At surface	Slabs	5		1
JS C2	UND	[5-9]		Multiple	At surface	Slabs			
JS C3	UND	[> 30]		Multiple	At surface	Slabs			
JS 100	UND	[5-9]		Multiple	70 cm	Slabs			
JS 100 extra	UND	[0-<1]		Multiple					
JS 101A-B	UND	[1-4]		Multiple	70 cm	Slabs			
JS 102	pF	[> 30]	x	Multiple	70 cm	Slabs	1		
JS 103	UND	[10-14]	x	Multiple	65 cm	Slabs	1	1¤	
JS 104 & JS 107	pF?	[> 30]	x	Disturbed	70-90 cm				
JS 105	UND	[10-14]	x	Individual	90 cm				
JS 106	M	[10-14]	x	Individual	60 cm	Slabs	1		

Table S2 – Inventory of Jebel Sahaba individuals with the burial characteristics and associated artefacts. UND = undeterminate; M = male; pM = probable male; pM? = possible male; F = female; pF = probable female; pF? = possible female. ¤) Artefact absent from the British Museum collection; *) additional artefact compared to the original publication.

Tableau S2 *– Inventaire des individus de Jebel Sahaba avec les caractéristiques funéraires et les artefacts associés aux tombes. UND = indéterminé ; M = homme ; pM = probable homme ; pM ? = possible homme ; F = femme ; pF = probable femme ; pF? = possible femme. ¤) artefact absent de la collection du British Museum ; *) artefact supplémentaire par rapport à la publication originale.*

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A Singular Story between Deserts and the Nile
The Egyptian Path toward Food Production

Une histoire singulière entre déserts et Nil
La trajectoire égyptienne vers l’économie de production

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Abstract: Intensive research in recent decades has shed new light on Holocene Prehistory in northeastern Africa, particularly on the areas of the Nile Valley and adjacent deserts. Located at the northeast of the African continent, at the intersection with the Middle East, Egypt (valley and deserts) has followed a particular path between these two poles, from the end of the Big Dry to the emergence of food production during the 6th millennium and its establishment in the 5th millennium. If the Nile Valley is not very prolific until the end of the 5th millennium, partly for taphonomic reasons, the major surveys carried out in the western desert between the 1980s and the early 2000s made it possible to set up more and more complete regional chrono-cultural sequences and to develop scenarios involving economic and cultural dynamics linked with the dramatic climate changes of that period. The first populations to reoccupy the area that the Big Dry had completely emptied at the end of the Pleistocene, and which became again dwelling areas upon return to wet conditions, are Epipalaeolithic hunter-gatherers, whose economy was based on the exploitation of wild resources. Aurochs, bubals, gazelles, hares and ostriches invested around many water spots, a grassy savannah that substituted the desert thanks to the northward progression of monsoon rains. Plants adapted to this regime grew abundantly on the shores of lakes. As evidenced by the numerous grinding stones found on sites, they respond to the food needs of human groups, which are distributed throughout the African geographical area where the Nile flows. In the north, neither the sea nor the Sinai Peninsula have ever constituted any insuperable hurdles as shown by the occurrence in Heluan and Wadi Araba (eastern desert) of groups of hunters belonging to the PPNA/PPNB traditions. The transition toward new lifestyles, marked by the adoption of food production, took place over a long period of time, against the backdrop of a climate crisis that witnessed the development of Saharan hunter-gatherers within an autonomous economic and social space on one side and the mobility of pastoralists and then farmers from the Levant on the other side.
Keywords: Neolithic, Egypt, food production, domestication, climatic change, Nilotic adaptation.

Résumé : Les recherches intensives menées durant ces dernières décennies ont jeté une lumière nouvelle sur la Préhistoire holocène du nord-est africain, et plus particulièrement sur les espaces constitués par la vallée du Nil et les déserts adjacents. Localisée au nord-est du continent africain, au carrefour avec le Proche-Orient, l’Égypte (vallée et déserts) a suivi, entre ces deux pôles, un parcours particulier depuis la fin du Big Dry jusqu’aux formes nouvelles de production de nourriture, qui s’amorcent dès le VIe millénaire et se mettent en place au ve millénaire. Si la vallée du Nil est peu prolixe jusqu’à la fin du Ve millénaire, pour des raisons en partie taphonomiques, les grands sondages opérés dans le désert occidental entre les années 1980 et le début des années 2000 ont permis la mise en place de séquences chrono-culturelles régionales de plus en plus complètes et l’élaboration de scénarios mettant en jeu des dynamiques économiques et culturelles en lien avec les évolutions climatiques drastiques de cette période. Les premières populations à réoccuper les espaces que le Big Dry de la fin du Pléistocène avait totalement vidés et que le retour des conditions humides a rendu de nouveau habitables sont des chasseurs-cueilleurs épipaléolithiques, dont l’économie est fondée sur l’exploitation des ressources sauvages. Autour de nombreux points d’eau, aurochs, bubales, gazelles, lièvres, autruches investissent une savane herbeuse que la remontée vers le nord des pluies de mousson a substituée au désert. Adaptées à ce régime, des plantes croissent à profusion sur les rivages des lacs, répondant, comme l’atteste l’abondant matériel de broyage retrouvé sur les sites, aux besoins alimentaires de groupes humains, qui se répartissent dans l’espace géographique africain où coule le Nil. Cependant, au nord, ni la mer ni la péninsule du Sinaï

n'ont jamais constitué d'obstacles infranchissables et la présence de groupes de chasseurs levantins du PPNA/PPNB est attestée dans la région d'Hélouan et au Wadi Araba, dans le désert oriental. La transition vers des formes de vie nouvelles, marquées par l'adoption des économies de production, s'opère sur un temps long mettant en jeu et en interaction sur fond de crise climatique le développement des uns, les chasseurs-cueilleurs sahariens, au sein d'un espace autonome économique et social, et la mobilité des autres, pasteurs puis agriculteurs levantins.
Mots-clés : Néolithique, Égypte, économie de production, domestication, changement climatique, adaptation nilotique.

Intensive research in recent decades shed new light on Holocene Prehistory in northeastern Africa. Egypt is a gateway at the crossroad of the African and Asian continents, a geographic position that has been crucial in the transfer of people and ideas in and out of Africa. In this framework, this region has followed a singular path toward food production.

The earliest evidence of plant and animal domestication goes back as far as the 10th millennium in the Near and Middle-East with the "Pre-Pottery Neolithic" (Miller and Wetterstrom, 2000; Zeder, 2011), but the first traces of animal domestication in the deserts bordering the Nile Valley only appear at the very end of the 7th millennium BC (Linseele et al., 2014 and 2016). From 6700 BC onwards, all the near East populations have long adopted a sedentary agropastoral way of life, whereas populations living on the banks of the Nile and in the adjacent deserts conserved a way of life based on fishing, hunting and gathering.

The notion that Egypt was "late" implies that things should have happened at an expected time, as if the prevailing social structures and production modes in South-Western Asian regions in the 7th millennium, which were themselves derived from an evolution spanning several millennia (Vigne, 2011, p. 178), were a reference, and that, in comparison, other populations were in advance, or late, if they could not be in time. The diffusion of the food production economy starting from the innovation core of the Levant has been particularly studied on the islands and the northern shore of the Mediterranean. If one could previously think that the main vector of this "neolithization" was the rapid and continuous physical movement of groups of settlers (Childe, 1949; Ammerman and Cavalli-Sforza, 1984), all recent research tends to show that it was an extremely complex, long-lasting and arrhythmic process (Guilaine, 2000).

The southern shore of the Mediterranean has been less studied, but in the present state of knowledge, it seems that resistance to the diffusion phenomenon was clearly stronger.

One of the reasons advanced to explain this delay is what we called "Nilotic adaptation", with reference to the exceptional ecosystem of the Nile Valley, which formed during Late Palaeolithic (Vermeersch, 2004; Vermeersch and Van Neer, 2015). In spite of climatic variations and the "Wild Nile" crisis around 12000 BP (Butzer, 1998, p. 161-163), life on the banks of the Nile in the Early Holocene may not have been fundamentally different to life at the end of the Palaeolithic (Wetterstrom, 1996a). The only site of Elkab (Vermeersch, 1978) records this period, which is otherwise well documented in the deserts. The annual flood cycle marked out the rhythm of life, prefiguring the three seasons of Ancient Egypt. Fishing was practicable all year round depending on fish behaviour according to the hydrological regime of the river (Van Neer, 2004). The high-water period left time for harvesting the fruits of the Doum palm tree and the acacia. It was propitious to hunting large game (aurochs, hartebeest, etc.) in the grassy savanna of the low desert, when animals approached the river banks for water. The slow withdrawal of the waters provided access to *Cyperus* rhizomes and to a wide range of marsh plants (rushes, asphodels, lotus, reeds, etc.). Populations were mobile in a restricted area, living a semi-sedentary life paced by the eternal rhythm of the river cycles. In this "paradisiac" environment, no seasons or periods of the year brought shortages and suffering; only the irregular rhythm of floods could entail hardships. Prolonged flooding submerged the vegetation, which could not regenerate, whereas short flooding seasons gave rise to terrible droughts. However, overall, the system was sufficiently stable to ensure its sustainability year in year out for nearly eight millennia. At the beginning of the Holocene, the material culture of Egyptian sites was then relatively homogeneous. This lithic industry shows a laminar and lamellar soft stone debitage with large notched blades probably intended for plant work and microlithic tools used for composite hunting projectile points. This type of industry is known in the deserts and the oases where it receives different names according to local variability, among the best known are the cultures of El Adam and El Ghorab in Nabta Playa (Wendorf and Schild, 2001). On the banks of the Nile, a very similar industry dating from the 8th millennium BC has been highlighted on the site of hunter-fisher-gatherers of El Kab (Vermeersch, 1978). Beyond Egypt, laminar debitage and microliths are found throughout North Africa as far as the Maghreb (Tixier, 1963) testifying to a common cultural background from one bank to the other of the continent.

However, identifying the specific Egyptian development towards the adoption of a production economy comes up against a cruel absence of data in the Nile Valley for the 6th and 5th millennia, in spite of the huge fields of knowledge opened up by major surveys in the Eastern Sahara over the past decades. For over a century, we have been prone to circular reasoning based on data from three main sites, all located in the northern part of Egypt: Merimde Beni Salâme, west of the Delta, El Omari, near Cairo and Fayum, a huge oasis, formerly linked to the Nile by the Bahr Youssef, an arm of the river. Some new data have emerged recently from the deltaic area itself (Saïs: Wilson et al., 2014; Samara: Guyot et al., 2022). The reason for this lack of data can probably be explained by the progressive accumulation of the sedimentary deposits that buried the sites below several metres of silts, as a response to climate change and sea level oscillations (Stanley and Warne, 1993).

1. CHANGES AND EXPERIMENTS

Around the 7th millennium BC, a humid oscillation took place within the African Humid Period, a double rain system (winter and summer) reached a large part of Egypt, filling numerous lakes in the Eastern Sahara. The populations of hunter-gatherers could then roam largely in the Eastern Sahara. In the most favorable places, they adopted an increased sedentary lifestyle: settlements were built near the seasonal lakes playas with an internal stratigraphy showing successive phases of abandonment and reoccupation according to the fluctuations of the neighboring lakes. Circular huts of a few square metres made of stone or perishable materials are attested in Farafra, Dakhla and on the plateau bordering Kharga (McDonald, 2009; Barich et al., 2014). Wild african cereals, especially *Sorghum*, were processed thanks to abundant grinding equipment and subject to management like the long-term storage in silos attested in Nabta Playa (Wendorf and Schild, 2002). The pottery, decorated with impression in the autochthonous African tradition begins to be widely in use. However, in the lack of evidence for the essential Neolithic traits as food production or at least a pastoral component, we do not use the term “Neolithic”.

2. THE FIRST DOMESTICATED SPECIES IN EGYPT

The first domesticated species to appear in Egypt at the very end of the 7th millennium are animal. The earliest evidence for caprines have been found at Sodmein Cave and at the Hidden Valley site in Farafra, both dated between 6200 and 6000 cal. BC (Linseele et al., 2016). In the Fayum, the western desert (oases and plateaux) and in the eastern desert, bordering the Red Sea (Linseele, 2013), remains have been dated from the beginning of the 6th millennium BC. Our knowledge of what happened at that time in the Delta and the Nile Valley is far from complete. The domesticated animals were mostly caprines (*Ovis aries* and *Capra hircus*), but also some cattle in Fayum and Nabta Playa-Bir Kiseiba, although the question of the time of domestication of African cattle is still controversial (Lesur, 2017, p. 66-78). We must not imagine a surge of domestic animals, as only very small quantities of such remains have been found. At Sodmein Cave, for example, only 13 remains of domestic animals were recovered from a stratigraphic sequence of several metres (Vermeersch et al., 2015).

Therefore, the adoption of domesticates is not an upheaval, but an adjustment, as no fundamental change in lifestyle occurs. Groups of hunter-gatherers who had been crossing the Sahara for several millennia and who were already familiar with pottery (hunter-gatherer-potters) brought several goats and sheep with them to supplement subsistence, by providing stocks of meat, milk, wool and hide. In a semi-arid environment, with wetter periods and a seasonality mainly based on the monsoon system, these groups could travel over long distances depending on water availability. As H. Riemer (2007) asked: Are they really pastoralists? Domestic fauna is derisory compared to wild fauna, and the numerous arrowheads point towards an economy based on hunting and gathering, as showed by the abundant material for grinding. In all these Middle Holocene sites, we note the importance of wild plant species, and in particular of local African cereals, such as sorghum and millet, found in abundance in silos at Nabta Playa (Wendorf and Schild, 2002). G. Lucarini (2014) also highlights the role played by wild African cereals in the oasis of Farafra, at that time.

Where do these first domestic animals come from? Leaving aside the tricky case of cattle (Brass, 2017), sheep and goat have no wild ancestors in Africa, and thus come from elsewhere. The neighbouring Near East, where we find the wild species and where their domestication occurs at an early stage, is obviously an unrivalled candidate (Lesur, 2017, p. 56-61). Considering the sparse proof for this period, it is difficult to define the paths domestication took. Is it even pertinent to define these pathways? Once we know that these animals reached the west, and the same is true for the following period, they may have taken all the available routes: by the Delta, and from there down the valley, along the route of the oases, turning westwards towards the Maghreb or along the Sinai bordering or crossing the Red Sea. The Mediterranean is another possible route, by coastal trade (Zeder, 2018; Broodbank and Lucarini, 2019).

But the animals did not come alone. They were accompanied by humans who passed them on to the Nilo-Saharan hunter-gatherers with whom they were in contact, probably via the Sinai Peninsula, which would later become “the way of Horus”, the overland route between Egypt and Canaan. This arrival coincides with a period of climatic deterioration in the Near East, around 6900-6300 cal. BC (Sanlaville, 1996), which marked the end of the PPNB, although it is not the cause, or at least not the exclusive cause. Neolithic activities then moved towards the edges of the Levantine corridor, to the east or the south, where populations who had become nomadic again were in contact with the Nilo-Saharan hunter-gatherers. Between 5500 and 5000 cal. BC, pastoralism appeared to be well established in the Sinai, based on faunal remains and the presence of enclosure type structures (Goring-Morris, 1993). These contacts between populations continued over a very long period and provided the opportunity for the Nilo-Saharans to take what they needed without changing their way of life.

This adoption of Asian domesticates is synchronous with radical technological changes in the material culture. The lithic industry is no more based on laminar debitage but on flakes and natural thermoclastic blanks with facial and bifacial retouching. An Asian influence has been hypothesized (Shirai, 2016) but the origin of this technology is not yet determined with certainty due to the lack of reliable dates. It could as well find its source on the Egyptian limestone plateau, where the "bifacial technocomplex" is well established in the Middle Holocene (Riemer, 2007). The ceramic material as well is totally renewed with the appearance of a new type of locally made plain pottery. But things were about to change.

3. THE 5TH MILLENNIUM: THE FIRST PRODUCTION ECONOMIES

After 5300 cal. BC, the retreat of monsoon rains towards the south considerably accentuated aridity (Kuper and Kröpelin, 2006), making it progressively impossible for nomadic Saharan hunter-gatherers to continue their traditional way of life (Riemer, 2007). As a consequence, they moved towards the permanent water zones of oases, the Nile Valley and the mountainous massifs of the Sahara, creating a major population influx in these regions. This is reflected in the emergence of new sites in Egypt, whereas the desert emptied (fig. 1). In Fayum, Neolithic settlement peaked between 4600 and 4300 cal. BC, at a time when sites became rare in the Eastern Sahara (Phillips et al., 2012, fig. 2).

The main event of the 5th millennium BC is the appearance of the first domesticated plants and again, we must turn towards Fayum, where their presence has been confirmed.

3.1. Fayum in the 5th millennium: First domesticated plants

The excavation carried out by G. Caton-Thompson in the 1930s (Caton-Thompson and Gardner, 1934) brought to light two main sites, Kom W and Kom K, on the northern shore of Lake Qarun. These include a series of storage structures, large silo pits lined with basketry, which provided some of the earliest domesticated cereal seeds known in Egypt: wheat (*Triticum turgidum L.* subsp. *dicoccum*), barley (*Hordeum vulgare* subsp. *vulgare*) and seeds of *Polygonum* and *linum*. Bifacial flint sickles were found in association with this first evidence of agriculture (for the flint industry in Fayum, see Shirai, 2010). This silo technology allowed for long-term storage and is compatible with mobility (Dachy, 2014).

Previous faunal studies have shown that faunal samples are predominantly composed of fish and lake-related species. However, cattle, sheep and goats, which were present in low numbers during the previous period, increase in number. A newcomer also joins the party: the pig. It goes on to play an important role in the farming activities of the following periods.

In the early 2000s, a mission organised by the University of California retraced G. Caton-Thompson's steps and undertook new excavations in Fayum North shore (Holdaway and Wendrich, 2017). The renewed studies provided the opportunity to gather more C14 dates, establish a reliable chronological framework and compare the site with the abundant data from the Eastern Sahara (Wendrich et al., 2009; Phillips et al., 2012). The new radiocarbon dates show that the revisited sites were occupied over the period between 4600 and 4300 cal. BC (for a discussion of the radiocarbon dates, see Holdaway and Wendrich, 2017, p. 215-218).

No traces of villages at Fayum point to eastern-type settlement. These first lakeshore Neolithic populations were relatively mobile. They mainly practised fishing, used pottery and hunted, as shown by the abundant bifacial arrowheads (Shirai, 2010). This settlement system has been classified as a "low-level food producers' economy" (Holdaway et al., 2010 and 2015), a multi-component subsistence strategy.

3.2. Merimde Beni-Salâme, El Omari, the delta

Merimde Beni-Salâme and El Omari are currently the two oldest known Neolithic villages in Egypt. And this state of affairs may not be ready to change as no site of similar scope has been discovered since their excavation. They are situated in the northern part of the country, one west of the delta, the other at its southern extremity, near the present-day town of Cairo.

Merimde Beni-Salâme was discovered and excavated by H. Junker at the beginning of the 20th century, then the study was resumed in the 1980s (Eiwanger, 1984, 1988 and 1992) and investigations restarted recently (Rowland and Bertini, 2016). The site is located on a desertic plateau, west of the delta, and extends over nearly 24 ha, with several settlement phases from around 5000 to 4100 cal. BC, over a 2.5 m-thick stratigraphy. It is easy to imagine how difficult it is to understand such a site and the extent to which early excavations deteriorated the potential for site interpretation. During the early phase, the *Urschicht* (Eiwanger, 1984), the first cultivated plants appeared in the Nile Valley: emmer wheat, six-row barley, lentils and peas, and in smaller quantities, vetches and flax (Wetterstrom, 1993 and 1996b; Cappers, 2013). The faunal spectrum is dominated by wild species (fish, antelopes, hippopotami, crocodiles, molluscs, etc.), but also comprises goats, sheep and cattle, as well as pigs (Lesur, 2013). However, there are no traces of sedentarism or storage. The domestic structures consist of large shallow pits. Domesticated species only play a limited role in an economy still rooted in ancestral Nilotic adaptation. In the following levels, populations became increasingly sedentary, as shown by increased investment in developing storage structures and a rise in the proportion of

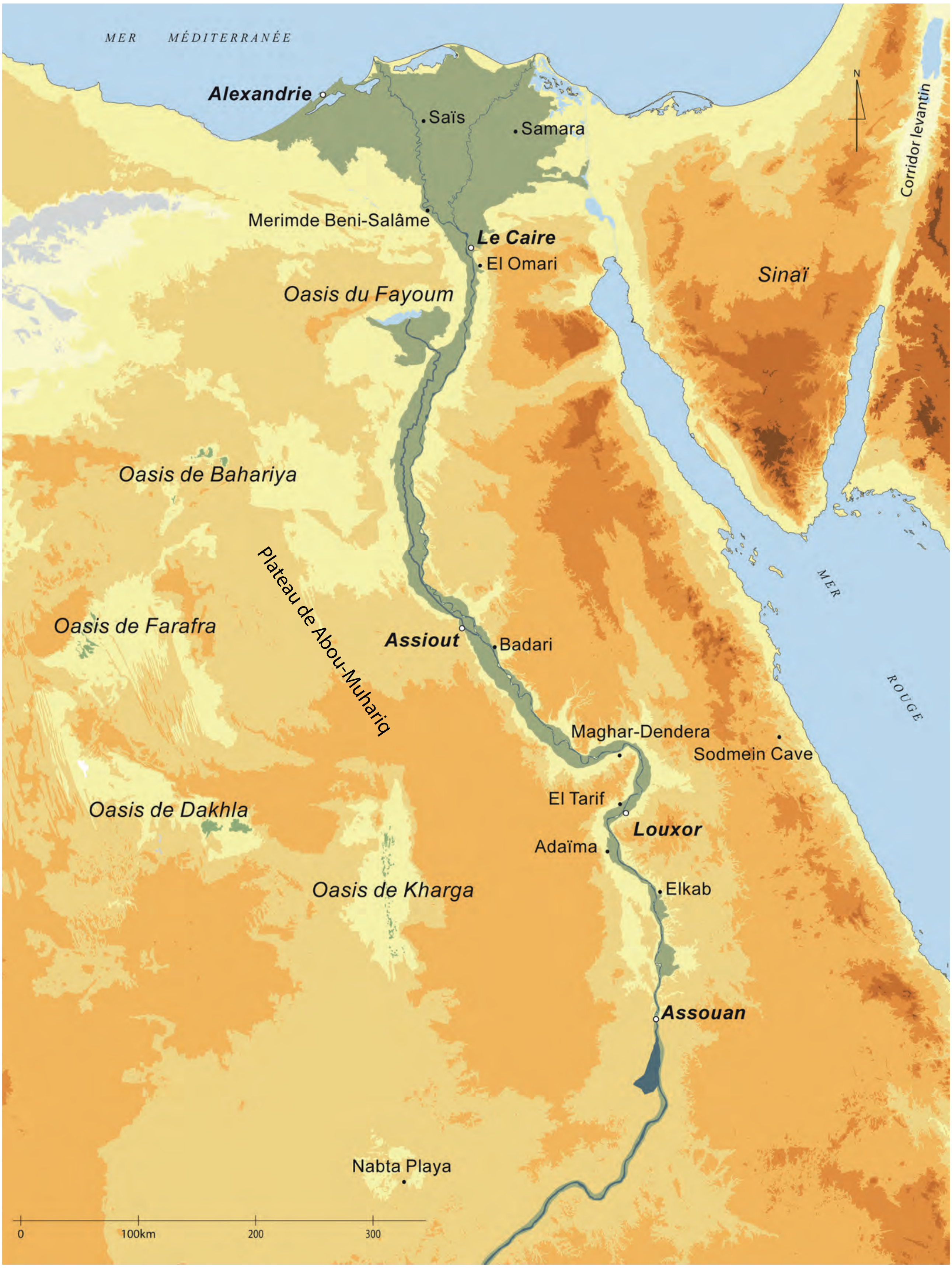

Fig. 1 – Localization of mentioned areas.
***Fig. 1** – Localisation des lieux mentionnés.*

pigs. In the last level (level V), oval dwellings in raw earth, associated with silos, constitute the first Neolithic village in Egypt.

El Omari consists of several localities spaced out along the edge of a terrace overlooking the Wadi Hof, near Helouan. Only two out of seven localities were excavated (Debono and Mortensen, 1990). Like at Merimde, the evolution of the settlement shows the transition from mobile Neolithic groups, where domestic species (plants and animals) only play a secondary role, to a sedentary community where subsistence relies more heavily on agriculture and livestock (Wetterstrom, 1996b).

In the delta, this first Neolithic is in all probability present everywhere, although almost invisible. It is only revealed when opportunities arise, in very deep test pits cutting through the deposited silts. It is important to point out that the delta is a recent geological formation and its current morphology only formed during the 6th millennium (Stanley and Warne, 1993; Butzer, 2002), when the rising sea level reduced the slope of the rivers and favoured the accumulation of silts over an average thickness of 11 m. All that was left of the former topography were small sandy mounds called “Gezira”, which were flooded a little more each year by annual flows. Neolithic populations settled on the edges of these mounds and found refuge on top of them during flooding. The Neolithic levels of the pharaonic site of Saïs (Wilson et al., 2014) were unexpectedly discovered, in a 5 x 5 m test pit, down to the water table, where the deepest levels were clearly sealed by a sandy layer that could correspond to a phase of abandonment. The numerous pottery sherds point to contemporaneity with the final phases of Merimde Beni-Salâme. No domestic structure was identified. However, carbonised remains of fauna and flora show that the occupant of this settlement practised husbandry and farming. The faunal spectrum is dominated by pigs. We also find cattle, goats and sheep, as well as the donkey, which may have been used as a pack animal (for the domestication of the donkey in Africa, see Rossel et al., 2008).

There are thus few sites, and they are all in the northern part of the country; the southernmost site is located at the point of the delta. All show a progressive transition towards a production economy similar to the eastern model. The populations geographically nearest the Levantine corridor, in direct connection with the Sinai Peninsula, progressively incorporated domestic species into their semi-sedentary way of life. For millennia, they became accustomed to juggling with the complementary resources offered by an ecosystem blessed by the gods. First of all, as a supplement, then as an essential component, until domestic species became their economic staple.

However, the diffusion of farming in the Nile Valley had to respond to more complex adaptation processes. Indeed, we observe that the occupation of Neolithic settlements in the Fayum ceased suddenly around 4300 cal. BC, suggesting that cereal cultivation was only possible during the Neolithic under certain conditions (Holdaway and Wendrich, 2017, p. 220). Among the hypotheses advanced, recent data converge towards what we will call the Mediterranean option, namely, that the plants cultivated at Fayum were winter crops dependent on rains from November to April. The retreat of Mediterranean rains towards the northern latitude marked the end of Neolithic farming at Fayum (Phillips et al., 2012). But agriculture continued successfully in the valley. In order to do so, it had to make drastic changes to adapt to a totally new environment: the rising and receding of the river in a hyper arid environment. The adaptation of eastern crops to flood-recession agriculture constituted considerable progress and undoubtedly steered Egypt towards an unexpected destiny in the following millennium.

3.3. The 5th millennium in the Eastern Sahara: around the oases

During the 6th millennium BC, the projectors were directed towards the deserts and the whole valley was left in the shade. It sprung back to life during the 5th millennium, when desert populations fleeing aridity settled in the oases spread out like an arc, to the west, in parallel to the Nile Valley: Baharia, Farafra (Barich et al., 2014), Dakhla (McDonald, 2008 and 2013), Kharga (Dachy et al., 2018). Nomadic pastors moved around, but also beyond, sources and artesian wells, in a territory delimited by water supplies, as shown by the presence of exogeneous products in the archaeological material. Domestic fauna constitutes a significant part of the assemblages. We find abundant goats, sheep and cattle, whereas the pig is restricted to wet and marshy zones. Do the emmer wheat seeds found at the site of KS43, in the south of the Douch Basin indicate contacts with cultivators from the valley (Briois et al., 2012), the seasonal movement of these valley peasants in the oases or autochtonous farming practices rendered possible on an occasional basis by exceptional rains (Barnard and Wendrich, 2008, p. 514)?

3.4. Upper Egypt: Badari

Apart from the site of El Tarif, with lithic material probably dating to the beginning of the 5th millennium (Ginter et al., 1979), the oldest 5th millennium human settlement in the valley, outside the delta, is in Middle Egypt, south of the present-day town of Asyut, in the region of Badari. It is there, to the north of Upper Egypt, that about a hundred cemeteries and settlement sites were found at the beginning of the 20th century (Brunton and Caton-Thompson, 1928), spread out over nearly 30 km along the eastern bank of the river. In this zone, the very narrow valley is dominated by the steep slopes of limestone massifs. The remains of the first Neolithic culture of Upper Egypt, the Badarian, were found on the edges of deep wadis. The culture is better illustrated by cemeteries than settlements as archaeologists were mainly interested in the former. A tomb is more attractive to archaeologists in that it constitutes an enclosed complex, that can be interpreted at first glance, with intact or well-preserved funerary material, in contrast with dwelling zones with fragmented material, almost always brutally reworked by subsequent settlement. In this way, the region of Badari was settled until the end of the predynastic period and for more than a millennium, the original occupations were trampled by the following generations. In spite of good archaeological practices for that time, the dwelling areas did not receive the same attention as cemeteries. Only G. Caton-Thompson excavated El Hemamieh in stratigraphy (Brunton and Caton-Thompson, 1928, p. 69-78) and confirmed the pertinence of the succession of main phases determined by F. Petrie. In her Memoirs, she wrote: “Brunton’s style of excavation with a large labour force […] was not geared to humdrum digs of predynastic villages or encampments” (cited by Holmes, 1989, vol. 1, p. 95). Due to the lack of attention paid to the excavation of dwellings, we have very few data on domesticated species. Prospections carried out by D. Holmes and R. Friedman in the 1980s did not bring any new elements in this regard (Holmes and Friedman, 1994). We have to go further south, to the site of Maghar-Dendera, where a rescue excavation was carried out in 1987, to obtain the first faunal spectrum of a Badarian settlement site (Hendrickx et al., 2001, p. 91-102). The occupants were installed on a plateau above the Nile flood level and lived mainly from fishing, to a lesser extent from husbandry and the collection of molluscs. We have no indications on the flora. In his book, *The Badarian Civilisation*, G. Brunton evokes the presence of cereals, but with no further details (Brunton and Caton-Thompson, 1928, p. 40). W. Wetterstrom (1993) highlights the problematic nature of the botanical record (see also Cappers and Hamdy, 2007). Among the main elements of the lithic assemblage, the bifacial sickle blade and bifacial arrowheads are similar to those found at Fayum (Holmes, 1989, p. 106; Shirai, 2010, p. 307). From a chronological point of view, there are few radiometric dates. They place the Badarian at the very end of the 5th millennium, between 4400 and 4000 cal. BC (Hendrickx, 1999; Hendrickx et al., 2001, p. 89-90). The recent new assessment program of radiometric dates (Shortland and Bronk Ramsey, 2013) extends that timescale to the beginning of the 4th millennium, between 4400 and 3800 cal. BC (Dee et al., 2013).

The origin of these first farmers of Upper Egypt is a debate beyond the scope of this paper. Our focus naturally turns towards the west and south, towards regions from where mobile pottery-using people mainly came after the arid episode of the end of the 7th millennium (see Wengrow et al., 2014). Indeed, the material from the valley tombs presents clear similarities with goods from the cemeteries of final Neolithic desert populations, discovered in particular at Gebel Ramlah (Kobusiewicz et al., 2010), and dated between 4500 and 4400 cal. BC.

CONCLUSION

The socio-economic transformations in Southwest Asia which led to the emergence of farming lasted for at least four or five millennia. Rather than a revolution, it was a slow innovation process which took place at different times in different ecosystems (Zeder, 2011). North Africa and Egypt in particular followed another path. At the beginning of the Holocene, nomadic hunter-gatherers, who already used pottery, followed the movement of monsoon rains towards the north. For several millennia, these communities of African origin crossed the Eastern Sahara and undoubtedly entered the Nile Valley. There, they were in contact with populations with the same lifestyle based on the intensive exploitation of wild resources in a contained territory, but also with the same vision of social life and relationships between individuals. During this long period of time, local plants, including sorghum, were intensively used, and early experiments with animal husbandry very probably took place. We must keep in mind that everywhere in the world, the birth of domestication does not start when changes in bone morphologies are visible, but results from a long process involving the intensification of relationships between animals, plants and human societies (Vigne, 2011).

Things changed after the arid phase of the end of the 7th millennium when the spotlight focused on the Levant. The deltaic plain, at the crossroads between Africa and the East, became an actor in the anthropization of the landscape. The history of the first livestock in Egypt very probably lies under several meters of Delta silt.

Saharan hunter-gatherer-foragers added a few goats, sheep and cattle to their way of life, which followed them in their seasonal displacements. This new form of subsistence cannot be classified under the dualistic model of hunter-fisher-foragers *vs* agriculturalists-pastoralists. It gave way to the concept of “middle ground” or “low-level-food producing society” that developed around the Mediterranean during the Mid-Holocene (Smith, 2001; Phillips et al., 2012). This means that, although the domesticated species do indeed originate in South-Western Asia, the process of domestication as part of the technical, social and symbolic system (Vigne, 2011) is local, parallel but independent of the East.

The 5th millennium witnessed the widespread adoption of domesticated livestock and the gradual evolution of herding societies. The shift in the monsoonal summer rain belt towards the south entailed the aridification of the Sahara and the retreat of populations towards permanent water zones. From that time onwards, the saga was played out on different stages. In Egypt, the major change came from the introduction of domesticated plants in areas with a Mediterranean rainfall regime. For Fayum, it was a one-way story. Whereas, in the valley, the adaptation of these plants of Mediterranean origin to receding-water agriculture constituted the starting point of a new adventure. The adoption of a farming-based economy, which was the case in the 5th millennium and in particular after 3500 cal. BC, is not a mere technical adjustment, however intelligent it is. It indicates profound underlying social and spiritual transformations, some of which undoubtedly predated it (Cauvin, 2000). Egyptian civilisation is probably at an embryonic stage somewhere between these two main trends, which are different from a biological, technical, social and cultural point of view; one formed according to an eastern model, the other immersed in the African universe of nomadic pastors. Is it a coincidence that the oldest known crops in the Nile Valley are situated to the north of Upper Egypt, at the junction of the north-south east-west routes?

In this respect, we need to address a final point, namely the role played by demography. Did successive waves of Saharan nomads boost Nilotic demography and contribute to the adoption and the development of agriculture? Or, on the contrary, was the transition to farming responsible for the demographic explosion recorded everywhere in the world when agriculture was adopted? This phenomenon has been called Neolithic Demographic Transition (NDT; Bocquet-Appel and Bar-Yosef, 2008).

The succession of arid episodes during the course of the Holocene engendered a concentration of the population around permanent water zones and, consequently, a demographic increase in these places. But we cannot speak of an influx. It is more of a progressive infusion that did not fundamentally destabilize ways of life. On the other hand, the transition towards agriculture, and the accompanying sedentarism, gave rise to a multiplication of sites corresponding to the NDT model. Recent studies (Boquet-Appel, 2008) have shown the major role played by sedentarism *vs* mobility in the increase in female fertility, and list the demographic increase as a consequence and not as one of the causes of the transition to agriculture. The return to a homeostatic balance, that is when the mortality rate counterbalances the natality rate, occurs in a second stage by the emergence of new pathogens linked to domestication and their diffusion in denser village units (Boquet-Appel, 2005, p. 18). The tuberculosis peak in the children's cemetery of the Predynastic site of Adaïma, in upper Egypt, is undoubtedly an illustration of this (Crubezy, 2017 and 2018). But we are already in the antechamber of pharaonic history.

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Challenges and Opportunities during the Last Glacial Maximum at the Forest Margins in Central Africa

Défis et opportunités aux abords de la forêt tropicale à la fin du Pléistocène en Afrique centrale

Els Cornelissen

Abstract: The environmental impact of The Big Dry (TBD) in Central Africa is mainly addressed with reference to the better documented dry phases of the Late Holocene. For its impact on the people, previous archaeological research shows the presence before, during and after TBD of two large technological traditions. The first bifacial tradition concerns the Lupemban and Tshitolian industries and the second that of microlithic industries on quartz. The characteristics of the latter correspond to the definition of miniaturization. This overview focuses on the Democratic Republic of Congo including the heartland of Lupemban and Tshitolian industries at the southwestern rim of the equatorial forest. However, at least for the Holocene, miniaturized industries in quartz are now documented here as well. They remain the only tradition found on dated Late Pleistocene and Holocene sites on the northwestern and northeastern edges of the forest.

Apart from the reassessment of lithic industries from older excavations, new perspectives on population history come from the reexamination of human remains of these excavations. Such a detailed analysis has shown that the Late Pleistocene hunter-gatherer-fishers from Ishango have more in common with their contemporaries in and outside of Africa than with people living in the area today. This agrees well with genetic evidence for increasing diversity in the Late Pleistocene *Homo sapiens* population in Africa. Ancient DNA from two Holocene burial phases in the rock shelter of Shum Laka (NW Cameroon) has revealed their deep shared past with Central African forest hunter-gatherers.

Keywords: Central Africa, equatorial forest, Lupemban, Tshitolian, microlithic and miniaturized quartz industries, Ishango, Shum Laka.

Résumé : L'impact environnemental du Big Dry en Afrique centrale est principalement abordé en référence aux phases sèches les mieux documentées de l'Holocène supérieur. Les recherches archéologiques antérieures montrent la présence avant, pendant et après cette grande sécheresse de deux grandes traditions technologiques. La première tradition dite bifaciale concerne les industries lupembiennes et tshitoliennes ; et la seconde, celle des industries microlithiques sur quartz. Les caractéristiques de ces dernières correspondent à la définition de la miniaturisation. Ce survol se centre sur la République démocratique du Congo, pays où se situe à la lisière sud-ouest de la forêt équatoriale la région de référence pour la séquence du Lupembien au Tshitolien. Les industries miniaturisées sur quartz y sont aussi documentées pour l'Holocène. Elles restent en revanche la seule tradition trouvée sur les sites datés du Pléistocène supérieur et de l'Holocène aux lisières nord-ouest et nord-est de la forêt.

Outre la réévaluation des industries lithiques issues de fouilles plus anciennes, de nouvelles perspectives sur l'histoire de la population proviennent du réexamen des restes humains de ces fouilles. Une analyse détaillée a montré que les chasseurs-cueilleurs-pêcheurs du Pléistocène tardif d'Ishango ont plus en commun avec d'autres populations contemporaines en Afrique et ailleurs qu'avec celles vivant dans la région aujourd'hui. Cela concorde avec les résultats génétiques d'une diversité au sein de la population d'*Homo sapiens* au Pléistocène tardif en Afrique. Les analyses ADN de deux phases d'inhumation holocènes dans l'abri sous roche de Shum Laka au Cameroun ont révélé leur longue interaction dans le passé avec les chasseurs-cueilleurs de la forêt d'Afrique centrale.

Mots-clés : Afrique centrale, forêt équatoriale, Lupembien, Tshitolien, industrie sur quartz, microlithique, miniaturisation, Ishango, Shum Laka.

INTRODUCTION

The Late Glacial Maximum (LGM) or The Big Dry (TBD) in Central Africa presents as anywhere else particular challenges for the environment and the populations. The dense rain forest is characteristic for the area today (fig. 1). Proxies for modelling the impact that the Late Pleistocene drought may have had on the rain forest, come from the better documented Late Holocene climatic arid phases between 4000 and 2000 cal. BP[1]. At present, the forest is home to hunter-gatherers (fig. 1) who are often considered to be the direct descendants from ancient Stone Age ancestors that would have been confined to forested environments. Comparative studies of their genetic profiles are a field exponentially growing and offer an alternative view into the past of an enormous region where palaeo-environmental records, archaeological sites both undated and radiometrically dated and human fossil remains are very thinly and unevenly spread. The western Atlantic rain forest is the best documented for the environment and genetic reconstructions. The least known part from all perspectives is the Inner Congo basin. A previous study (Cornelissen, 2002) looked specifically at the impact of TBD on distribution patterns of the available archaeological sites from Central Africa that were radiometrically dated between 40 and 12 ka BP (26 sites in Cornelissen, 2002, table 1). The key sites then are essentially those included in various later regional overviews (e.g. Mercader, 2002; Barham and Mitchell, 2008; Cornelissen, 2013 and 2016; Taylor, 2016).

In this chapter, a first topic to be discussed are the possible ways to envisage environmental reconstructions for the Central African rainforest in the Late Pleistocene. For the archaeological record focus will be on regions in the Democratic Republic of Congo (DRC). Political boundaries admittedly have little value for deep history, but the country today harbours the largest part of the African rain forest. Finally, ancient human DNA and human fossil remains that shed light on the population dynamics in the Later Pleistocene and Holocene in Central Africa will be shortly discussed.

1. EQUATORIAL FORESTS: A DYNAMIC ENVIRONMENTAL SETTING

Tropical rainforests are no longer considered as pristine environments and there is a growing body of evidence illustrating how the forest today is the result of human disturbances in historical times and of climate changes in the Late Holocene. At the end of the Pleistocene, TBD was a period of desertification, expansion of savannah and contraction of the rainforest into forest refugia. J. Maley (1996) is the key reference for forest refugia in Central Africa and recent updates are found in J. Maley et al. (2018). From the biodiversity standpoint, a refugium is identified in areas that today have high rates of endemic species, or for which evidence is found in palaeobotanical records. In terms of direct witnesses from the time of the TBD, palaeo-environmental records are very few. Only two sites (fig. 2) with paleo-environmental data cover TBD. They are the pollen record of the sediments of lake Barombi Mbo in SW Cameroon, first published in J. Maley and P. Brenac (1998), and fossil tree trunks in soil profiles at Osokari along a road cut from Walikale to Ubuntu in the eastern part of the DRC (Runge, 1997 and 2000; Runge et al., 2014). These are presented below followed by a concise survey of additional information from archaeological sites that were occupied at the time of TBD.

1.1 Direct record of palaeo-environment during TBD at lake Barombi Mbo (SW Cameroon) and Osokari (E DRC)

Since the original publication (Maley et Brenac, 1998) and twenty years later (Maley et al., 2018), the lower part of the pollen record of lake Barombi Mbo going back to 32 ka cal. BP remains the “only central equatorial site extending its record of past environmental change” to the TBD. The TBD is marked out by a sharp increase in Cyperaceae pollen of ± 35% between c. 24-18 ka cal. BP (Maley et al., 2018, fig. 10). These typical wetland herbs spread on the deltaic platform when the lake level decreased and can be used to reconstruct the lake level fluctuations (Maley et al., 2018, p. 12). The authors conclude from this that during the Pleistocene the lake level dropped to as much as 6 m and below the outlet. This significant decrease of the lake level points to more severe conditions at the end of the Pleistocene, compared to those of the Late Holocene climatic variations. Poaceae or grass pollen are markedly present before 11 ka cal. BP, attaining their highest peak between 18.7 and 16.2 ka cal. BP. They almost disappear between 11 and 4.1 ka cal. BP to the advantage of arboreal pollen. Poaceae peak again to 40% in the Late Holocene dry episodes situated between 4.1 and 1.7 ka cal. BP, yet grass pollen never dominated the tree pollen throughout the long sequence (Maley et al., 2018, fig. 10).

Osokari (Runge, 1997 et 2000; Runge et al., 2014) is situated in the eastern part of the equatorial forest in DRC. Largescale road construction groundworks over a distance of 600 km offered a unique view into the soils below today’s forest. Numerous fossil tree trunks were found at depths of 4.5 m to almost 8 m in the lower part of a profile along the road cut. Some trunks were found in direct contact with the top of the weathered basement or parent rock. Radiocarbon AMS on samples of more than 10 fossil trunks up to 1 m diameter at different locations of the road cut yielded dates ranging between 16.4-14.2 ka cal. BP (Hv-20288 in Runge, 1997, table 1) and 42.1-41 ka cal. BP (Beta-85901 in Runge, 1997, table 1). The state of conservation of the tree trunks was too degraded for identification of genus or species yet the $\delta^{13}C$ values lie between - 20 to - 26‰ and are in support of forest trees (Runge, 2000, p. 253). The colluvium and

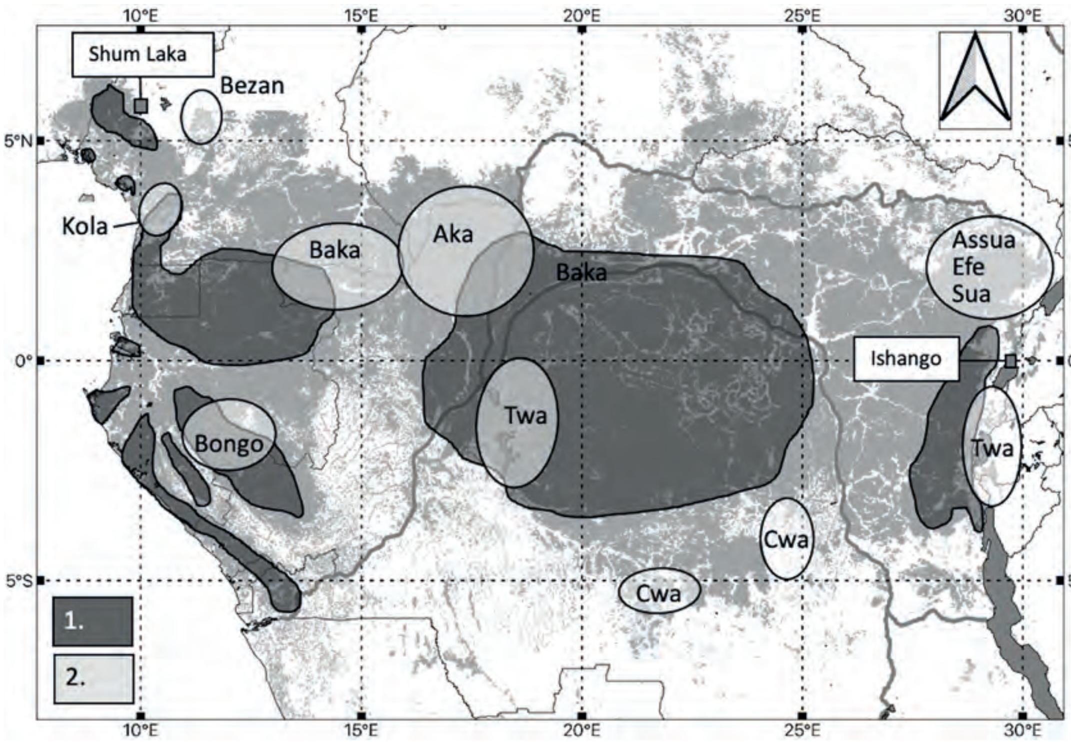

Fig. 1 – (1) Extent of reconstructed Late Holocene forest refuges (after Maley et al., 2018, fig. 1) projected on the extent of the Central African rain forest today; (2) Areas of present-day hunter-gatherer communities (after Bahuchet, 2014, fig. 1.1). Rain forest today based on categories 1-5 of P. Mayaux et al. (2003).

***Fig. 1** – (1) Étendue des blocs refuges forestiers reconstitués pour l'Holocène tardif et projetés sur l'étendue de la forêt aujourd'hui (d'après Maley* et al., *2018, fig. 1) ; (2) zones où se trouvent des chasseurs-cueilleurs aujourd'hui (d'après Bahuchet, 2014, fig. 1.1). Extension actuelle fondée sur P. Mayaux* et al. *(2003), catégories 1 à 5. Étendue de la forêt lors de l'Holocène tardif d'après J. Maley* et al. *(2018, fig. 1).*

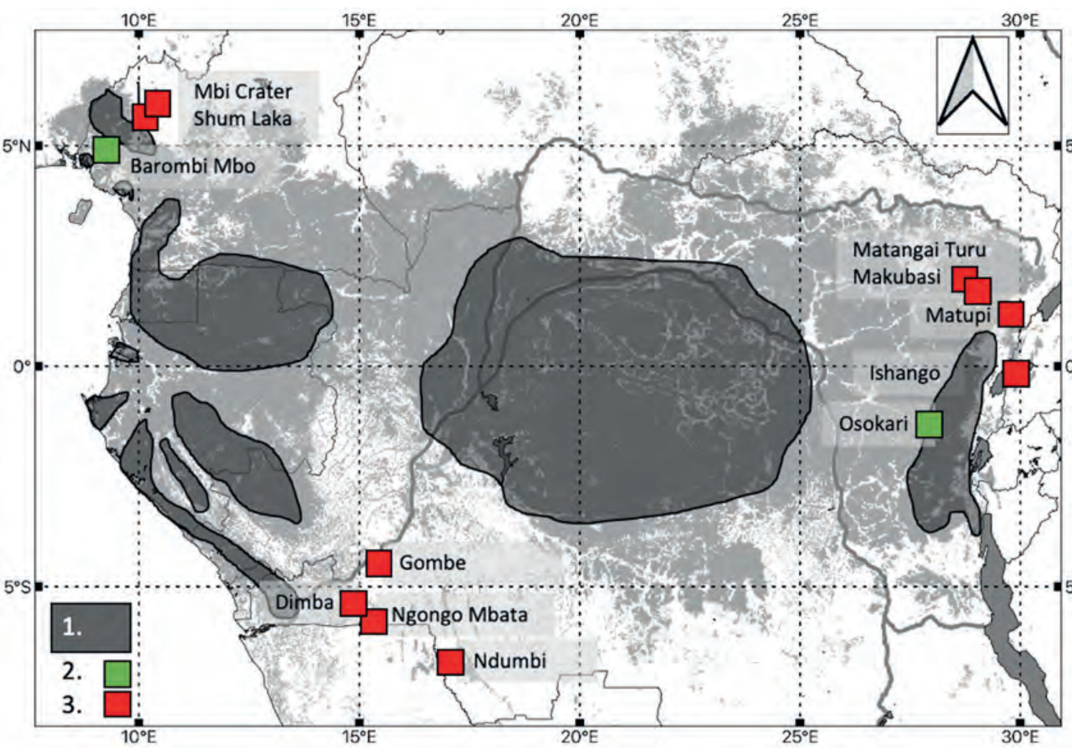

Fig. 2 – (1) Extent of reconstructed Late Holocene forest refuges (after Maley et al., 2018, fig. 1) projected on the extent of the Central African rain forest today (based on categories 1-5 of Mayaux et al., 2003) with locations of (2) palaeo-environmental and (3) archaeological sites mentioned in the text.

***Fig. 2** – Étendue des blocs refuges forestiers reconstitués pour l'Holocène tardif (1) et projetés sur l'étendue de la forêt aujourd'hui (Mayaux* et al., *2003) avec la localisation des sites (2) paléo-environnementaux et (3) archéologiques mentionnés dans le texte.*

the two stone-lines in the overlaying meters of sediment contain allochthonous elements. Heavy mineral analysis and geochemical composition reveal that the parent rock material is different from the soils below and above the stone-lines. Stone-line formation is related to erosion that can only take place in an open landscape with sparse vegetation, under increasing precipitation that would cause mass transport along the riverine network. The eroded materials are supposed to derive from the slopes of the higher mountains, the western ridge of the Albertine Rift Valley. The combination of increased precipitation on a thinly vegetated landscape triggering massive morphodynamic changes to the landscape is assumed to have taken place at the end of dry periods like TBD sometime around 14.5-13 ka cal. BP, when there is a strong increase in the Congo deep sea fan in sediment rate of detritic sediments (Maley et al., 2018). Charcoal contained in the upper stone line was dated to ca. 2.2 ka cal. BP and is synchronous with the Late Holocene perturbation as described from the western part of Central Africa (see below 1.3).

1.2 Environmental data from archaeological sites

Additional data for the impact of TBD on environment and human populations come from a few archaeological sites in Central Africa. Geographically, information is highly dispersed; in a straight line, the distance between the sites in NW Cameroon and those in NE DRC is c. 2,200 km (fig. 2). The sources in which human agency plays a role are diverse; charcoal might represent a selection from available firewood not too far from the site, phytoliths in caves are supposed to reflect the immediate surroundings of the caves brought in via human selection for food, thatching material, bedding, medicinal or ritual use, and as fire wood (Mercader et al., 2000, p. 106-107). Remains of hunted game may not represent the immediate surroundings of the site, but the environment at a larger distance that hunters habitually cover during their activities.

Two rock shelters at the north-western margin of the rain forest in NW Cameroon provide a partial environmental account. The first source is a sequence of charcoal samples at Shum Laka and the second source consists of a combination of pollen and fauna from Mbi Crater. At Shum Laka (Lavachery, 2001; Cornelissen, 2003), radiocarbon dating of charcoal fragments of *Protea madiensis* has yielded dates from bottom to top from 42-31 ka cal. BP, 39-34 ka cal. BP or prior to TBD, 25-24 ka cal. BP and 22-21.5 ka cal. BP during TBD as well as from the transition to the Holocene, 16-14.5 ka cal. BP and 12-11 ka cal. BP (calibrated cal. BP from Lavachery, 2001; Cornelissen, 2003). The savanna shrub was used as fire wood and thus most likely collected in the vicinity of the rock shelter. It is also found in upland grassland at elevations from 1,500-2,280 m which corresponds well with the altitude of the site. In the Pleistocene sediments, only four other plant species were identified which occurred just once in the charcoal samples. The one identifiable bone fragment found in the Pleistocene layers derives from a forest species *Hylochoerus meinertzhageni* (identification by Van Neer in Cornelissen, 2003). During the accumulation of the Pleistocene deposits, this suggests an open landscape with perhaps mountain/gallery forest near the site (Cornelissen, 2003, p. 8). *Protea madiensis* continues its presence throughout the Holocene deposits, yet species composition becomes increasingly more varied including forest trees and wooded savannah species (Lavachery, 2001, table IV). A similar pattern of increasing forest is evident in the species composition of fauna remains (Lavachery, 2001, table III); *Hylochoerus meinertzhageni* or the giant forest hog is present in all five Holocene, ash layers as well as *Syncerus caffer nanus* or forest buffalo in four of the ash layers. The Late Holocene climate perturbation (see below 1.3) apparently had no immediate effect on the environment around Shum Laka.

At Mbi Crater also in NW Cameroon and at a relatively high altitude of 2,000 m, palaeo-environmental data during the occupation of the site first come from the habitat of fauna (Hedges et al., 1987; Asombang, 1988, table 6.10; Cornelissen, 2002, p. 225 and fig. 7). The animals of which remains were brought into the cave in layer II dated to c. 24.3 ka-20.1 ka cal. BP, predominantly lived in open landscapes, although species from densely wooded and forested areas are represented in modest proportions. As from layer III dated to c. 10.5-9.9 ka cal. BP, the proportions change in favour of more and more species from forested and densely wooded environments. In the Mid Holocene layer IVA, dated to c. 5.1 and 4.3 ka cal. BP, more than half of the game comes from forested environments and this continues throughout the Late Holocene prior to the dry phase (layer VI dated to 3.2-2.7 ka cal. BP) as well as in the top layer. A preliminary assessment of pollen samples from the top 70 cm of sediment and at 170 cm from the surface yield the same taxa including Podocarpus. This is considered as an indication of a fairly stable environment with a relatively important forest component (Maley, pers. comm., 1986, in Asombang, 1988, p. 208).

On the opposite side of the rain forest in NE DRC, in the Ituri lowland rainforest, several caves were excavated and from three, phytoliths were identified (Mercader et al., 2000). In one of the caves, Matangai Turu NW, a date of 12.7 to 12.1 ka cal. BP was obtained from charcoal at 1.25 m below surface (UtC Nr 5075; Mercader et al., 2000, table 1 and fig. 2). The underlying 90 cm of sediments are thus considered of Late Pleistocene age. There is an abrupt change in tree-grass ratios between the sample dated to 12.7-12.1 ka cal. BP that has more arboreal and fewer grass phytoliths than samples lower in the column. In all, the results are taken as indication that the forests during TBD may have had a more open canopy than today and may have changed in plant species floral composition, but not to the extent that grassland would have replaced the tropical forest.

The long sequence of the Matupi cave on the eastern edge of the Central African rainforest presents a similar pattern as the sheltered sites from NW Cameroon. Today, the Mount Hoyo massif is covered in forest. The upper 10 cm have proportionally the highest representation of forest animals and postdate the most recent date of 680-554 cal. BP (Van Neer, 1989, p. 80-82). In the lower layers, animal bone is less well preserved, yet the identifiable species come from open environments. W. Van Neer concluded that a major environmental shift occurred sometime between 14.9-13.4 ka cal. BP and 3.6-2.4 ka cal. BP (recalibrated from Van Noten, 1977).

This shift is also observed in a study of speleothem pollen from caves near the archaeological excavations; a C4-dominated savannah grassland is present near the cave at ca. 14 ka cal. BP (Brook et al., 1990, 230Th/234U series). By 6 ka cal. BP, possibly much earlier, forest invaded the area.

Finally, a total of nine radiocarbon dates at Ishango (De Heinzelin, 1957; Brooks and Smith, 1987; Brooks and Robertshaw, 1990; Brooks et al., 1995; also in Crevecœur et al., 2016, p. 37-38) situate the Late Pleistocene occupation of the N.F.Pr. (Principal Fossiliferous Level), the main fossil bearing horizon, between 30 and 20 ka cal. BP. Ishango is situated at shore of lake Edward at the source of the Semliki river that flows today to the north into lake Albert, on the floor of the western branch of the East African Rift, the Albertine Rift. Five dates fall in the range between 26 and 23 ka cal. BP. The environmental associations of recovered mammals from the Late Pleistocene layers (Peeters, 1990) are lake margins, gallery forest and woodland between the open grasslands of the plateau and the valley. Riverine and lakeside exploitation are clearly visible in the abundant fish remains (see further 2.2).

The very faint picture emerging from the archaeological record is once again that of a dynamic environmental setting, showing comparatively less forested environments near the sites during the Late Pleistocene part than during the Holocene, but never to the extent that forest was entirely replaced by grasslands in the lowland and with continued gallery forests in the higher altitudes.

1.3 By proxy: genetic reconstructions from the Penultimate Glacial Maximum

For more remote periods including TBD, genetic studies of rainforest tree populations today may provide complementary information for reconstructing forest history over Pleistocene long timescales. Such is the study of R. Piñeiro et al. (2017), of two tropical trees characteristic of mature lowland rainforests, *Greenwayodendron suaveolens* subsp. *suaveolens* and *Scorodophloeus zenkeri*. The results support the fragmentation of the rainforest in western Atlantic Central Africa during glacial periods; fragmentation seems to have been stronger during the Penultimate Glacial Maxium at c. 130 ka than during TBD. Another interesting result is that trees do not all respond in the same way to climatic changes: their differential dispersal capacity may have impacted their response. A more efficient colonization would be through animal dispersion than in gravity dispersion leading to a broader colonization.

1.4 By proxy: The Late Holocene forest perturbations

For the 2500-2000 cal. BP reconstruction of forest refugia, data come from 19 studied palaeo-records. Of these 19 palaeoenvironmental sites 14 are located in the western half of Central Africa, only one in the Inner Congo Basin and four in the eastern part of the current forests (Maley et al., 2018, fig. 1).

Mapping (fig. 1) of the various so far located Late Holocene refugia across Central Africa reveals an extensive fluvial and lowland forest refuge west of Kisangani along the Congo river in the east, covering the Inner Congo basin down to the south of lake Mai Ndombe, and extending to the west to the interfluves of the lower Congo, Ubangi and Sangha rivers. A series of smaller fluvial refuges, persisting thanks to the high water tables, lie dotted along the Atlantic coast between 4°N and 1°S. Lowland to submontane forest refuges are reconstructed for south western Cameroon, a number of parallel refuges stretching over Equatorial Guinea in the west to the northwest of the Republic of Congo. Finally, a lowland to submontane forest refuge follows the western side of the Albertine Rift between the northern point of lake Tanganyika and the northern shore of lake Edward.

Outside the refuges (Maley et al., 2018, p. 51) and most likely presenting regional differences, forests were highly distributed, or were maintained as "micro-refuges" in favourable topographic positions, or disappeared and were replaced mainly by drier forest types, wooded savannahs and woodlands.

An earlier climatic crisis had set in at 4000 yrs cal. BP and had also affected the Central African rainforests but in a different manner (Maley et al., 2018); it favoured savannah expansion at the northern and southern margins of the rain forest, yet would have let the forest intact in its core area.

1.5 Forest contraction and forest fragmentation with floral diversity

The more open landscape during the TDB on archaeological sites at the north-eastern and north-western margin of the forest fits into the hypothesis formulated by J. Maley et al. (2018) that forest contraction was the TBD scenario rather than that of forest fragmentation as reconstructed for the Late Holocene forest perturbation. Yet the evidence inside the Ituri lowland would favour a forest fragmentation with change in floral composition.

The Mid to Late Holocene dry phases cannot be copied onto the period of TBD, yet they stand as a model or proxy for what the impact can be on the rainforests in less than 5000 years witnessing two climatic crises. J. Maley et al. (2018) see as major driver of these climatic crises "rapid sea-surface temperature variations in the equatorial eastern Atlantic, which modified the regional atmospheric circulation" and that "the change between ca. 2500 to 2000 cal. BP led to a large increase in thunderstorm activity, which explains the phase of forest fragmentation".

Despite the fragmentary nature of the palaeo-environmental record for TBD in Central Africa, direct botanical evidence and that coming from archaeological sites, Late Holocene reconstructions and genetic data from tree species going back to the Penultimate Glacial Maximum, combine to support the hypothesis that the equatorial forest today is the outcome of a particularly dynamic history. This implies that humans in this region if and when present were able to exploit, live and survive in this continuously changing environment.

2. THE LATE PLEISTOCENE AND EARLY HOLOCENE ARCHAEOLOGICAL RECORD: SOUTH-WESTERN AND NORTH-EASTERN CENTRAL AFRICA

The poor state of the archaeological record in Central Africa is habitually explained in terms of research design and interest, difficult field access, low site visibility precisely in a densely forested environment, political instability and instable research facilities. The absence of datable volcanic layers and geological interest in general oriented on mining facilities and construction activities rather than on Pleistocene and Holocene landscape formation do not encourage locating archaeological sites with secure stratigraphy. The dearth of archaeological and behavioural data is most certainly not because Central Africa and its environments were inhospitable for human population. In fact, fragmentation and contraction of the forest and concomitant expansion of grassland may result potentially in relatively larger ecotone zones that provide the best of both worlds (Cornelissen, 2002). But when looking at the massive land movements documented at Osokari (Runge, 1997 and 2000; Runge et al., 2014), one may wonder whether the same hospitability would apply to such a dynamic landscape.

Archaeological sites radiometrically dated to the Late Pleistocene and Early Holocene remain in and at the fringes of the Central African rainforest, essentially those listed in E. Cornelissen (2002). Of some of these sites, more comprehensive studies were published in the meantime (Njuinye and Mosomu in Mercader and Martí, 2002; Shum Laka in Cornelissen, 2003). N. Taylor (2016) reassessed the finding circumstances of Lupemban sites in the broad region of Central Africa by applying various filters of site integrity. For DRC I took a broader look at surface finds in the north-eastern part of the Central African rainforest where the Ituri rock shelters, the cave of Matupi and the open-air sites of Ishango are located (Cornelissen, 2016), as well as at surface and open-air sites in Bas-Congo from the Early Holocene (Cornelissen, 2018) where reference sites Gombe (Cahen, 1976, 1978a and 1978b) and Dimba cave (Lavachery, 1990) lie. Two broad patterns are evident in the lithic component that to some extent is explained by the finding circumstances. In the sheltered situation of caves and rock shelters at the western and eastern margin of the rain forest as well as in the lowland Ituri forest, quartz was the preferred raw material for microlithic or miniaturized (see below 2.1) industries. The second technological pattern includes use of various rocks, which in the region on the south-western margin of the rain forest, are often silcretes, also known as *grès polymorphe*. Emphasis here is on bifacial shaping of tools such as the category of lanceolates, core-axes and elongated points, leaf-shaped and eventually transverse arrowheads and *petits tranchets*. Though Levallois and prepared cores for blade production are found on sites like Gombe (Cahen, 1976 and 1978a), they are not the essential part. The issue of what constitutes Lupemban, Tshitolian, microlithic or miniaturized quartz industries, or their age and label of Middle or Late Stone Age, is open for discussion due to the continuing lack of radiometrically dated sites in secure stratigraphic contexts. From that perspective and in many instances, typology remains often the only way to describe archaeological industries in the region.

With all these usual caveats in mind, an attempt is made below to present a regional assessment in the north-eastern quarter of the rain forest and in the main area of the Lupemban-Thsitolian sequence in Bas-Congo at the south western margin of the forest.

2.1 Pleistocene-Holocene bifacial technology and Holocene miniaturized quartz industries at the south western margin of the Central African rainforest

Compared to other regions in DRC, Bas-Congo is relatively well documented from the archaeological point of view since the early 20th century. Among these are the excavations of the 1920s on the open-air site at Gombe, Kinshasa, DRC, yielding a reference sequence of industries spanning the Early Stone Age through the Neolithic. Unfortunately, later excavations lead to a reassessment and identification of post-depositional processes that had blurred the previously separated archaeological horizons (Cahen, 1976, 1978a and 1978b). In their paper based on the Gombe site and the then available radiocarbon dates, D. Cahen et al. (1983) describe the disturbances as a regional feature for the entire southern part of the Congo basin. They also observed a large time gap at Gombe between the bottom of the sandy mantle and the top of the gravel floor. On a regional scale, the gap was consistent with no dates between 31.8-31.0 ka cal. BP for the lower limit and 19.4-17.1 ka cal. BP for the upper limit of the gap (calculated from Cahen et al., 1983, table 2, Lv-166 and Grn-7721). Though the authors do not explicitly refer to TBD, given the dating evidence, this climate crisis must have had an impact on the settlement in the area. Lithic industries with emphasis on bifacial technology are present before and after the gap in the region. The only date for such an industry in TBD comes from the Dibma cave which was not included in the regional overview. Most likely, this is explained by the inversion in the dating sequence at Dimba. The top layer was dated to ca. 2100-1800 cal. BP (de Maret, 1986) and yielded

Ngovo pottery and a few polished tools. Below, an accumulation of 3 m of red clays contained 3 archaeological horizons separated by archaeologically sterile layers (Lavachery, 1990). Bulk radiocarbon dating on charcoal from the middle horizon yielded a date of 23.4-20.3 ka cal. BP (Hv-6255), and another bulk date of 7.9-6.0 ka cal. BP (Hv-6256) comes from the underlying layer I, questioning the Late Pleistocene age of layer II (first published as b.c. dates in de Maret et al., 1977, without comments).

The main characteristic of the lithic assemblages found in three horizons in the red clays at Dimba cave is the presence of core-axes that are also found outside the cave on the surface (fig. 3).

Core-axes are "at the core" of the discussions on whether a lithic assemblage belongs to the Tshitolian and/or Lupemban technocomplex with a strong emphasis on "façonnage" or shaping instead of on prepared core technology resulting in blanks or flakes or blades of a predetermined shape in Middle Stone Age assemblages to be used as such, or to serve as blanks for microlithic inserts backed into standardized shapes and sizes. Core-axes described by J. D. Clark (1963), which D. Cahen (1978b) redefined as a "bifacial more or less parallel-sided tool on a large flake but most frequently on a chunk or cobble of relatively modest size", are extremely diversified as a typo-technological category. Both distal and proximal edge may be either pointed, chisel-shaped, oblique, straight or rounded. Their cross section may be triangular, plano-convex or lenticular. Though the definition includes bifacial shaping, in fact the shaping may be limited to a unifacial non-invasive modification of the edges. Other bifacially shaped tools are various points, lanceolates, arrowheads, leaf-shaped or tanged. Small transverse arrowheads and large tranchets are the two extremes of a whole range of tools with unmodified cutting edges and backed, blunted sides.

Another characteristic of the Dimba assemblages is the low portion of quartz among raw materials composed essentially of quartzitic and chalcedonic silcretes grading into chalcedony and cherts (Lavachery, 1990). Only c. 5% of the 190 artefacts from the upper layer III are made of quartz, including a tanged bifacially flaked arrowhead (fig. 4). The other 14 tools out of a total of 190 artefacts from level III are relatively small and do not exceed 6.3 cm in maximum size (fig. 4). Together with the three transverse arrowheads (one illustrated in fig. 4) all tool-types habitually associated with the Tshitolian are represented. In the lower levels, maximum size increases to 12 cm and more or less the same tool-types are present. Regardless of whether the Late Pleistocene date is correct or not, even if the Mid Holocene date would prevail, the Holocene presence of this essentially bifacial component in Bas-Congo seems established.

Quartz assemblages are infrequent in the archaeological record of southwestern Central Africa in the area of the key sites of Gombe and the Kinshasa plain. This might be explained by the abundant availability of silcretes of good flaking quality in the supposition that quartz would

Fig. 3 – Dimba, DRC. From top to bottom: dorsal, side and ventral view of one unifacial (left) and two bifacial core-axes found on the surface near the cave, 1973 (photo RMCA). All three in silcrete.

Fig. 3 *– Dimba, RDC. Du haut vers le bas : vues dorsale, latérale et ventrale d'un core-axe unifacial (à gauche) et de deux core-axes bifaciaux, tous en grès polymorphes et trouvés en surface près de la grotte de Dimba en 1973 (cliché RMCA).*

Fig. 4. Dimba, DRC: level III of Holocene age. From top to bottom: Core-axe and leaf-shaped arrowhead of the same maximum size of 6.3 cm, in silcrete (photo RMCA). Tanged arrowhead in quartz and transverse arrowhead in chert.

Fig. 4. Dimba, RDC : niveau III de l'Holocène. Du haut vers le bas : core-axe et pointe foliacée qui ont une même dimension maximale de 6,3 cm, en grès polymorphe, pointe de flèche pédonculée en quartz et pointe de flèche à tranchant transversal en chert (cliché MRAC).

be a second choice or back-up scenario in the absence of other rocks. Further to the south in the Kwango area, the undated site of Ndumbi (Planquaert, 1976) hinted that this might not be always the case. Larger implements in silcretes were found strewn on the surface of the slopes and include pics, bifaces, lanceolates and core-axes, whereas Levallois and blade cores are quasi absent like at Gombe. A controlled collection on the top of a small hill over 24 m² of 20 cm of sediment resting directly on the bedrock yielded essentially quartz artefacts, but also some in silcretes. Among the quartz tools are small leaf-shaped points as well as cores and a biface in quartzitic silcrete with polished working edge (Planquaert, 1976, p. 21). The author notes for Ndumbi (p. 26): "On the other hand, the almost exclusive choice of a raw material as ungrateful as quartz seems more surprising, especially in a region where polymorphic sandstones abound. This choice is certainly a deliberate one, for motives that are currently eluding us(2)."

The open-air site of Mbanza Ngungu provides another clear example of the deliberate choice for quartz in Bas-Congo (Cornelissen, 2018). Though Late Stone Age was not the focus of the KongoKing project (Clist et al., 2018), various researchers conducted surface surveys and excavations between 2012-2015 that resulted in Stone Age material from 31 surface and 10 excavated assemblages. Nine out of the 31 surface collections contained the same type of core-axe found outside the Dimba cave and in the red clays inside the cave. These core-axes are totally absent from the 10 sites where limited excavations took place, and are made almost exclusively on silcretes and quartzites. Geometric or backed implements of small size did not figure among surface collected material (Cornelissen, 2018).

At the open-air site of Ngongo Mbata, the quartz assemblage was dated to the Early Holocene (10.8-10.5 ka cal. BP, 9470 ± 50 BP Poz-60770 published as "en association avec du quartz microlithique d'origine Late Stone age" [Clist et al., 2015, p. 475] and 10.2-9.7 ka cal. BP, 8910 ± 50 BP Poz-80297 in E. Cornelissen [2018]). Characteristic for the assemblage of 785 artefacts is the high proportion of quartz (88.5%) and the diminutive nature. The largest quartz artefact does not exceed 8 cm. Of the remainder of 11.5% raw materials, half are on a grey banded chert. The presence of cortical quartz artefacts is quite striking; 75% have retained cortex. Like at Ndumbi, the exploitation of split quartz cobbles where the neocortex is used as the flaking platform is very recurrent at Ngongo Mbata, which as can be expected results in a tremendous amount of cortical flakes. Half of the 228 unmodified quartz flakes have a cortical proximal edge and a non-cortical dorsal face regardless of their size (Cornelissen, 2018, fig. 5.4). Modified pieces are few. These retouched pieces, scraper edges and notches do not exhibit much standardization. From Ishango (de Heinzelin, 1957 and 1962) we know that small quartz splinters have been set into bone handles without much modification in this particular case. A comparative study of the Ishango and the Ituri sites learns that small river cobbles of quartz were used for raw material (Mercader and Brooks, 2001), but not with the same observation on the intentional production of flakes with large cortical proximal edges. At Shum Laka (Cornelissen, 2003), vein quartz extracted from granite banks is exploited. Cortex on artefacts in general does not exceed 5% and there is no deliberate production of small cortical flakes. The quartz assemblages from the north-eastern, north-western, and south-western sites seem to be regional or local interpretations of a broad technological substratum.

The discussion on what is microlithic is far from settled like the discussion on Lupemban and Thsitolian. Size most certainly cannot be the sole parameter; small unmodified yet functional implements are part of stone equipment since a million of years (Kuhn and Elson, 2002; Pargeter, 2016, p. 233-234). The quartz assemblages from Bas-Congo only respond very partially to the four criteria that S. L. Kuhn and R. G. Elston (2002) propose for microlithic industries. They do not exhibit intentional production of blades of bladelets, backing for blunting edges is very rare, small tools of standard size and shape are absent as well as a macrolithic component. Essentially radial flaking of small split river cobbles results in a flake population of excessively many small flakes with a cortical proximal edge and no dorsal cortex. This proportion is so striking that there must be a true intention for their production. Also, if backing is intended to render one edge of the stone insert blunt in order to fit it into the handle, this may also be obtained by using the cortical part of these unmodified sharp quartz flakes. The characteristics for miniaturization listed by J. Pargeter (2016) for the Later Pleistocene site of Ntloana Tsoana in Lesotho apply much more to the Bas-Congo quartz assemblages. They are, sheer absence of formally retouched pieces, a systematic production of small flakes from small cores which is intentional and not imposed by the size or nature of available raw materials. At the site of Ntloana Tsoana, traces of utilisation were identified on the unmodified flakes, which has not been attempted for the Holocene quartz assemblages in Bas-Congo.

2.2 Pleistocene bifacial technology and Late Pleistocene-Holocene quartz technology at the north eastern margin of the Central African rainforest

The few excavated sites that are highly informative on environmental and behavioural patterns in the period under consideration are located in the north-eastern part of the Central African rain forest. The Ituri (Mercader and Brooks, 2001) and Matupi (Van Noten, 1977) rock shelters, and the Ishango open-air sites (De Heinzelin, 1957 and 1963; Brooks and Smith, 1987) cover a period from at least c. 40 ka cal. BP to the Late Holocene. The lithic assemblages have been described as microlithic, yet they would also fit into the description of a miniaturized technology (see 2.1; Pargeter, 2016); no centripetal debitage, primarily "simple" debitage and no bipolar percussion, small formal tools such as scrapers, very rare geometrics, points and perforators. On all these sites, the Pleistocene quartz industry continues in the Holocene layers to which gradually pottery is added. In a regional comparison (Mercader and Brooks, 2001), the similarities in stone equipment and technology between the sites situated in Pleistocene lowland forest and open landscapes lead to the conclusion that quartz technology is of practical use in any kind of environment and most certainly not an environmental indicator. All sites have in common that there is no trace of a prevalent bifacial large tool component; and on all sites, an intentional choice for quartz is evident.

Whereas on the sites in Bas-Congo the absence of preserved animal remains prevents any direct information on subsistence strategies, hunting in open environments and along gallery forests is obvious from the Pleistocene fauna remains of Matupi (Van Neer, 1989) and of Ishango (Peeters, 1990). At the Ituri sites, animal bone is not preserved in the layers dated between c. 3.1 ka cal. BP and c. 22.9-22.4 ka cal. BP (Mercader and Brooks, 2001, table 1 Beta 1270709 and Os-21250). At Ishango, intensive exploitation of aquatic resources is recorded, which is a subsistence strategy often underrepresented on archaeological sites. Detailed analysis of fish bones (Stewart, 1989) reveals fishing and fish consumption of small and very large fish. The very large fish were most probably harpooned and speared during spawning runs. Bone harpoons and barbed points are part of the standard equipment in the three Late Pleistocene layers at Ishango. The representation of the various fish skeletal parts indicates that processing, preparing and consuming all took place at the site. Closely in time, related repeated visits to the same locality might have been either part of logistic mobility by a task specific group, or of residential mobility implying that the environment offered a safe recurrent food source (see also Lane, 2014).

In the absence of a solid dated excavated Stone Age record, an assessment of how these excavated sites integrate in a broader regional frame was made through museum collections (Cornelissen, 2016). These are very partial and distorted through the selection of the easily recognizable, carefully made stone tools by collectors who were either untrained in archaeology or who proceeded according to now obsolete archaeological practice.

Lanceolates, core-axes and other bifacially trimmed artefacts in various volcanic and sedimentary rocks were collected from the surface or found in alluvial and colluvial deposits many meters below the surface during mining and construction works. They are totally absent from the few well dated Late Pleistocene sites such as Ishango, Matupi cave and the Ituri rock shelters. Their absence holds for the more ancient sites of Katanda as well (c. 80-70 ka; Feathers and Migliorini, 2001) that yielded finely finished bone tools, yet the stone tools on local quartz and quartzites are characterized by the absence of standardized tool categories (Yellen et al., 1995; Yellen 1996). Given the ancient dates outside of the north-eastern forest for the Lupemban at Twin Rivers (Barham and Smart, 1996; Barham, 2012), the finds might relate to an older technological tradition that at the end of the Pleistocene in the north-east part of the forest became replaced by the quartz technology. There are no Holocene sites belonging to bifacial technology in the north-east, except for the case of the Late Holocene sites on the lower Lomami river (Livingstone-Smith et al., 2017). The ad hoc bifacial flaking of small axes or adzes was found in association with pottery dated to c. 2000 cal. BP, and has no technological bearing at all with the Lupemban lanceolates and points.

The combined distribution pattern (Cornelissen, 2016) of microlithic and miniaturized industries on quartz with no bifacial component concentrates east of 28°E. The distribution of implements of Lupemban affinity and bifacially flaked artefacts goes further west to 26°E, yet they do not extend beyond. This artificial boundary coincides more or less with the valley of the north-flowing Lualaba river that becomes the Congo river flowing at Kisangani. Often Stone Age artefacts and particularly those of Lupemban affinity are associated or found within stone lines ("Stone line" accumulation filters 4 and 5 in Taylor, 2016). Interestingly, to the south, following the transect of road construction from Osokari to Kisangani to the west, the regional distribution of coarse stony horizons in soils decreases, whereas they increase in thickness in the opposite direction moving east to the Western Rift mountains (Runge, 2000, p. 252). The thinning out of the stone lines, be they of colluvial or alluvial nature, from east to west, may explain why the Lupemban artefacts also associated with stone lines do not cross the artificial boundary at 26°E. During the fieldwork along the road transect there were, however, no artefacts found in these stonelines (Runge, 2000, p. 252; Runge et al., 2014, p. 76).

3. THE HUMAN RECORD IN CENTRAL AFRICA'S RAIN FORESTS

3.1 Hunter-gatherers today

Human remains dating to TBD are extremely few in Central Africa, nor are they numerous for the Holocene. Yet the hunter-gatherer groups that are living in the forest today (fig. 1) are often taken as the direct descendants of Pleistocene ancestors, for instance in genetic studies. The assumption to explain the genetic diversity between the hunter gatherer populations today in the east and those in the west (Verdu, 2014 based on Patin et al., 2009 and Batini et al., 2011) is that during TBD the forest would have contracted in these specific areas cutting of any contact and gene exchange for such a long period that this provoked the observed genetic distance. There are however many assumptions underlying this hypothesis (Verdu, 2014): present populations settle the same areas as their ancestors, these areas have always been forested, which is far from established (see previous discussion on palaeo-environment), and the populations themselves are and have always been confined to forest environments, which does not seem probable either.

As often, the label of hunter-gatherer today covers a diversity in subsistence mode, environment, cultural affiliation or stature of these populations (Bahuchet, 2014). When overlaying their current approximate distribution (Bahuchet, 2014, fig. 1.1) onto the forest today (fig. 1), most groups, but not all for instance in the eastern area, are situated within the rain forest. When their distribution was projected back into the past, and on the assumption that their area or pattern of mobility would not have changed (which given the time depth seems highly unlikely) not all of them would have been confined to the forested environments. For the area where Assua, Efe and Sua live today, at the north-eastern fringe, there is no refuge reconstructed, though archaeological phytoliths (Mercader et al., 2000) would indicate continued forest cover albeit different in floral composition and extent. The area of the Twa on either side of the Western Rift valley, and where the Cwa are at the southern fringe, all fall out of the reconstructed refuges. The area of the Twa in the Inner Congo basin may have been part of the fluvial refuge which is also true for part of the area where today the Aka live. The areas where Bezan, Kola, Baka and perhaps to a lesser extent also that of the Bongo may have seen a very dynamic environmental history. If there is a deep history for all these populations, and if the Holocene disturbances of the forest are taken as a proxy for possible scenarios, then their ancestors were equipped to respond to environmental changes caused by the TBD which does not necessarily imply to move and contract with the forest refuges.

3.2 Direct fossil human record: A Hunter-gather-fisher community during the TBD at Ishango

Ishango is the only site in the whole of Central Africa to have yielded fossil human evidence from TBD. The 138 humans remains from the main horizon N.F.Pr. (Principal Fossiliferous Level) have been described and reanalysed by I. Crevecœur and colleagues (2016). The minimum number is 12 individuals, five adults, one adolescent, four children and two perinatals. The bones are fragmentary and diverse, not found in anatomic connection, yet given the good preservation state of neo- and perinatal bones, one may assume that they were not washed onto the shore, but perhaps intentionally deposited on the lake shore where they decomposed and eventually became embedded in the sediments. The Ishango human bones have always been puzzling since their discovery in 1950 and their initial description for being robust in cranial and mandibular characteristics. They exhibit more similarities with Middle and early Late Pleistocene fossils worldwide than they do to recent, chronologically and geographically closer modern human populations. From this perspective, the Ishango population corroborates genetic theories on the complex history of isolation and diversification of Late Pleistocene African populations where archaic characteristics continued in specific areas (Crevecœur et al., 2016, p. 53).

An assessment of mobility habits consisted of comparing the relative tibial rigidity of one Ishango hunter-gatherer-fisher to that of modern runners and swimmers, LSA southern African terrestrial hunter-gatherers or foragers, and an Andaman fisher-forager population (Crevecœur et al., 2016, p. 51-53, fig. 18). The Ishango individual aligns well with the latter population, who have marine mobility including moving around in canoes for transportation and for fishing activities. The Ishango relative tibial rigidity is quite different from that of the Late Stone Age southern African terrestrial foragers. This would point to reduced mobility. Though the fragmentary state of preservation of the Ishango human bones does not permit to evaluate whether this was a general feature of the entire active population or was restricted to this single individual, the aquatic mobility corresponds with the conclusions on exploitation of aquatic resources in fish remains and the bone harpoons and barbed points assumed to have been used in spearing and procuring fish. A subsistence strategy relying on aquatic resources must surely have been an asset in a rainforest where waterways can function as routes of dispersion and mobility. The human bones represent all age profiles of a population, and may have been intentionally deposited on the beach. Taken together with the ensured seasonal access to fish, a protein-rich resource, this might be indicative of logistical mobility or seasonal residential mobility where the group remained at least part of the year at the outlet of the Semliki river. Careful deposition of the dead may be considered as part of a way to claim specific and recurrent resources.

3.3 Indirect aDNA analysis from Holocene hunter-gatherers at Shum Laka

Apart from using modern DNA to reconstruct patterning in deep history including the TBD, aDNA reconstructions are now available from four individuals out of the 18 that were buried in two phases during the Holocene in the rock shelter of Shum Laka (Ribot et al., 2001; Lipson et al., 2020). The two funeral phases are dated to c. 8 ka cal. BP and c. 3 ka cal. BP (Lipson et al., 2020, table 1 and supplementary table 2). The 18 individuals were deposited in various ways: during the earlier phase, one adult was laid down in a horizontal position, two youngsters in a primary double inhumation and the fourth burial consists of a bundle of long bones. Of the double inhumation, one boy died at the age of 4 ± 1 years and the other was an adolescent male who died at an age of 15 ± 3 years old. These two individuals were sampled and their preservation allowed aDNA profiling. Grave goods are rare, consisting of a round stone in association with the two adolescents and 8 bone tools found in the bundle. The Late Holocene funeral phase concerns 14 individuals; two adjacent primary single burials of a boy 8 ± 2 years old and a girl of 4 ± 1 years old also provided insight in ancient DNA.

In fact, the early burial phase dated to 8000 cal. BP was hypothesized to represent hunter-gatherers as the material culture associated with layers below and immediately above the structures did not represent any break with the preceding 20,000 years of miniaturized quartz industry. The recent funerary phase on the other hand, dated to 3000 cal. BP followed the introduction of new technologies (Lavachery, 2001) such as the use of basalt and tuffs for a macrolithic industry containing prepared cores resulting in triangular flakes and blade production reminiscent of Middle Stone Age technology, and bifacially flaked "waisted" axes with sometimes traces of polish. Pottery made its modest introduction with grooved, thick walled sherds. Because of these changes in technology, the assumption was that the second phase may represent newcomers in the area or contact; perhaps physical remains of the Bantu-speaking populations that migrated from the north-northwest to the south sometime in the Mid Holocene (for link between Shum Laka and migration of Bantu-speaking populations, see Grollemund et al., 2015). However, in the skeletal and anatomical characteristics of the populations from the two phases, there were no determinant features that may have allowed their identification as nomadic hunter-gatherers or as sedentary food-producers (Ribot et al., 2001). Also, the site itself, a rock shelter, might have been used as a stop during hunting parties or as a ritual place by either of those groups. In an alternative hypothesis, populations of both funerary phases may have been hunter-gatherers and the Late Holocene hunter-gatherers would have integrated new technology from migrating groups. This "contact" is however difficult to recognize in the archaeological record that is too coarse-grained for making the distinction between occupation on a seasonal, annual, or generational scale by various groups present in the region. In a rock shelter with limited sedimentation in the upper part mixed with ashes, this scale becomes completely blurred.

Ancient DNA of the four Shum Laka individuals showed strong similarities in genetic material between the two burial phases despite the c. 5,000 years that separate them (Lipson et al., 2020). Within each phase, the two persons had family ties; second degree such as uncle and cousin or half-siblings for the two Late Holocene children, and fourth degree or cousins for the Mid Holocene youngsters. When their DNA is compared to aDNA from elsewhere in Africa and with that of people today, the people of Shum Laka are not related to groups currently living in western Cameroon, nor to present-day Bantu-speakers. Their genome-wide ancestry profiles are strongly related to present-day hunter-gatherers of Central Africa. From this perspective, the pattern of a widely distributed and genetically related population in deep history correlates to the common background and evenly wide distribution of microlithic and miniaturized quartz industries. This would underscore the ability and flexibility of this population to deal with various climatic and concomitant environmental changes.

There are very few comparative sites to the ritual funeral use of Shum Laka. Much further to the east, the mortuary practices at Gogoshiis rock shelter in southern Somalia (Brandt, 1988) have been interpreted in terms of increased logistical mobility. The group of hunter-gatherers stays in one place and special task forces move and return which implies more sedentarism, defended habitats leading to formal disposal areas of the dead as claim and control of critical resources especially where there is an increase in population density and more tension over available resources.

4. DISCUSSION AND CONCLUSION: AN ARCHAEOLOGICAL RECORD IN THE MAKING

Reconstructions of Holocene climate fluctuations (Maley et al., 2018) show the nature of possible impact on the equatorial forest. These can be used as a proxy for the poorly directly documented effect of TBD in Central Africa. Assuming that the prolonged drought at the end of the Pleistocene would have similar consequences, a dynamic scenario seems plausible in which the Late Pleistocene forest fragmented or contracted into refugia, in some areas changed in species composition, was conserved on higher altitudes or along rivers, and in yet other places was replaced by open vegetation. Traces of game from gallery forest on archaeological sites may indicate that the river network in the Congo basin did not dry out. This implies that communication remained feasible between various regions. At times with torrential massive landslides as documented in the east (Runge et al., 2014), the Central African basin might have been less hospitable and indeed hunter-gatherer communities would get isolated. Once the riverine network and the vegetation were re-established, communication may have resumed which would explain the general shared substrate of the Holocene hunter-gatherers of Shum Laka with Central African hunter-gatherers in the rainforest (Lipson et al., 2020). Today, they are dispersed over a large geographic area covered in forest and restricted to certain areas, yet this spatial configuration is surely the outcome of a dynamic history of contact, isolation and reconnection. Many scenarios are feasible to cope with environmental changes: a change in mobility patterns, a conservative reaction implying moving with the preferred and exploited environments, and if that environment were to disappear completely, disappear as well, or a highly adaptive strategy allowing to settle various environments; or leaving the area and thus disappearing from the archaeological record. As argued elsewhere (Cornelissen, 2016), the river network ensures access to fresh water as well as to stable food sources like fish. Aquatic capturing techniques had firmly integrated Late Pleistocene subsistence strategies at the eastern edge of the rain forest in the Semliki valley by 20 ka cal. BP together with seasonal logistical mobility and incipient territorial claims.

In this highly dynamic environmental setting, two broad stone technologies were practiced.

In the north-eastern part of the equatorial forest, microlithic or miniaturized quartz industries are of Late Pleistocene and of Holocene age. If large lanceolates and bifacially trimmed artefacts are to represent the Lupemban, the bifacial technocomplex remains undated here, out of secure stratigraphic position and absent from dated Late Pleistocene and Holocene sites. Taking this absence of evidence as highly circumstantial evidence of absence, the bifacial technology may be a much older substrate that was supplanted by the wide spread of miniaturized technology on quartz. Whether this shift in technology and in choice of raw materials results from population migrations or from technological transfers cannot be evaluated on the basis of the available data.

A slightly different picture emerges from the Late Pleistocene and Early Holocene archaeological sites at the south-western fringe of the Equatorial. The site of Ngongo Mbata proves how brittle and fragile the archaeological record is in Central Africa. Before the dating evidence that sets miniaturized quartz technology in the Early Holocene at Ngongo Mbata, this technology was hardly visible in the south-western region. What exactly the advantage or use was for quartz inserts remains an open question. Site integrity including environmental setting and exploitation is poor for the bifacial technology. A single Holocene occurrence of miniaturized quartz technology does not exclude nor confirm the introduction of a “new” technology to the area. Hence looking for an explanation for the co-occurrence of two broad technocomplexes in the southwestern part is premature. A technology that allows for the exploitation of quartz is nevertheless an asset because the mineral is so ubiquitous. The systematic radial reduction of small river cobbles resulting in small flakes with a large cortical proximal edge may be an excellent alternative to the more elaborate sequence of blade- and bladelet production, backed or blunted into standardized geometric inserts in composite tools. Miniaturized quartz exploitation may be a valid technological alternative also in areas where various lithic raw materials are available.

The archaeological, palaeo-environmental and human fossil record spanning the Late Pleistocene and Holocene in and at the margins of the equatorial forest in Central Africa remains under construction. Despite the disparate nature of the evidence, a dynamic deep history transpires and refutes an immutable and static past for its people and environments.

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NOTES

(1) All previously published C14 dates were calibrated using Oxcal v.4.4.2 C. Bronk Ramsey (2009) r.5: Atmospheric data from A. G. Hogg et al. (2020) according to SHCal20 and expressed as ca. ka or yrs cal. BP for readability.

(2) Author’s translation from M. Planquaert (1976, p. 26) : « En revanche, le choix presque exclusif d’une matière première aussi ingrate que le quartz paraît plus étonnant, surtout dans une région où les grès polymorphes abondent. Ce choix revêt certainement un caractère délibéré dont les motifs nous échappent actuellement. »

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