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Techno-economic behaviours during Middle Pleistocene: Valle Giumentina level ALB-42 (MIS 12b, Abbateggio, Central Italy)

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Abstract: The recent excavation of level ALB-42 of Valle Giumentina open air site (Italy) has yielded 407 lithic artefacts and some Red Deer bone fragments, showing anthropic marks. Lithic refits appear in this clayey-silty paleosol developed during an interstadial phase, assigned to MIS 12b (c. 450 ka) according to sedimentary studies and radiometric dating ($^{40}Ar/^{39}Ar$ and ESR-U/Th). Here we present taphonomic and spatial studies and a techno-economic approach including archeozoology, petrography, technology and use-wear analysis on artefacts. Good quality cherts were selected mainly from the immediate surroundings. They were brought into the site as small blocks or big flakes. Tool making or retouching are sometimes made on the spot. Tools are used for wood processing and butchery during brief but recurrent activities. A techno-morphological diversity of lithic products appears leading us to discuss intra- and extra- site diversity within the Lower Paleolithic of Italy and MIS 12 settlements in Europe.

Keywords: Middle Pleistocene, Lower Paleolithic, Acheulian, techno-economy, petrography, technology, sedimentology, taphonomy, MIS 12.

Résumé : La diversité typo-technique des industries lithiques du Paléolithique inférieur européen est avérée mais nul ne saurait encore l'expliquer en termes fonctionnels et techno-économiques. La rareté des sites, en particulier en période glaciaire, leur qualité de conservation variable et une faible résolution chronologique et paléoenvironnementale des occupations constituent un autre verrou majeur à la connaissance du peuplement humain au Pléistocène moyen.
Aussi avons-nous ouvert de nouvelles fenêtres stratigraphiques sur le site en plein air de Valle Giumentina, objet de fouilles dans les années 1950 par A.M. Radmilli. Situé dans le massif calcaire riche en silex de la Maiella (Abruzzes, Italie centrale), c'est un bassin d'1 km² désormais suspendu à 740 m d'altitude, empli de sédiments sur près de 45 m d'épaisseur en son centre. Une incision récente profonde de 25 m offre l'accès aux dépôts lacustres, palustres, glaciaires et aux paléosols interstratifiés contenant 11 niveaux archéologiques. Cette exceptionnelle séquence sédimentaire s'est mise en place entre les MIS 15 et 12, et les occupations humaines peuvent être datées entre 585 ka et 450 ka environ (Nicoud et al., 2016a ; Villa et al., 2016a, 2016b).
Une aire de 55 m² a été fouillée de 2012 à 2015 dans le niveau archéologique supérieur in situ nommé ALB-42. Cette couche d'argiles limoneuses brunes à structure prismatique comporte des sables calcaires et des graviers de silex, des fragments de verres volcaniques fortement altérés et des minéraux volcaniques épars, d'origine détritique. L'horizon pédologique est très homogène avec des traits de bioturbation et d'assèchements et gonflements des argiles. ALB-42 correspond à une phase climatique tempérée et humide pendant une période glaciaire, permettant le développement de ce sol mature à fortes caractéristiques hydromorphes. Une nouvelle datation exposée ici (454.5 ± 5.0 ka, méthode $^{40}Ar/^{39}Ar$), cohérente avec une datation ESR-U/Th sur dent de Cerf du même niveau archéologique, attribue ALB-42 au MIS 12. Les données sédimentologiques et paléoenvironnementales affinent cette attribution et le corrèlent à l'interstadiaire MIS 12b.
Quatre cent sept pièces lithiques sont apparues ainsi que 55 fragments d'os de Cerf dont certains présentent des traces anthropiques. 12 unités de remontages lithiques, bien circonscrites dans l'espace, regroupent un total de 52 pièces. Les surfaces souffrent peu d'altérations mécaniques. Un aspect brillant et une légère patine blanche sont présents sur la plupart des pièces, ce qui est cohérent avec un sol hydromorphe en milieu argileux. L'évaluation taphonomique atteste ainsi d'une cohérence de l'assemblage archéologique suffisante pour mener une étude techno-économique, fondée sur l'étude des chaînes opératoires de production lithique.

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L'étude pétrographique décrit notamment les deux grandes familles de silex de la Maiella qui constituent la quasi-totalité du mobilier, réparti en une quinzaine d'unité de matières premières (RMU). Des silex de très bonne qualité ont été sélectionnés dans un conglomérat voisin et apportés sur le site sous forme de petits blocs ou de gros éclats, voire d'outils finis, ne dépassant jamais 15 cm de long et pesant au maximum 800 g. Un stock de silex d'origine plus lointaine (Maiolica) est aussi importé sous forme d'éclats épais.

Le façonnage bifacial est absent. On compte 5 nucléus stricto sensu. Le débitage relève d'un même concept de taille exploitant un ou plusieurs sous-volumes du nucléus selon plusieurs méthodes sans préparation des surfaces et par percussion directe interne à la pierre dure. Parfois, un RMU montre une production récurrente d'un morphotype d'éclat et/ou de tranchant mais, en général, le débitage fournit un large panel de supports. Les éclats à dos sont rares. Une caractéristique majeure de la série est la présence d'éclats épais, dont la fonction est questionnable : outils et/ou nucléus ? Parfois, la présence d'une retouche régularise le tranchant de la pièce-outil mais les nucléus ne sauraient être ici les seuls pourvoyeurs des nombreux éclats. On compte 38 éclats retouchés. La retouche est toujours directe, mais les tranchants réalisés varient fortement dans leur délinéation ou leur angle. Typologiquement, les outils sont des racloirs latéraux, des denticulés, et une pièce porte un museau. La convergence de deux segments du tranchant peut créer une pointe robuste. 26 pièces portent des traces d'utilisation peu marquées, en raison d'un emploi sur des matériaux tendres et/ou une utilisation brève. Le travail du bois est aussi attesté (raclage).

Valle Giumentina ALB-42 apparaît comme un site occupé de manière récurrente pendant le MIS 12b et dédié à des activités spécifiques au sein d'un territoire. Des activités de boucherie ont pu être reconnues. L'image d'une présence pérenne des populations dans les environs du site émerge, renforcée par les nombreux niveaux d'occupation du site, aussi bien en période glaciaire qu'interglaciaire. Le site nous amène à nous interroger sur les éléments de continuité plutôt que de changements, en particulier techno-économiques, au cours des 135 000 ans enregistrés dans la séquence. ALB-42 présente une industrie originale dans le panorama du Paléolithique inférieur italien peut-être liée à un contexte pétrographique caractérisé par une matière première abondante et de qualité. Des comparaisons sont menées avec cinq sites européens attribués au MIS 12, dont les contextes sont précisés ici, sans que des ressemblances typo-techniques n'apparaissent clairement. Toutefois, l'utilisation de matières premières locales est la norme tout comme l'absence de préparation des nucléus. Les outils retouchés ou non, sont de morphologie très variée.

Pour être affinée, notre connaissance des sociétés du Paléolithique inférieur requiert aujourd'hui une multiplication de données issues de sites dont la datation peut être précisée par un croisement d'indices jusqu'au sous-stade isotopique, et la cohérence des vestiges, avérée par l'analyse taphonomique. Quatre autres niveaux bien préservés ont été fouillés récemment à Valle Giumentina (du MIS 13b au MIS 12b). Ils viendront abonder cette accumulation nécessaire.

Mots-clés : Pléistocène moyen, Paléolithique inférieur, Acheuléen, technologie, techno-économie, pétrographie, sédimentologie, taphonomie, MIS 12.

INTRODUCTION: LOWER PALAEOLITHIC SOCIETIES BEYOND THE ARTEFACTS

Lower Palaeolithic studies show us two crucial points. Firstly, we are unable to give the reasons behind the typo-technical diversity of the Middle Pleistocene lithic industries. Since the 19th century, unsatisfying cultural groups are defined according to the presence or absence of a typological entity whose definition is ambiguous: bifaces, pebble tools, large flakes or small tools. The technological combinations within the lithic series are multiples. Some productions result only from *façonnage* (bifacial shaping) and others only from *débitage* (flaking), some can be mixed and others contain small accurately selected raw blanks, or cleavers and other heavy tools (e.g. Boëda, 1997, 2013; Lhomme, 2007; Rocca *et al.*, 2016). Functional analyses of tools are rare, mainly because of the poor state of preservation of these ancient artifacts. Spatial analyses and techno-economic observations are limited when post-depositional processes destroy the integrity of the site. Moreover, lithic industries are often the only archaeological remains recovered, which complicates the palaeo-ethnological interpretation of the occupation level.

Secondly, Lower Palaeolithic in Europe mainly occurs during the Middle Pleistocene, between MIS 16 and MIS 9. The scarcity of archaeological sites during this 400 000 years-long period is a major problem to discuss intercontinental human population diffusions (e.g. Rightmire, 2001; Rocca & Bodin 2010; Chevrier, 2012; Nicoud, 2013b; Tourloukis et Harvati, 2017; Rocca *et al*., 2020). Reliable stratigraphic, climatic and environmental data are only occasional and not regularly distributed on the Ancient World both in space and in time. Occurrences are rare during glacial periods. Obtaining reliable dating is a challenge and a major issue for Quaternary studies. Besides, well-preserved Lower Palaeolithic settlements with only weak post-depositional events are even harder to find.

We argue here that for now, any cultural definition of Lower Palaeolithic societies, settlements dynamics and diffusion patterns must be based on the accumulation of more reliable Early and Middle Pleistocene sites, as well as a broader knowledge of human behaviour, beyond lithic typo-technology. What activities took place at the site? How were the landscapes managed?

In keeping with these questions, we opened in 2012 a new trench at the open-air site of Valle Giumentina in the Abruzzo region in Central Italy to obtain a reliable chronostratigraphic context for the artefacts discovered during the 1950's excavation led by A.M. Radmilli and

J. Demangeot (Demangeot et Radmilli, 1953; fig. 1). We reached our first goal after five full years of fieldworks and laboratory multidisciplinary studies. We also opened an excavation area of 55 m² in the well-preserved silty-clayey and upper archaeological layer "ALB-42" assigned to MIS 12 (Villa *et al.*, 2016a; Degeai *et al.*, 2018). In this paper, we combine geological and sedimentological data, techno-functional, petrographic and spatial analysis. We present an evaluation of taphonomic processes to ensure the reliability of the archaeological assemblage. We then discuss the site function, the territory awareness and the technological position of these lithic industries within the whole site, Italy and Western European Lower Palaeolithic complex during MIS 12. Preliminary results obtained on half of the lithic series have been published earlier (Nicoud *et al.*, 2016b). They focused on techno-functional data. Here we complete the data and reach some techno-economic information that help us understanding the diversity of the lithic production and take a further step towards the people who produced it.

VALLE GIUMENTINA MIDDLE PLEISTOCENE ARCHAEOLOGICAL SITE, ABRUZZO, ITALY (MIS 15-12)

History of research and new fieldworks at Valle Giumentina

The Middle Pleistocene site of Valle Giumentina (Abbateggio, Abruzzo, Italy) has been known since the first excavations led in 1953-54 by the Italian archaeologist A.M. Radmilli in collaboration with the French geologist J. Demangeot (Demangeot and Radmilli, 1966). It is an open-air site located in the calcareous Maiella mountain massif, east of the Apennines ridge, on the Adriatic side of Italy (fig. 1). It is now a hanging valley with a quite flat surface at 740 m asl, 1 km² wide, filled up by 45 m of Quaternary deposits in its center (Villa *et al.,* 2021a; fig. 2). These deposits are mainly made of lake or marsh sediments, paleosols, fluvial sands and fluvio-glacial deposits. Several tephra deposited inside the basin during the infilling. A recent cutting affects the distal part of the basin, exposing the 25 m-thick upper part of the sedimentary succession. A.M. Radmilli (1982) discovered nine archaeological levels he assigned to Acheulian and Clactonian cultures because of the presence of handaxes in one level, located in the middle of the archaeological sequence (level SLM-37). The majority of levels contains flakes of large dimensions produced by *débitage.* The absence of similar industry in Italy led A.M. Radmilli to search for comparisons in England and to create an "Evolved Clactonian of Valle Giumentina facies" (Radmilli, 1965). At this time the discussion about the contemporaneity of Clactonian and Acheulian facies is central (since Breuil, 1932; for development see Ashton *et al.* dir., 1998) and the Alpine chronology is then the main reference. So, according to both geology and artefacts, a Rissian age is assigned to these layers.

In 2012, we opened an excavation slightly north of the A.M. Radmilli locus which has been eroded. Our new data result from sedimentary and paleonvironnmental studies as well as $^{40}Ar/^{39}Ar$ and ESR/U-series dating (fig. 2). They give a more precise climatic and chronological frame for the sedimentary succession that recorded 2,5 glacial-interglacial cycles, correlated with the onset of MIS 15 until MIS 12 (from about 610 ka to 450 ka). Human settlements are preserved both during interglacial and glacial periods. These results have been published earlier. In addition to stratigraphic, sedimentary and micromorphological descriptions, they include geophysical investigations, geochemical analysis of paleosols, as well as molluscan fauna, micromammals and pollens studies (Nicoud *et al.*, 2016b; Villa *et al.*, 2015; Villa *et al.*, 2016a, 2016b; Villa, 2017; Villa *et al.,* 2021b; Limondin-Lozouet *et al.*, 2017; Pereira, 2017; Degeai *et al.*, 2018). A summary of the stratigraphy is given below.

We excavated layer ALB-42 from 2012 to 2015 and then, we have been going on into the underlying levels (see ALB-42 excavation annual report in the École française de Rome « Chroniques »: Nicoud *et al.*, 2013, 2014, 2015, 2016a). Thirteen archaeological levels have been identified, 5 of them have been excavated on 50 m² to 30 m² areas. The extension of the excavation area is progressively reduced going deeper, to maintain safety levels. These areas are small windows into the archaeological layers that extend over a large part of the basin.

Chronostratigraphic setting of Valle Giumentina

The long stratigraphic sequence of Valle Giumentina is divided into five litho-pedostratigraphic units labelled EN 5 to 1 (EN for *Ensemble*) from the bottom to the top based on the sedimentological and pedological characteristics of the deposits (fig. 2). These five main sedimentary units are further subdivided in 40 stratigraphic layers (Villa *et al.*, 2016a). Our observations are based on a 45 m-deep borehole (VG1) and a 17 m-long cross section called VV1 as well as geophysical trenches. The numbers "42, 40…" refer to the 1950's excavation while the letters "ALB, LABM" refer to our new description. ALB is for *Argiles Limoneuses Brunes* (i.e. Dark Silty Clay). When a stratigraphic correlation is established between our new excavation and the sequence described by Demangeot and Radmilli (1953), we use the double naming like in ALB-42.

Unit 5 consists of a thick fluvial gravel layer that overlies directly the Miocene limestone bedrock (Bolognano Formation; Vezzani et Ghisetti, 1998). It is the most ancient part of the Quaternary infilling of the Valle Giumentina basin. According to the $^{40}Ar/^{39}Ar$ dating of a volcanic ashes layer identified at its top (615 ± 5 ka), Unit 5 was formed between the end of MIS 16 and the beginning of MIS 15.

Unit 4 includes mostly clayey and silty sediments suggesting a marginal lacustrine/swamp environment, affected by repeated fluctuations of the water table and

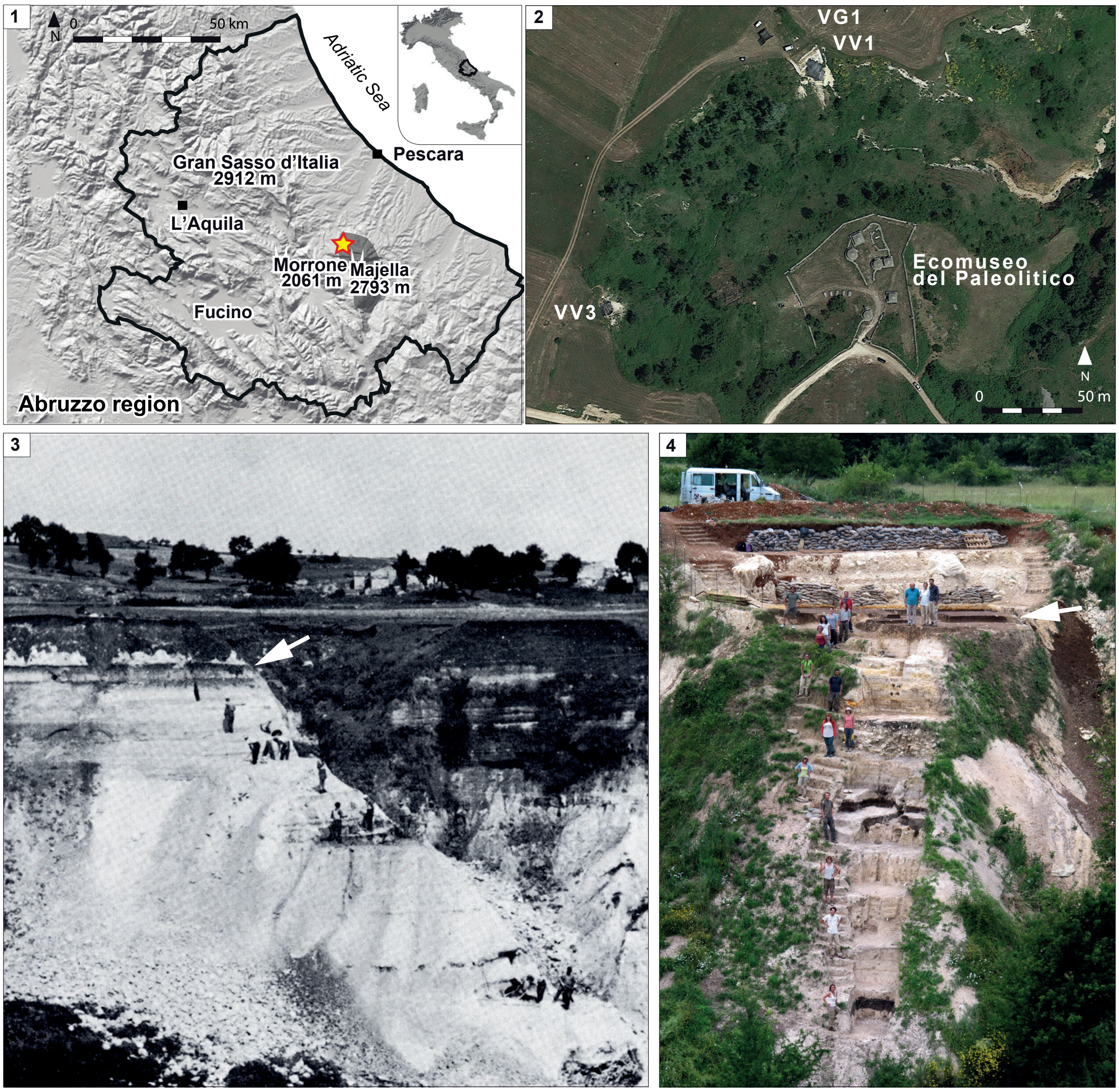


Fig. 1 – Location and pictures of Valle Giumentina Middle Pleistocene site: **1**, the site is in the north-western side of the Maiella mountain in the Abruzzo region (yellow star); **2**, location of 2012-2019 excavations (locus VV1, VV3) and borehole (VG1) on a satellite view. A 100 m wide ravine separates the excavation of locus VV1 from the "Ecomuseo del Paleolitico", a small museum made of traditional dry-stone huts; **3**, picture of the 1953-54 excavation led by A. M. Radmilli (unknown author); **4**, picture of the 17 m thick VV1 stratigraphic section in 2014. Level ALB-42 is the upper dark and silty-clayey layer marked by a white arrow (pictures: **2**, Google Earth; **3**, Radmilli, 1965; **4**, E. Nicoud/EFR).

Fig. 1 *– Localisation et clichés du site du Pléistocène moyen de Valle Giumentina :* ***1****, le gisement est au nord-ouest du massif de la Maiella dans la région des Abruzzes ;* ***2****, emplacement des fouilles 2012-2019 (locus VV1, VV3) et du carottage (VG1) sur vue satellitaire. Un ravin large de 100 m sépare la fouille du locus VV1 de l'Ecomusée du Paléolithique, établi dans des cabanes en pierre sèches traditionnelles ;* ***3****, photographie anonyme des fouilles des années 1953-54 menées par A. M. Radmilli ;* ***4****, photographie de 2014 de la coupe stratigraphique puissante de 17 m. Le niveau ALB-42 correspond à la couche de limons et argiles marron foncé en partie supérieure, signalée par une flèche blanche (clichés :* ***2****, Google Earth ;* ***3****, Radmilli, 1965 ;* ***4****, E. Nicoud/EFR).*

pedogenic processes. Several phases of higher sedimentation are recorded, probably related to the shrinkage of the vegetation caused by climate degradation. $^{40}Ar/^{39}Ar$ dates indicate that Unit 4 formed during the first half of MIS 15, a period characterized by rapid cold/warm climatic oscillation in the Mediterranean area (Pierre *et al.*, 1999; Girone *et al.*, 2013).

In the following phase, Unit 3 recorded the gradual transition from lacustrine to marshy environments. It includes fine organic sediments typical of a marshy environment. Sedimentological and pollen data indicate that the upper part of Unit 3 was deposited during a period of strong climate cooling: intense detrital input from the basin catchment and pollen assemblages depict an open

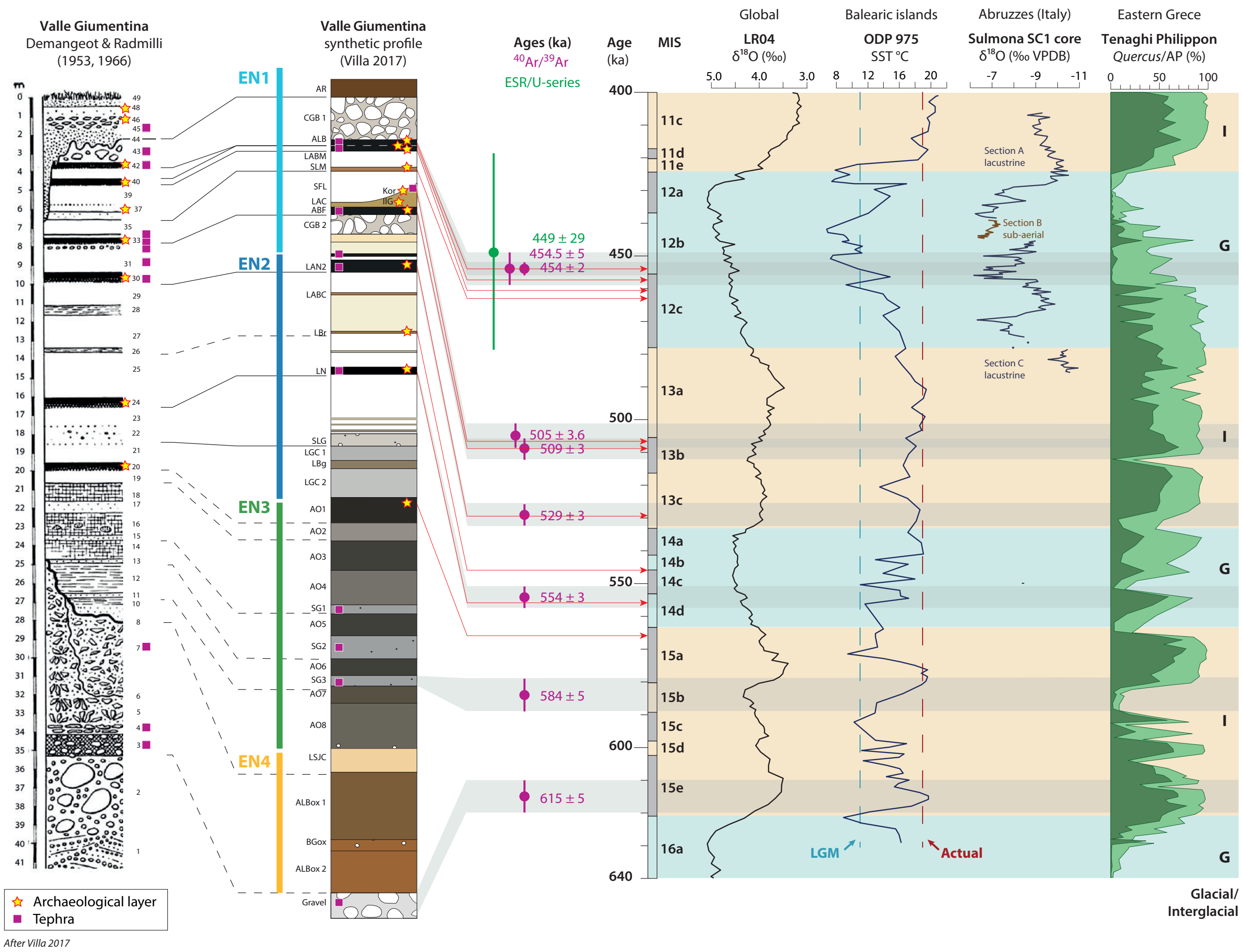


Fig. 2 – Chronostratigraphical setting of Valle Giumentina (according to Villa, 2017). Correlations between the synthetic stratigraphic sequence of Valle Giumentina and the sedimentary sequence described by Demangeot and Radmilli (1953, 1966) in the 1950s. The sedimentary succession is correlated with the marine isotopic stages (MIS) chronology, the benthic δ18O LR04 stack (Lisiecki et Raymo, 2005), the Mediterranean Sea Surface Temperatures (SST) record from the ODP 975 Site (Pierre *et al.*, 1999; Girone *et al.*, 2013), the Sulmona SC1 δ18O record (Regattieri *et al.*, 2016) and the Tenaghi Philippon pollen sequence (Tzedakis *et al.*, 2006) according to the sedimentological and palaeoevironmental data and the 40Ar/39Ar and ESR-U seriesdates from both VG1 and VV1 sequences (Villa *et al.*, 2016a; Pereira, 2017; Degeai *et al.*, 2018; Villa *et al.*, 2021b; Bahain *et al.*, 2021). Red arrows indicate the correlation of archaeological levels with these climatic records.

Fig. 2 – *Cadre chronostratigraphique de Valle Giumentina (d'après Villa, 2017). Corrélations entre la séquence sédimentaire synthétique de Valle Giumentina et celle étudiée par J. Demangeot et A. M. Radmilli (1953, 1966). La séquence de Valle Giumentina est corrélée à la chronologie isotopique marine (MIS), à la courbe du stack benthique LR04 (Lisiecki et Raymo, 2005), à la courbe des températures de surface de la mer Méditerranée (SST) issue du site ODP 975 (Pierre* et al.*, 1999 ; Girone* et al.*, 2013), à l'enregistrement isotopique de la carotte SC1 de Sulmona (Regattieri* et al.*, 2016) et à la séquence pollinique de Tenaghi Philippon (Tzedakis* et al.*, 2006) grâce aux données sédimentologiques et paléoenvironnementales et aux datations 40Ar/39Ar et ESR-U/Th provenant des séquences VG1 et VV1 (Villa* et al.*, 2016a ; Pereira, 2017 ; Degeai* et al.*, 2018 ; Villa* et al.*, 2021b; Bahain* et al.*, 2021). Les flèches rouges indiquent les corrélations des niveaux archéologiques avec les enregistrements climatiques.*

steppe landscape with scattered population of conifers. This environmental and climatic evolution took place during the MIS 15-MIS 14 interglacial-glacial transition, according to the $^{40}Ar/^{39}Ar$ date of 584 ± 5 ka obtained on one tephra layer interbedded with the organic clayey deposits of Unit 3 (SG3 layer).

The clastic input observed in the upper part of Unit 3 continues in Unit 2. Here, detrital deposits are interlayered with fine calcareous sediments, which indicate the presence of a shallow lake. At least three thick tephra layers deposited during the formation of Unit 2. In the VV1 profile, located in the marginal zone of the basin, these tephra are strongly altered and led to the formation of soils with andic properties. Mollusc fauna from the VV1 profile attest an evolutionary trend from open vegetation, typical of cold and dry climatic conditions, to the spread of closed and humid habitats representative of a temperate climate (Limondin-Lozouet *et al.*, 2017). $^{40}Ar/^{39}Ar$ dating performed on two tephra layers (554 ± 3 ka on LN layer and 529 ± 3 ka on LAN2 layer), correlate the formation of Unit 2 with MIS 14 and MIS 13.

The uppermost sedimentary unit of the Valle Giumentina sequence, Unit 1, is mainly composed of detrital calcareous and pedogenized colluvial deposits interlayered with several paleosoils, one of which is ALB-42. Malacological assemblages of Unit 1 are characteristic of open and dry environment and suggest a phase of cold and dry climate. The $^{40}Ar/^{39}Ar$ dating obtained for three tephra layers from Unit 1 (layers ABF-33, LABM-40 and the new date from ALB-42 presented in this study), correlate its formation with the period between MIS 13b and MIS 12 (509 ± 3 ka, 454 ± 2 ka and 454.5 ± 5 ka respectively; fig. 2). These chronological data are consistent with the results of the ESR/U-series dating carried out on a mandible of Cervidae collected in ALB-42 (449 ± 29 ka; Bahain *et al.*, 2021).

Hence, the sedimentary history of the Valle Giumentina succession is constrained to the MIS 15-MIS 12 interval, between ~620 and ~450 ka. During or slightly after MIS 12, a tributary stream of the San Bartolomeo canyon captured the Valle Giumentina basin. This event is part of a wide-scale process, recorded in the whole Central Apennines area, controlled by the regional tectonic uplift of the Apennines chain (D'Agostino *et al.*, 2001; Pizzi, 2003). Thus, the sedimentary sequence ends with a polycyclic paleosol developed on red sandy-clayey colluvium deposits, which developed at least from MIS 11 onwards (layer AR).

Cherts petrography in the Maiella mountain range and its surroundings

Cherts availabilities in Central Italy have been object of several recent studies (Serradimigni, 2013; Cancellieri, 2015; Bertola, 2016). These studies mainly focus on the high-quality raw materials lying in the Jurassic-Eocene sequence including primarily the Scaglia Rossa and Maiolica. These raw materials deposited into deep oceanic environments and are essentially characterized by radiolarian (Maiolica) and planktonic foraminifera (Scaglia). While no study provides a precise mapping of these cherts, occurrences can be expected circa 40 km to the west and north-west of Valle Giumentina.

Valle Giumentina is located in a younger geological context, the Maiella Mountain, with outcrops from the Upper Jurassic to the Miocene. Several siliceous materials are identified in these formations but no exhaustive surveys have been already conducted. We did a first characterization of local raw materials variability by analyzing some blocks from two detrital deposits of the site called AR and CGB1 (fig. 1 and 2). These layers are younger than the archaeological ALB-42 level (fig. 2) and so, cannot be considered as potential sources for prehistoric groups. Yet, they offer an illustration of raw materials that can be locally transported in conglomeratic formations. We completed this first sampling with chert from the Tortonian-Burdigalian formations (M4-21) available in the San Bartolomeo canyon 200 m far from the site. The calcareous M4-21 formation is present even more closely around the site but no chert has been identified in this area up to now (fig. 3). Samples are kept in the MPALP referential collection held at the CEPAM laboratory (Nice, France).

We identified two chert families. MPALP#123 is originating from the Tortonian-Burdigalian (M4-2 or San Bartolomeo Formation). It has been sampled both in a nearby limestone rock wall of San Bartolomeo Canyon (123A) and within the colluvial deposits (123B) forming the top of Valle Giumentina infilling (AR layer; fig. 3). It has a massive structure (fig. 4, nos 1-2, 4-5). The clasts reach proportion of circa 30-40 % and are well-sorted (200-500 µm). Coloration varies from grey to brown. Dominant clasts are non-identifiable and consist in elongated sticks (200-500 µm) that can represent proportions over 20-30%. Determinable clasts never represent proportion over 5% and consist in spicules (notably tetraxones, ca. 500 µm) and often foraminifera with a trochospiraled test and globular to ovate chambers (ca. 200 µm). We also identified foraminifera with uniseriated test and globular chambers and foraminifera with a trochospiraled test and triangular chambers. Red and black grains (ca. 1-10 µm) can be discerned but not determinate at this scale of observation. Cherts sampled in primary position (123A) appear richest in undeterminable clasts and spicules. By contrast, cherts sampled in secondary position in the colluvial deposits (123B) show less sticks and spicules and much more foraminifera. These differences could result from the evolution of the same type, but it must be noticed that uniseriated foraminifera and black tubular clasts are only identified in the facies 123B. Macroscopically the facies 123B is more translucent.

The second family of cherts, MPALP#124 (O-PC or Decontra formation), has only been sampled in secondary position in stratum AR. These cherts also have a massive structure (fig. 4, nos 7-8). Dominant coloration is grey. Bioclast can represent proportions over 50% and are poorly sorted. Dominant bioclasts are discoidal foraminifera with trapezoidal chambers (Nummulitidae). They reach dimensions up to 5 mm. They are associated with millimetric discoidal foraminifera with rectangular chambers (Lepidorbitoidae). All foraminifera present the same orientation. Spicules are also present (tetraxone, up to 100 µm) but remain rarest (1-5%) as well as rare trochospiraled foraminifera with globular chambers (ca. 200 µm); uniseriated foraminifera with ovate chambers (up to 1 mm) and biseriated foraminifera (ca. 500 µm). These cherts could originate from the O-PC formation according to their description in the geological map. Further prospections are needed to confirm this hypothesis.

According to the geological map, two other local formations provide cherts: the calcarenite of the Aptian-Upper Jurassic (C4-G11) and the calcilutite of the Lower Senonian (C10-8) but they are not documented until now.

METHODS AND CORPUS

Stratigraphy and micromorphology

We performed sedimentological and geochemical analyses on ALB layer (laser grain-size, magnetic susceptibility, total organic carbon, $CaCO_3$ content and ed-

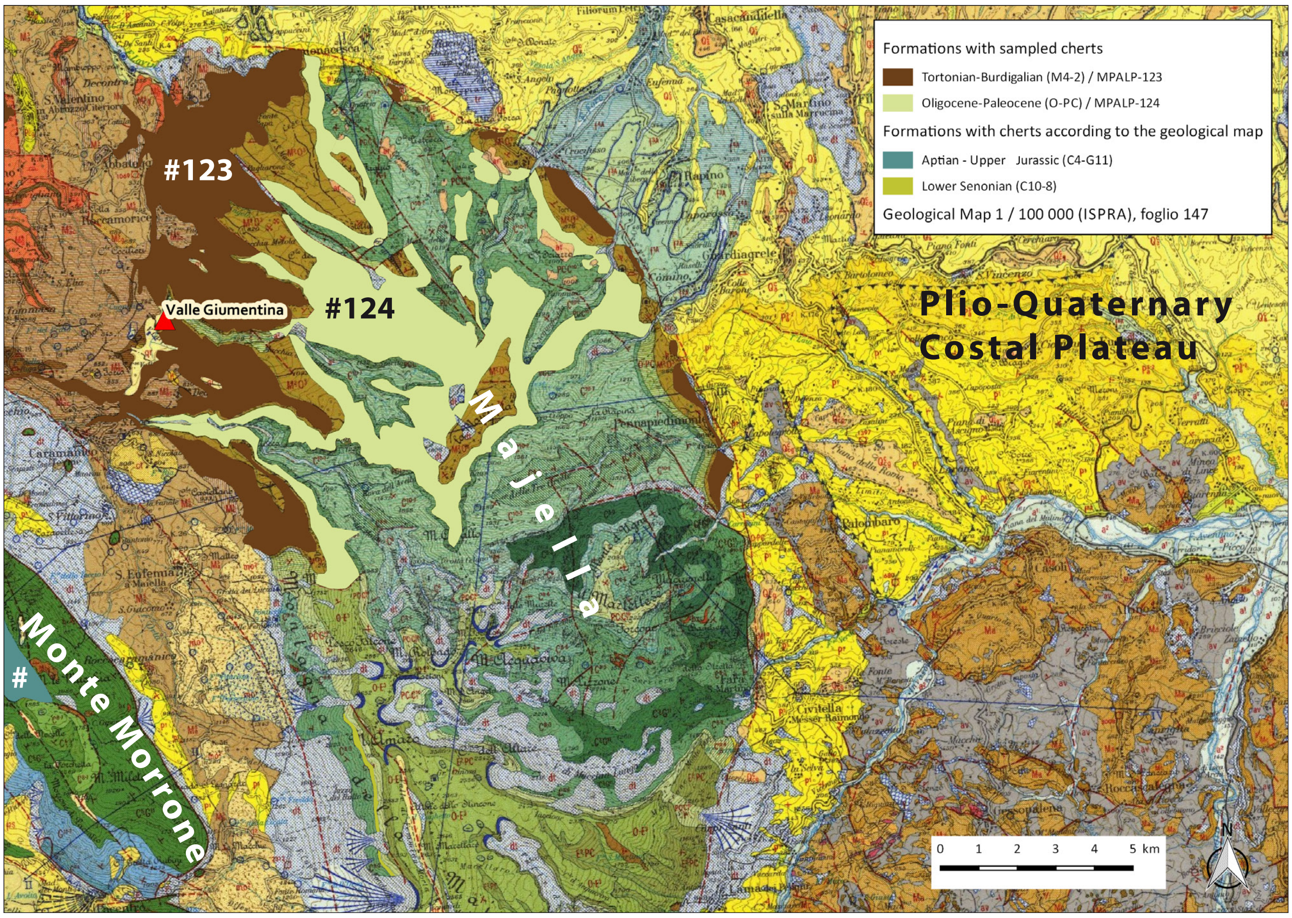


Fig. 3 – Excerpt of the Geological map of the Maiella mountain range and its surroundings showing the distribution of local chert formations and the location of Valle Giumentina (Servizio geologico d'Italia 1:25 000 No. 147 Lanciano, modified).

***Fig. 3 –** Extrait de la carte géologique du massif de la Maiella et de ses environs montrant la distribution des formations locales de chert et la localisation de la Valle Giumentina (Servizio geologico d'Italia 1:25 000 nº 147 Lanciano, modifié).*

XRF spectrometry measures; Villa, 2017; Degeai *et al.*, 2018). Moreover, 3 undisturbed blocks of sediments were collected from the VV1 profile for thin sections (about 6 x 9 cm in size). Samples were oven dried and impregnated under vacuum with polyester resin. Thin sections were observed under plane-polarized light (PPL) and cross-polarized light (XPL) using a standard Leica DM petrographic microscope. The descriptions follow the guidelines established by Bullock *et al.* (1985) and Stoops (2003).

$^{40}Ar/^{39}Ar$ dating

In addition to previous dating made along the whole sequence (Villa *et al.*, 2016a; Pereira, 2017; Degeai *et al.*, 2018; Villa *et al.*, 2021b; Bahain *et al.*, 2021), an $^{40}Ar/^{39}Ar$ dating for level ALB-42 layer has been done at the Laboratoire des Sciences du Climat et de l'Environnement, at Gif-sur-Yvette, France. In this layer, we did not identify a discrete tephra level (as in the underlying LABM layer), but rather reworked volcanic glass fragments and minerals. The sample was prepared following the procedure described in Villa *et al.* (2016). After crushing, sieving and cleaning within distilled water, at least 50 pristine and unaltered potassic feldspars, ranging in size between 630 µm and 500 µm, were handpicked and leached with a 7% HF acid solution for about 5 min to remove the particles aggregated on the surface of the crystals. About 30 crystals were then loaded in an aluminum disk and were irradiated for 45 min (IRR 119) in the β1 tube of the Osiris reactor (CEA, Saclay, France). After irradiation, 15 crystals were individually loaded in a copper sample holder that was then put into a double vacuum Cleartran window. Each crystal was fused using a 25W Synrad CO_2 laser at about 10–15% nominal power. The extracted gases were then purified for 10 min by two hot GP 110 getters (ZrAl). Argon isotopes (^{36}Ar, ^{37}Ar, ^{38}Ar, ^{39}Ar, ^{40}Ar) were analysed using a VG5400 mass spectrometer equipped with a Balzers 217 SEV SEN electron multiplier coupled to an ion counter. The full analytical protocol can be found in Nomade *et al.* (2010). Neutron fluence J was calculated using co-irradiated Alder Creek sanidine (ACs-2) standard with an age of 1.194 Ma ($J_{ALB\text{-}m101} = 0.0003510 \pm 0.00000176$; Nomade *et al.,* 2005) and the total decay constant of Steiger and Jaeger (1977). In this study the age is recalculated using the most recent optimization calibration of Niespolo *et al.* (2017) suggesting an age of 1.1891 Ma for ACs related to the total K decay constant of Renne *et al.* (2011). All other ages already obtained have been recalculated with this calibration, which explains

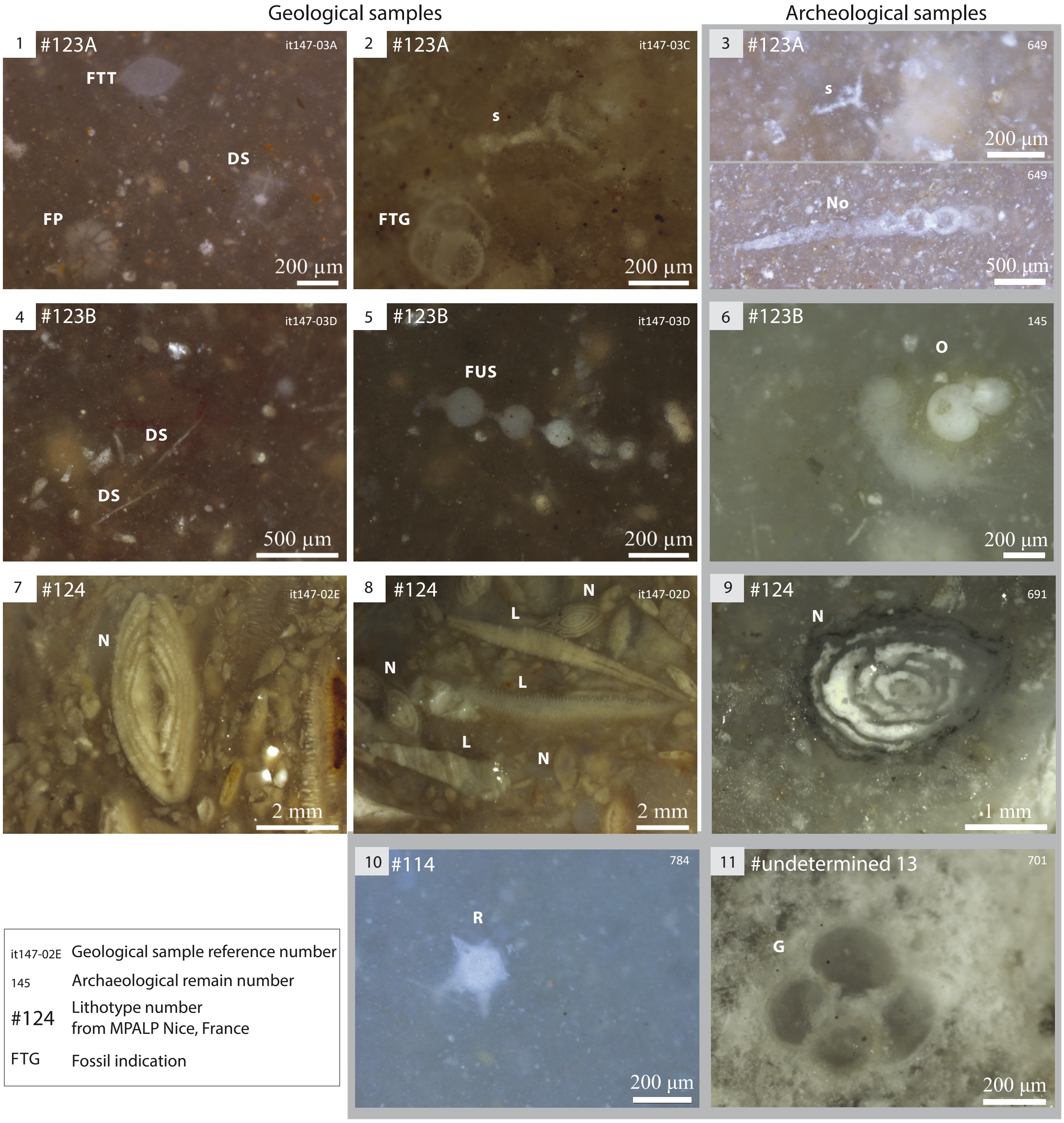


Fig. 4 – Description and pictures of the cherts lithotypes identified in geological and archaeological samples from Valle Giumentina (stereomicroscope, reflected light) : **1**, FTT: Foraminifera, trochospiraled test with trapezoids chambers; FP: Foraminifera planispiraled test; DS: Deteriorated spicule; **2**, FTG: Foraminifera, trochospiraled test with globular chambers; S: Spicule; **3**, No: Nodosoria; S: Spicule; **4**, DS: Deteriorated spicules remains identifiable; **5**, FUS: Foraminifera, uniseriated test with spherical chambers; **6**, O: Orbulinae; **7**, N: Nummulitidae; **8**, L: Lepidorbitoidae; N: Nummilitidae; **9**, N: Nummulitidae; **10**, #114 refers to the Maiolica chert, not available in the Maiella moutain; R: Radiolaria; **11**, G: Globigerinidae (pictures : A. Tomasso, CAD: E. Nicoud).

Fig. 4 – *Description et photographies des lithotypes identifiés à Valle Giumentina parmi des échantillons géologiques et archéologiques (stéréomicroscope, lumière réfléchie) :* ***1****, FTT : Foraminifère à test trochospiralé avec chambres trapézoïdales ; FP : Foraminifère à test planispiralé ; DS : Spicules détériorées ;* ***2****, FTG : Foraminifère à test trochospiralé avec chambres globulaires; S : Spicule ;* ***3****, No : Nodosoria; S : Spicule ;* ***4****, DS : Spicules détériorées identifiables ;* ***5****, FUS : Foraminifère à test unisérié avec chambres sphériques ;* ***6****, O : Orbulinae ;* ***7****, N : Nummulitidae ;* ***8****, L : Lepidorbitoidae; N : Nummilitidae ;* ***9****, N : Nummulitidae ;* ***10****, #114 correspond au type Maiolica qui n'est pas disponible dans la Maiella ; R : Radiolaria ;* ***11****, G : Globigerinidae. (clichés : A. Tomasso, DAO : E. Nicoud).*

the small differences between the dates in this publication and those previously published. Peak intensity data are reduced using ArArCALC V2.4 (Koppers, 2002). Procedural blank measurements were performed after every three unknown samples. Mass discrimination correction was monitored by measurements of air argon of various beam sizes and is calculated relative to a $^{40}Ar/^{36}Ar$ ratio of 298.56 (Lee *et al.*, 2006).

Techno-economic analysis: principles

In order to understand how prehistoric groups structure their activities within a territory, we apply a techno-economic approach (Geneste, 1991). It relies on Lithic Technology and the *chaîne opératoire* concept (Leroi-Gourhan, 1945; Tixier *et al.*, 2012; Soressi et Geneste, 2011). We first consider the raw materials in order to identify the different sources exploited and to delimit the supply territory. Raw materials offer us a key to divide the archaeological series into several raw materials units (RMU). The RMU approach, born in the 1980' and applied in recent years in various chrono-cultural contexts, allows us to analyze and quantify the raw material introduced in a site through a space-time perspective (e.g. Roebroeks, 1988; Binder, 1998; Vaquero, 2008; Chacón *et al.*, 2015; Marciani *et al.*, 2016; Aureli *et al.*, 2016; Machado *et al.*, 2019; Vaissié *et al.*, 2021). We then identify the different *chaînes opératoires* and we describe their technology (technique, methods and concepts). For each RMU we try to identify the stage of introduction of raw materials into the site (blocks, cores, flakes, retouched or functional tools, etc.). We then look for any reduction sequence carried out inside the site (flaking, retouching). We also look for the function and use of the tools (use-wear and residues analysis). Finally, we study the discard or export modality associated with each RMU. Although this last aspect is the most difficult to study because it is based only on negative evidence, some tools that have been reshaped before export can be identified by retouch wastes (Porraz, 2008).

This exhaustive approach to the lithic series documents the activities carried out on the site, the mobility of human groups and their knowledge of resources within a territory. We can also discuss which tools are made and used during Lower Paleolithic, at least in this particular archaeological layer. Thus, this techno-economic study combines petroarchaeology, technology and use-wear analyses. An evaluation of post-sedimentary phenomena (taphonomy) including a spatial analysis can be considered a preamble.

Petro-archaeological approach

Petro-archeological methods must respect a specific prerequisite of the archaeological problematics: one need not only to determine a sample, but the whole assemblage. We consequently conduct analyses according to a multiscalar approach combining three levels of observation. First, we use mesoscopic observations (i.e. stereomicroscope, magnifications ×40 to ×200) on all archaeological and petrographic pieces. Then, we go for microscopic observations (i.e. thin section observed with a petrographic microscope at magnifications ×50 to ×100 LED-polarized light) for a representative selection of geological samples and when needed for problematic archaeological cases. When necessary, we also do "ultra-microscopic" observations using various methods (MEB-EDS, geochemical analyses…) to address specific problems (Fernandes, 2012; Tomasso *et al.*, 2019). These observations are usually sufficient to determine the original geological formation.

Nevertheless, various sources could relate to the same formation, either in primary or secondary position. Because cherts are evolving during their stay in various deposits, a systematic sampling on each deposit position is needed to identify some distinctive criteria (Fernandes, 2012). In the meantime, semi-quantitative methods on paleo-geographical markers can provide insights of the intraformation variation (Tomasso *et al.*, 2019).

In this first analysis on Valle Giumentina raw materials we reached the first level of determination. The mesoscopic observations basically rely on the description of the structure (i.e. the organization of the different phases in the material), the texture (the proportion between detrital and new formed component of the material) and the characteristic of the detrital components (nature, size and sorting, repartition, orientation and state of preservation).

All the artefacts of the assemblage are studied independently from their size or nature. We primarily divided the collection into several homogeneous raw material units (RMU). A RMU is defined by the perfect concordance of all characteristics for a set of artefacts. That means that every piece of one RMU could originate from the same block. Thereafter RMU are precisely described and compared with geological references in order to determine their origin. Here, we essentially try to recognize within the archaeological series the local and well-known raw materials and to look for the presence of other raw materials without determine their precise origin.

Lithic technology and techno-morphological analysis

Once the lithic remains are sorted by RMU or wider groups, a technological study can be done in order to understand how stone tools are produced (Inizan *et al.*, 1995; Boëda, 1991, 2013). We identify flaking technique (gesture, hammer), methods (chronology, recurrence and organization of removals) and concepts (common structures of cores and tools). Refits are very helpful there. We expect to find the usual debitage systems for the European Lower Paleolithic, characterized by a lack of preparation of the core and an alternating of the flaking platforms, as in the so-called Clactonian, orthogonal or SSDA-s*ystème par surface de debitage alternée* methods (e.g. Ashton *et al.,* 1992; Forestier, 1993) as well as the use of preexisting dihedrals and convexities to ensure the continuity of the debitage usually done in short unipolar series.

This technological reading is deployed on the tools with an attention to the last manufacturing step. It consists in describing the blank volume, surfaces and edges and the impact of retouch on these characteristics. So we defined the morphology and the features of the cutting-edge in order to identify different techno-functional units (*UTF* in French, Lepot, 1993 ; Boëda, 1997). A UTF is defined as a set of technical elements (cutting edge delineation, angles, surfaces morphology, volume characteristics), which represent a specific and coherent technological trait on one or different parts of a tool (Boëda 1997 ; 2001). These technical elements can exist on the blank, after the debitage, or can be created by retouch. Therefore, a UTF is one part of a tool built and used for a particular purpose: it can be the active part in contact with the worked material such as a cutting or a scraping edge, or the grasping part, for the prehension of the tool.

Traceology, functional analysis and residues analysis (FTIR)

A traceologic and a functional analysis complete the study of the entire lithic industry of the level ALB-42 (n = 407). To assess their degree of preservation, every artefact was observed to document mechanical and chemical alterations detectable at a macroscopic level (weathering, fractures, edge-damages, colour patina, glossy appearance and white patina). This observation was then refined at a microscopic level on a selection of items to better define the nature of the taphonomic processes.

The whole lithic series was observed through a stereomicroscope equipped with a reflected light system to detect macro-traces of use (edge-rounding, edge-removals). 143 artefacts whether they are retouched or not, showing potentially functional morphology and/or eventual macro-traces of use were selected and submitted to a more accurate analysis. To allow the optimal observation of use-wear traces, all these items have been preventively washed with bi-distilled water and soap in an ultrasonic tank for 10 minutes, then rinsed with bi-distilled water in the ultrasonic tank for 5 minutes. On 26 artefacts, the analysis integrates the Low- and the High-Power approach to observe, describe and interpretate macro- and micro-traces (polishes, striations, abrasions; Marreiros *et al.*, 2015) related to the action carried out and the worked material.

The interpretation of the traces of use is based on the reference collection of the LTFAPA laboratory (Rome, Sapienza University). An Optical Light Microscope (OLM) equipment is used to observe the macro- and the micro-traces: stereomicroscope Nikon STZ (oculars 10X and objectives 0,5X and 1X, magnification range 0,75X-7,5X), metallographic microscope Nikon Eclipse (oculars 10X, objectives 10X, 20X, 50X) as well as a digital camera Toupcam.

Before the washing procedure, a sample of 16 items has been randomly chosen within the 143 selected items to test the presence of possible residues of use applying the InfraRed technique (FTIR; Veall and Mateson, 2014). The aim of this study was to understand if such ancient remains found in clayey soil could still wear fatty residues. The infrared spectra were collected with a Bruker Optic Alpha-R portable interferometer with an external reflectance head covering a circular area of about 5 mm in diameter. The investigated spectral range is 7500-375 cm^{-1} with a resolution of 4 cm^{-1}. Each artefact was submitted to measurements on their internal surface and on their edges without preliminary treatments.

So, when use wear traces have been both observed, described and illustrated, we mention the results including when determinable, the material that has been worked as well as the gesture used for it.

A FOCUS ON ALB-42 LAYER: SOIL FORMATION, ENVIRONMENT, CHRONOLOGY, REMAINS AND TAPHONOMY

Stratigraphic position of ALB-42 within Unit 1

The ALB layer is located in the upper part of the Valle Giumentina sedimentary sequence, within Unit EN1. This unit includes coarse detrital layers (CGB2, CGB1 and AR) that frame a succession of fluvio-lacustrine silty-clayey deposits and several paleosols. Soil horizons present varying characteristics, linked to the parent material on which they developed and/or related to their maturity. The lower soil (ABF-33) which rests on the layer of gravel and CGB2 blocks is an evolved andic soil with accentuated hydromorphic characteristics. Immediately above the ABF soil, inside the LAC-34 layer, a soil horizon shows traces of bioturbation and illuviation. Going up along the sequence, the SLM-37 layer corresponds to a poorly mature soil, characterized by discrete bioturbation and alteration features, developed on fluvio-lacustrine and aeolian calcareous deposits. The upper paleosols LABM-40 and ALB-42 also develop on the same type of carbonate detrital material. LABM-40 has a marked hydromorphic character, indicated by the presence of numerous redoximorphic features. A tephra is present at the base of this pedologic horizon. This primary volcanoclastic deposit identified in the VG1 core is present as a partially reworked cryptotephra in the VV1 section. It is dated to 454 ± 2 ka by $^{40}Ar/^{39}Ar$ method. An erosion surface exists between the LABM-40 and ALB-42 layers, highlighted in section VV1 by a layer of calcareous gravels (“Stone Bed” LdP-41 level). Indeed, here the upper part of LABM-40 has been eroded, as well as the layer of intermediate white silt (LB) that is clearly identified in the 1950’s section and more discreetly in section VV1 (fig. 1 and 2). ALB-42 is sealed by the diamicton CGB1 that also eroded its upper part (fig. 5, No. 6).

Sedimentary and micromorphological observations

The ALB-42 layer consists of an abundant reddish brown unsorted silty-clay, showing a well-developed angular prismatic structure (fig. 5). The thickness of the layer varies from 30 cm in the VV1 and VV3 sections to approximately 50 cm in the western limit of the archaeological excavation. Indeed, removing the CGB1 layer to create the excavation platform at the ALB level caused the VV1 section to move back about 1.5 m to the west. The progress of the archaeological excavation has

Fig. 5 – Pictures of the ongoing excavations in layer ALB-42 at Valle Giumentina (2013-2015) and thin sections of the paleosol: **1**-**2**, a plastic sheet prevents the clayey sediments from drying; **3**-**4**, lithic artefacts lying vertically; **5**, hemi-mandibula of *Cervus elaphus*; **6**, detail of the erosional contact between CGB1 (white) and ALB (brown). The polygonal structure is well expressed when the sediment dries up; **7**, in thin section we can observe the clay matrix and the rare sand-sized limestone and flint grains (Plain Polarized Light, PPL); **8**, same picture than 7 in XPL (Crossed Polarized Light) showing the cross-striated b-fabric characterizing ALB. White dotted lines high-lights elongated parallel and crossed striations with simultaneous interference colours; **9**, typical ferro-manganic oxides nodule (yellow arrow: PPL); **10**, same picture than 9 in XPL showing the grano-striated b-fabric of the micromass. Striations are parallel and crossed (white dotted lines) and are also arranged around the coarse elements e.g. around the ferro-manganic nodule (yellow arrow) and around some detrital sandy grains (white arrows) (pictures : E. Nicoud/EFR).

***Fig. 5 –** Photographies des fouilles en cours du niveau ALB-42 de Valle Giumentina (2013-2015) et lames minces du paléosol : **1-2**, une bâche plastique empêche l'argile de sécher ; **3-4**, artefacts lithiques en position verticale ; **5**, hémi-mandibule de* Cervus elaphus *; **6**, détail du contact érosif entre CGB1 (blanc) et ALB (marron). La structure polygonale est bien exprimée lorsque le sédiment s'assèche ; **7**, en lame mince, on observe la matrice argileuse et les rares éléments grossiers, des grains de calcaire et de silex de la taille des sables (photo prise en lumière polarisée non analysée, PPL) ; **8**, même image que la 7 prise en lumière polarisée analysée (XPL) montrant la biréfringence entrecroisée qui caractérise la couche ALB. Les lignes pointillées blanches indiquent les stries parallèles et entrecroisées aux couleurs d'interférence simultanées ; **9**, nodule ferro-manganique typique (flèche jaune ; PPL) ; **10**, même image que 9, prise en XPL, montrant la biréfringence granostriée de la masse fine. Les stries sont parallèles et entrecroisées (lignes pointillées blanches) et se disposent également autour des éléments grossier e.g. autour du nodule ferro-manganique (flèche jaune) et autour des grains de sable détritiques (flèches blanches) (clichés : E. Nicoud/EFR).*

therefore brought to light a new section, oriented north-south, parallel to VV1. All these operations allowed a better observation of the deposits and of their geometry compared to the beginning of our researches. Indeed, the archaeological excavation is located near the margin of the Valle Giumentina basin, where the layers that form its infilling rise up to the edges and narrow. Therefore, as they move from west to east, from the edges to the centre of the basin, the sedimentary layers gradually widen and their reading is easier. The ALB soil horizon appears very homogeneous here, there is no distinction between subunits or secondary horizons. The prismatic structure is very well expressed over about 25 cm, then gradually fades towards the base of the layer. The transition to the underlying white LB silt layer is progressive over a thickness of about 25 cm.

The observation of the thin sections reveals that the coarse sandy fraction of the sediment is made of limestone and flint gravel, some volcanic minerals and highly altered volcanic glass fragments. Bone and molluscan shell fragments are also present. The relative distribution of the coarse and fine fraction varies along the layer, gradually passing from close porphyric to open porphyric from the base to the top. In thin sections, the clay matrix shows vertic features, including planar voids and various striated b-fabric and glossy coatings (slickensides) on the aggregates surface (fig. 5, Nos 7-8). The soil has a well-expressed polyhedral structure and is characterized by numerous biological voids, including channels and chambers. Bioturbation features, such as fine humified organic fragments, loose continuous and crescent infillings and some rhizoliths, are visible throughout the layer. Illuviation pedofeatures are very frequent: opaque clayey coatings and hypo-coatings and complex calcite and clay coatings are observed. There are also many redoximorphic features, including impregnative and concentric nodules of iron and manganese oxides (fig. 5, nos 9-10). The detrital nature of the sediment that forms the parent material of the soil is confirmed by the presence of some inherited clay nodules ("*papulae*" in Brewer, 1964) and fragments of clay coatings.

The vertic processes affecting the ALB-42 paleosol surely influenced the conservation of the archaeological remains contained within this layer. The repeated swelling and drying of the clays that make up its matrix caused the formation of fairly large cracks, materialized by slickensides and still visible today during the archaeological excavation. The occurrence of this cracks caused the displacement of some lithic pieces, which can find themselves in a vertical position (fig. 5, nos 3 and 4).

New ^{40}Ar/^{39}Ar dating

Nine crystals are individually analyzed (fig. 6 ; supplementary). The related probability diagram is almost unimodal. Only one xenocryst is evidenced and dated around 675 ka. The main crystal population is thus composed of eight crystals and allowed to calculate a robust weighted mean age of 454.5 ± 5.0 ka (2σ analytical

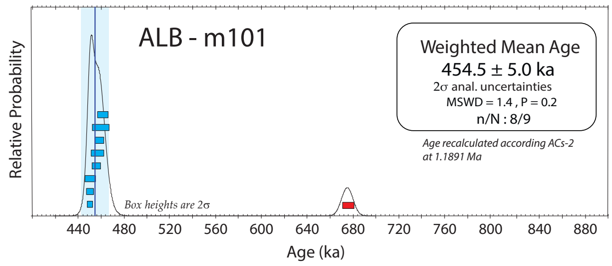


Fig. 6 – ^{40}Ar/^{39}Ar dating of cryptotephra identified in layer ALB-42 of Valle Giumentina (sample m101). Probability age diagram obtained.

***Fig. 6** – Datation ^{40}Ar/^{39}Ar du cryptotephra identifié dans la couche ALB-42 à Valle Giumentina (échantillon m101). Diagramme de probabilité obtenu.*

uncertainties, J-value included) (MSWD = 1.4 and P = 0.2). The ^{40}Ar/^{36}Ar initial ratio given by the inverse isochron diagram (299.5 ± 6.0) is equivalent within uncertainties to the atmospheric one of 298.56, suggesting the absence of argon excess in these dated crystals. The age calculated corresponds chronologically to the Pozzolane Rosse eruption originated from the Colli Albani volcanic complex (dated to 455.5 ± 2.0 ka ; Giaccio *et al.,* 2013).

ALB-42: a MIS 12b settlement

Given its position within the Valle Giumentina stratigraphic sequence and its pedologic characteristics, the ALB-42 paleosol corresponds to a temperate and humid climatic phase during a glacial period. Both the detrital and aeolian sediments on which the soil develops and the layer of fluvio-glacial origin that covers it indicate extremely cold and arid climatic conditions. The climatic improvement has been sufficiently long and/or the conditions sufficiently temperate and humid to allow the development of this mature soil with strong hydromorphic features.

The ^{40}Ar/^{39}Ar dates due to the homogeneity of the ages calculated for almost all the dated crystals, confirms the primary nature of the volcanic minerals imbedded in the paleosoil. This uniformity of the data confirms the almost contemporaneous formation of the soil with the volcanic eruption dated. The eruption chronologically fits the Pozzolane Rosse of the Colli Albani volcanic system also found in the neighboring Sulmona sedimentary basin (Regattieri *et al.*, 2016) and dated to 455.5 ± 2 ka (Giaccio *et al.*, 2013). These dating allow us to correlate the soil formation to the middle part of MIS 12, and more especially to the MIS12b (Lisiecki and Raymo, 2005). During this time interval, the global record LR04 shows a gradual climatic deterioration, with rapid oscillations of very small magnitude (fig. 2). The Mediterranean and Italian records, on the other hand, are far more contrasted, with abrupt and much larger variations. They indeed reflect more local climatic changes. The ODP 975 sea surface temperature curve (Pierre *et al.*, 1999; Girone *et al.*, 2013) records two phases of temperature increase separated by a short period of cooling. The two

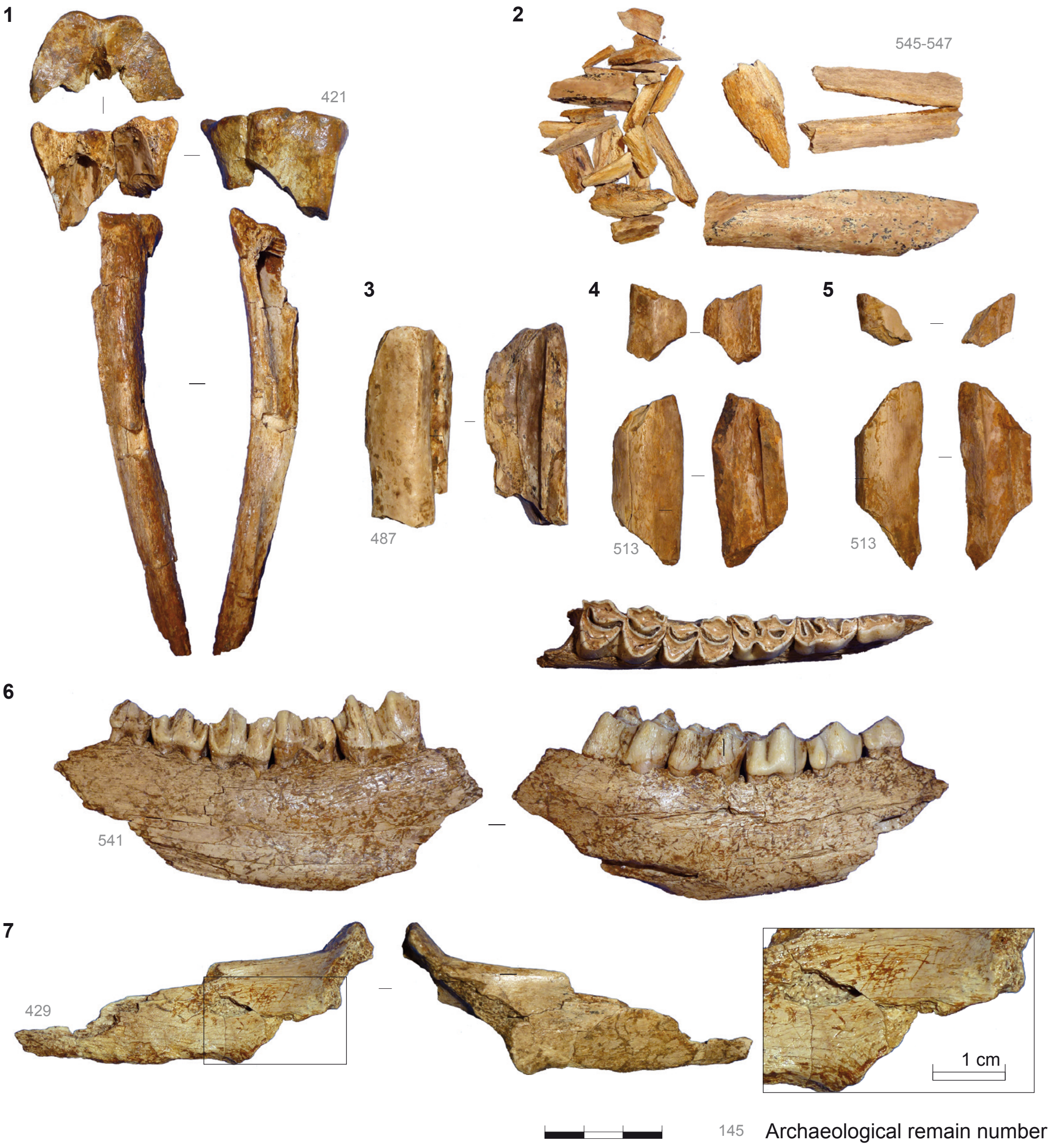


Fig. 7 – Bones fragments of a *Cervus elaphus* from level ALB-42 of Valle Giumentina: **1**, fragments of a humerus; **2**, bones fragments from a sedimentary block excavated in laboratory; **3**-**5**, fragments of shafts; **6**, right mandible of a 3 years old Red Deer; **7**, thoracic vertebral spine with cut marks (pictures: E. Nicoud/EFR).

***Fig. 7** – Restes osseux de* Cervus elaphus *provenant du niveau ALB-42 de Valle Giumentina : **1**, fragments d'un humérus ; **2**, fragments provenant d'un bloc sédimentaire excavé en laboratoire ; **3**-**5**, fragments de diaphyses ; **6**, mandibule droite d'un Cerf de 3 ans ; **7**, épine vertébrale thoracique avec des marques de découpe (clichés : E. Nicoud/EFR).*

LABM-40 and ALB-42 paleosols could have developed during these two warmer periods while the deposition of the white silty layer evidenced in the VV3 and in the 1950's sections (layer 41) and the formation of an erosion surface in section VV1 could correspond to the cooling phase in between these warmer periods (fig. 1 and 2). Isotopic data from the Sulmona basin (fig. 2) also indicate high instability at this period, with rapid alternating wet and dry phases (Regattieri *et al.*, 2016). Their chronology, which is very precise thanks to the tephra layers identified and dated in the Sulmona paleolake sequence, coincides exactly with the dates obtained for LABM-40 and ALB-42 layers. The correlation with the Tenaghi Philippon pollen record (Tzedakis *et al.*, 2006) is less certain, due to a less precise chronological setting. However, it can be hypothesized that the interstadial period that allowed the formation of the ALB palaeosol corresponds to one of the forest expansion and *Quercus* increase phases recorded between 455 and 440 ka.

The ESR/U-series date obtained from a mandible of Cervidae is coherent with this interpretation despite the wide associated error range (449 ± 29 ka; Bahain *et al.*, 2021). Based on stratigraphic, paleoenvironmental and geochronological data, ALB-42 soil is hence assigned to MIS 12b.

Faunal remains

Fifty-five bones and tooth fragments have been discovered in level ALB-42, most of them are small fragments (fig. 7). Ten remains have been determined. They all come from a *Cervus elaphus* (Red Deer), likely from

Valle Giumentina ALB-42				MPALP #124					MPALP #123							#114			Undetermined			SR?	
	Total	Lime-stone	All cherts	«Decontra» Oligocene Paleocene					«San Bartolomeo» Tortonian Burdigalian							«Maiolica» Upper Jurassic			supposed Majella origin			Scaglia rossa?	undes-cribed
									group 123A					123B									
RMU >>>				1	2	3	9	other	4	5	6	7	other	8	other	10	11	other	12	13	other	14	/
Untransformed blanks	366	2	364	4	18	9	7	39	4	1	5	33	33	11	15	6	11	14	28	38	51	3	34
Flakes or fragments	326	0	326	4	18	9	7	33	4	0	5	32	25	10	14	6	11	13	24	36	43	3	26
of which small flakes < 1 cm²	193	0	193	1	2	0	1	32	1	0	2	10	23	0	12	2	6	12	8	13	42	3	23
Core	4	0	4	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	1	0	0	0
Raw Block	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Casson	36	0	36	0	0	0	0	6	0	0	0	0	8	0	1	0	0	1	4	1	7	0	8
Retouched blanks	39	1	38	4	4	2	1	0	2	0	5	3	0	2	1	1	1	0	2	10	1	0	1
Flakes or fragments	37	0	37	4	4	2	1	0	2	0	5	3	0	3	1	0	1	0	2	10	1	0	1
of which small flakes < 1 cm²	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Core	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Percussor	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total				8	22	11	8	39	6	1	10	36	33	13	16	7	12	14					
									86					29									
	407	3	404	88					115							33			30	48	52	3	35

Table 1 – Raw material assignments of the lithic artefacts from level ALB-42 of Valle Giumentina. Most of the material comes from the local Maiella Mountain (#123 and 124). “Other” refers to some artefacts that have been assigned to a group but not to a specific RMU. RMU 12 and 13 may come from the Maiella.

***Tabl. 1 –** Classement des artefacts lithiques par matières premières du niveau ALB-42 de Valle Giumentina. La plupart du mobilier provient de la Maiella (MPALP #123 et 124). « Autre » fait référence à certains artefacts assignés à un groupe mais pas à un RMU spécifique. Les RMU 12 et 13 semblent provenir de la Maiella.*

the same individual as shown by two refits of a metacarpal (right and left cannon bones). *Cervus elaphus* lives in forest environments with a rather mild and humid climate. However, the species may have existed in a relict state under much harsher conditions (Gonzalez et Pépin, 1996). Its presence here is therefore consistent with the sedimentary observations.

The wear stages of the cheek teeth of a right mandible indicate an adult over 3 years old (fig. 7, nº 6). Scarce human-derived modifications are observed. They include percussion flaking (fig. 7, nos 3-5) but also striae and chopping evidence, on a thoracic vertebral spine (fig. 7, nº 7). On this latter remain, the caudal articular surfaces have been chopped off by a blow oblique to the axis of the spinal process. On the right-hand side, the specimen shows a set of parallel striae, oriented obliquely at the chopping plane. The spinal process is also weathered. Its apex is broken off and the fracture patterns suggest dry bone fracture. The right face of the specimen, altered by the striae, is also affected by weak weathering, whereas the cranial articular surfaces appear strongly weathered. In contrast to its right side, the left side of the specimen is not weathered, but altered by humic corrosion and root etching. These lines of evidence indicate that this remain is defleshed by humans and dumped, and then laid on the substratum with its right-hand side exposed for a while before its final burial (after P. Mazza and M.A. Rossi in Nicoud *et al.*, 2016a).

Main technological features, refit groups and map of the lithic and fauna remains

The 407 lithic artefacts (mostly flakes) and 55 bones fragments (mainly small-undetermined fragments) were discovered during the 2013-15 excavations. Either large and small flakes or fragments are present in the 55 m² excavation area (table 1). Twelve refit groups occur, including two to nine artefacts, for a total of 52 pieces (e.g. fig. 10, nos 4-7). An altitudinal projection of the remains shows a slight inclination towards the geographical north. The remains appear between 734.08 and 734.43 m asl on the entire surface, in a strip no more than 25 cm thick (average of 10 cm) in the upper part of the level, where the prismatic structure of the soil is most developed.

Both lithic and faunal material are distributed unequally on the excavation area and there is no real accumulation (fig. 8). In squares L, M, N/12, 13, 14 a higher number of remains occurs. Almost all the faunal material is concentrated in this area (fig. 9, no 1). Other concentrations only contain lithic remains. In an isolated area corresponding to square I9, lithic remains are extremely concentrated, forming a *débitage* cluster. Dispersion of refitting groups is generally low (fig. 8) whereas one refit group links two of these areas (group E, made of two flakes). Retouched flakes are equally distributed within the lithic remains (fig 9, no 3). Twenty-six remains show use-wear traces. Wood and meat processing seem to appear within the same area and hide processing in another (fig. 9, no 4).

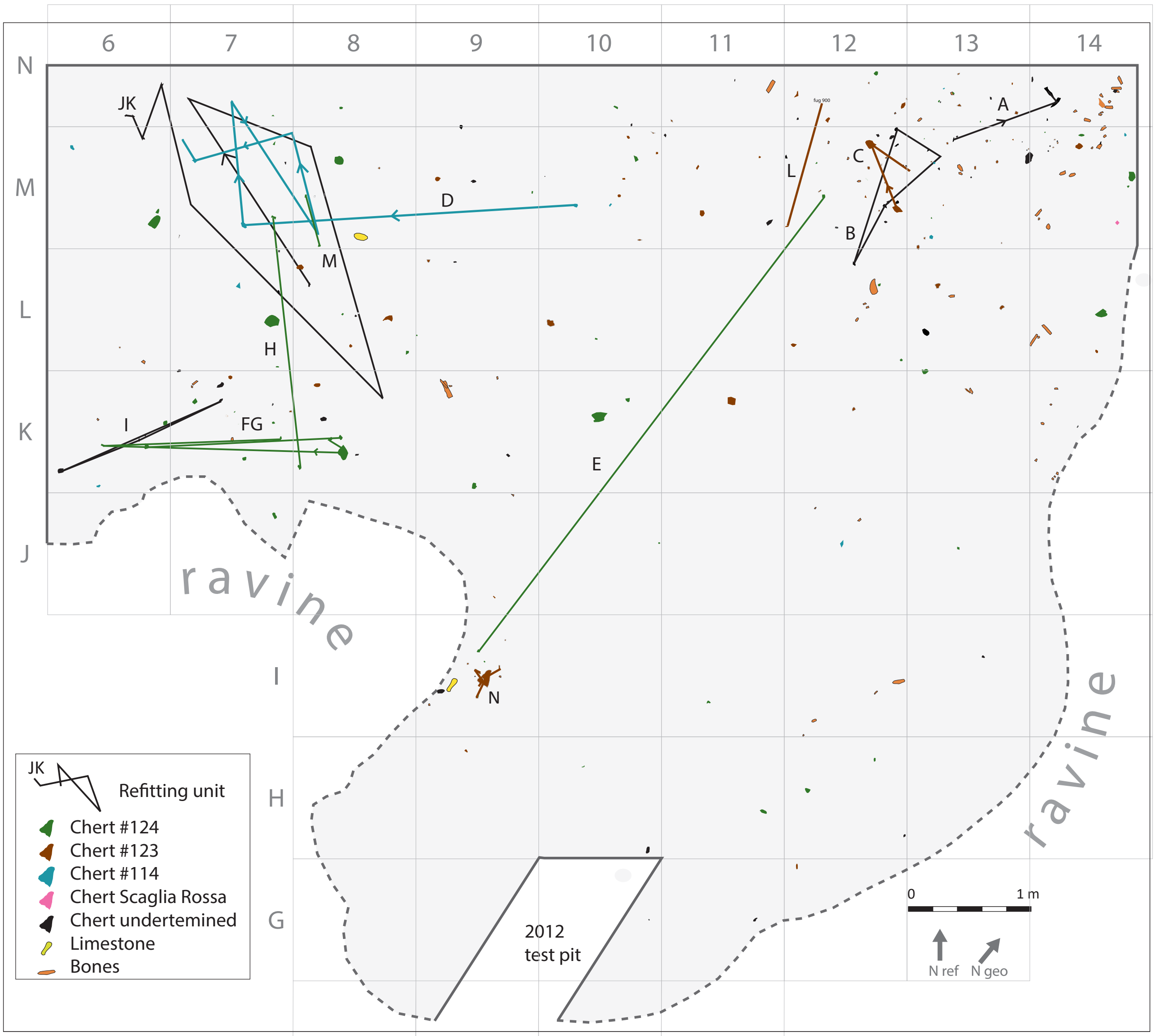


Fig. 8 – Map of remains and refit groups of layer ALB-42 of Valle Giumentina site. *Cervus elaphus* bones fragments mainly appear in the northern part of the excavation area (CAD: E. Nicoud/EFR).

***Fig. 8 –** Plan des vestiges et des unités de remontages de la couche ALB-42 du site de Valle Giumentina. Les fragments d'os de* Cervus elaphus *ont été trouvés principalement au nord de l'aire de fouille (DAO : E. Nicoud/EFR).*

State of preservation of the lithic series

The general macroscopic overview of the entire assemblage shows the rarity of edge damage resulting from trampling or compression of sediments like scars and notches. In addition, no rolled objects are detected. Most often, surfaces show a diffuse brightness with different degrees of intensity, called glossy patina (Rottländer, 1975; Fiers, 2020). The glossy patina develops by dissolution and re-precipitation of the silica on the surface of the chert. Controlled laboratory experiments have replicated the white patina process on cherts placed in an acidic environment (Stapert, 1976; Fiers, 2020). More rarely, a bluish/white patina may also appear. According to the same references on the subject, this patina is due to a dissolution of the surface of the chert which increases its porosity. Its formation has been reproduced experimentally in an alkaline environment. The bluish aspect is the initial phase of the patina process.

Microscopic observation of the surface of 143 objects selected for a use-wear analysis confirms the presence of the glossy appearance on 55 pieces (38%) and of the white patina on 30 pieces (21%); only 7 pieces (5%) show edge-damages due to mechanical alteration. Small removals typical of thermal stress are visible on two items (1.5%). The remaining 49 items (34%) have a well-preserved surface, except for a slight brightness suggesting the beginning of a glossy appearance alteration. Both the glossy and the white patina modify the micro-surface of the objects and may compromise the detection of micro-wear (fig. 10, nos 1 and 2). A cratered surface is sometimes highlighted. It is due to the dissolution of the chert: the surface structure disintegrates creating localized collapses. It occurs rarely here, but when it does, objects are affected by moderate collapse. The dissolution process can be combined with abrasion by fine sediment particles. This mechanical process, known as soil sheen, is attested by the slight scratching of the surface at the origin of the oriented polishes

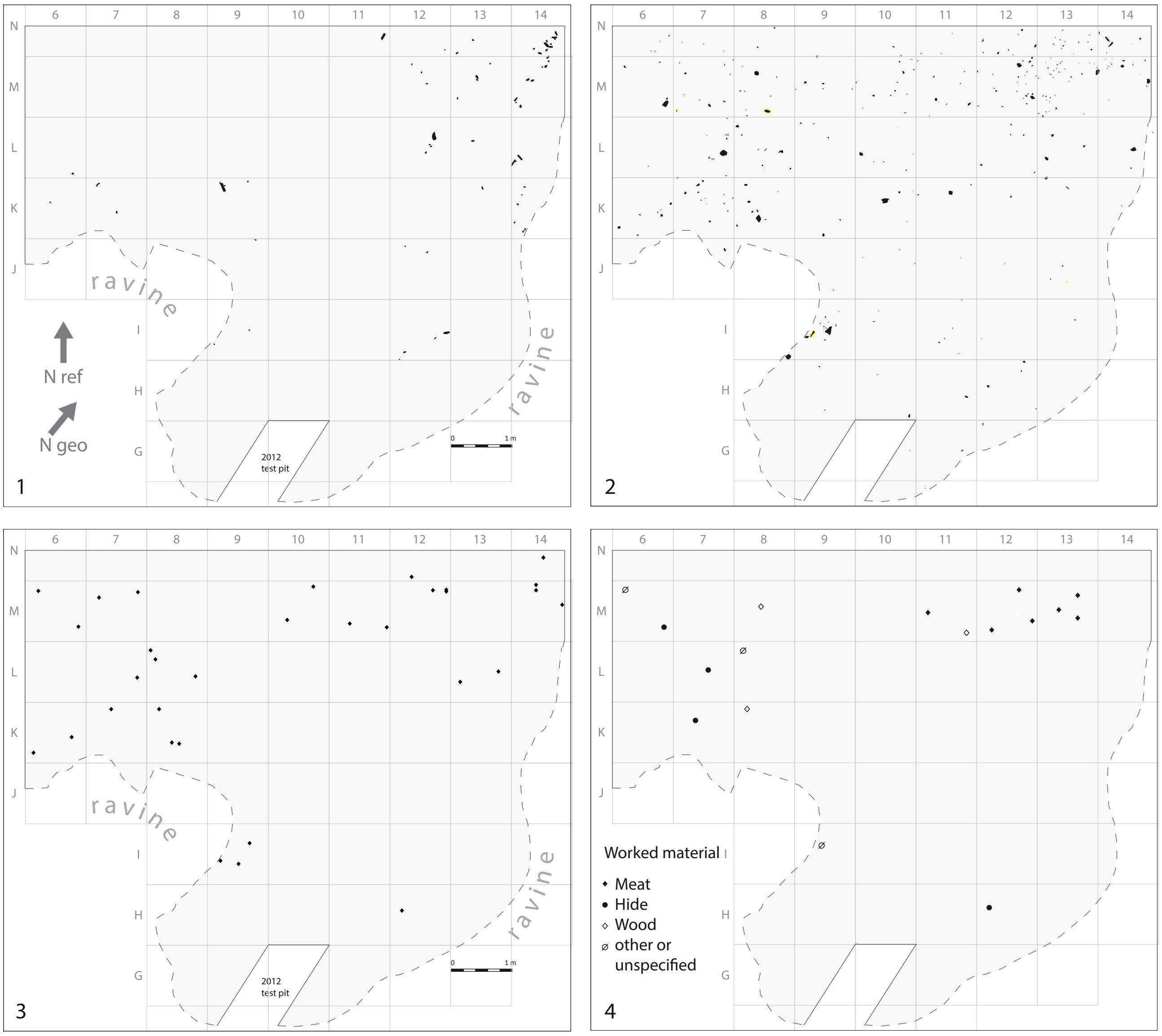
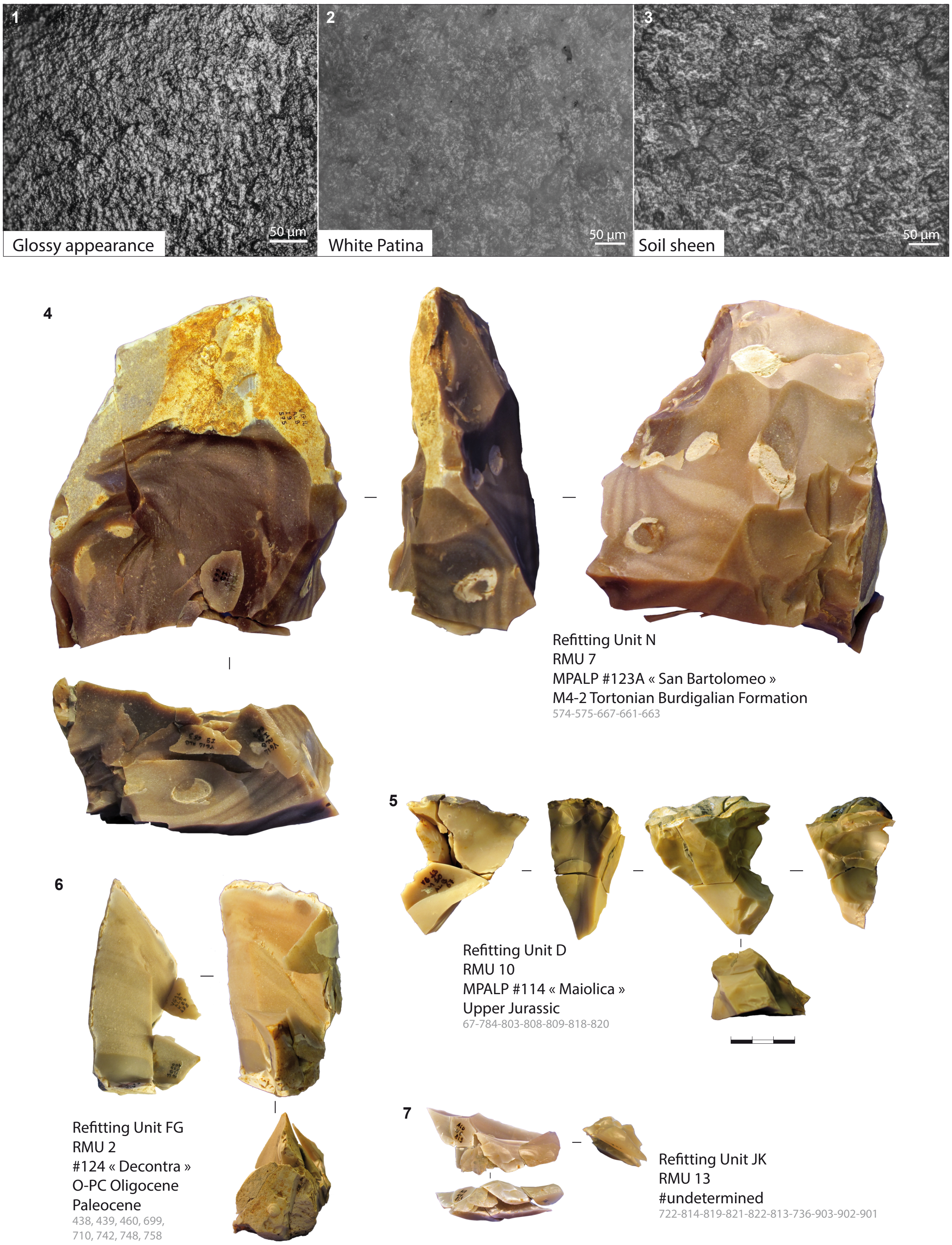


Fig. 9 – Maps of remains of layer ALB-42 of Valle Giumentina site: **1**, faunal remains; **2**, lithic remains; **3**, retouched flakes; **4**, remains with use-wear traces. (CAD: E. Nicoud/EFR).

Fig. 9 – *Plans des vestiges de la couche ALB-42 du site de Valle Giumentina :* ***1****, restes fauniques ;* ***2****, industrie lithique ;* ***3****, éclats retouchés ;* ***4****, artefacts à traces d'utilisation (DAO : E. Nicoud).*

Fig. 10 – Post-depositional modifications and example of lithic refit groups from level ALB-42 of Valle Giumentina: **1**, glossy appearance; **2**, white patina; **3**, soil sheen; **4**, unit N: an alternating-platforms core made on a block, with four flakes. The débitage occurred partially on the site and some flakes have been brought away; **5**, unit D: a thick flake which ventral face is used as the striking platform provided at least six flakes. It shows two identical reduction sequences that created in the meantime both notches-flakes and a nose on the blank; **6**, unit FG: a big cortical flake and seven small flakes shows that a block have been knapped in situ and both the core and few flakes have been then brought away; **7**, unit JK: nine small flakes correspond to the retouch of a scraper cutting-edge according the same angle and delineation that existed before. The scraper has been brought away. Petrographic classification refers to the CEPAM Lithic referential collection MPALP (pictures: 1-3, C. Lemorini; 4-7 and CAD: E. Nicoud).

Fig. 9 – *Modifications post-dépositionnelles et exemple d'unités de remontages lithiques du niveau ALB-42 de Valle Giumentina :* ***1****, aspect brillant ;* ***2****, patine blanche ;* ***3****, lustré de sol ;* ***4****, unité N : bloc débité selon une méthode par alternance des surfaces, avec quatre éclats. Le débitage a eu lieu en partie sur le site et plusieurs éclats ont été emportés ;* ***5****, unité D : un éclat épais dont la face inférieure est utilisée comme surface de plan de frappe a fourni au moins six éclats. Il présente deux séquences de réduction identiques qui ont créé simultanément deux éclats de coches et un museau sur le support ;* ***6****, unité FG : un grand éclat cortical et sept petits éclats montrent qu'un bloc a été débité in situ et que le nucléus et quelques éclats ont ensuite été emportés ;* ***7****, unité JK : neuf petits éclats correspondent à la retouche du tranchant d'un racloir selon le même angle et la même délimitation que celles préexistantes. Le racloir a été emporté. La nomenclature pétrographique se réfère à la collection MPALP du CEPAM (clichés : 1-3, C. Lemorini; 4-7 et DAO : E. Nicoud).*


1
Glossy appearance
50 µm
2
White Patina
50 µm
3
Soil sheen
50 µm
4
Refitting Unit N
RMU 7
MPALP #123A « San Bartolomeo »
M4-2 Tortonian Burdigalian Formation
574-575-667-661-663
5
Refitting Unit D
RMU 10
MPALP #114 « Maiolica »
Upper Jurassic
67-784-803-808-809-818-820
6
Refitting Unit FG
RMU 2
#124 « Decontra »
O-PC Oligocene
Paleocene
438, 439, 460, 699,
710, 742, 748, 758
7
Refitting Unit JK
RMU 13
#undetermined
722-814-819-821-822-813-736-903-902-901

bands observed on many objects that also have a glossy patina (fig. 10, nº 3). In this case, to emphasize that mechanical and chemical processes generated the bright surface, the patina is called "glossy appearance" (Lemorini, 2000).

Objects with a white patina are less numerous than those with a glossy appearance. They are also sparse in the deposit, which cannot therefore be attributed to spatially localized episodes of alkalization. They are probably related to the major or minor resistance of the raw material to this type of attack. It should be mentioned that if the raw material exploited by the hominines was already affected by alteration processes, the possibility of developing patinas during their deposition obviously increases (Fiers, 2020).

In short, the artifacts in ALB-42 have not been affected by high-energy river transport but probably quickly covered by sediments and then undisturbed by the successive presence of humans or animals. However, they suffered dissolution processes of varying intensity as well as mechanical abrasion processes due to slight movements of fine soil particles. The medium or light development of the patina makes it possible to recognize micro-wear on the best-preserved lithic tools (n = 26).

Post-depositional processes and degree of significance of the remains

In this c. 450 000 years old archaeological level, post-depositional processes must have occurred, but how destructive are they? Assessing the taphonomic state of the archeological remains is a preamble for a techno-economic analysis. We assemble here the observations resulting from the analysis of the sediments and remains. Most of the bones are highly fragmented after their exploitation by human groups, maybe due to the soil compaction that occurred during about 400 ka afterwards, under the weight of a 5-meter thick stratigraphic sequence. Some fragments bear two different alterations marks depending of their surfaces. This means that the Red Deer carcass was weathered before its burial.

As seen during the excavation, many artefacts are found in a vertical position (n = 97/263 large remains) or in horizontal position (n = 57/263). No other trends are observed neither in dip nor in orientation. Paleosol ALB-42 has a well-developed prismatic structure. Micromorphological studies show clay shrinking and swelling features. Artefacts must have slipped into these cracks which opened during dry periods. It is difficult to say how many times the clay retracted and swelled. This is a phenomenon that can be observed today on the current surface of Valle Giumentina. Bioturbation is also documented and the altitudinal dispersion of the pieces show an average spacing of 10 cm. At first glance, the lithic artifacts appear to be "fresh". Macro- and microscopic observations on the surfaces show very few mechanical alterations. A glossy appearance and a slight white patina are present on most of the pieces. This is very consistent with a well-developed hydromorphic soil with a clay matrix. Soil formation (bioturbation, swelling and drying of the clay) and compaction are the main causes of reworking and damage. The low percentage of artefacts (n = 26) showing use-wear traces cannot be justified by taphonomic processes. In addition, lithic refit groups have a very low dispersion and pieces of all sizes have been found. Very small pieces refit too, as shown, for example, by the small retouch flakes of the "JK refit group" (fig. 8 and 10). Thus, even if the pieces moved vertically in this thick soil, the fine matrix allowed sufficient preservation of the remains to carry out a techno-economic analysis.

RESULTS OF THE TECHNO-ECONOMIC ANALYSIS

Petrographic distinctions within the archaeological series

Among the 407 studied pieces, we identified 3 artefacts in limestone and 14 different cherts RMU gathered in six groups (MPALP #124, 123A, 123B, 114, undetermined, Scaglia Rossa (maybe); table 1). Some very small flakes (under 1 cm²) have also been assigned to RMU, but most of them are only related with groups. Local raw materials represented by the types 123 and 124 are dominant. They all present the same cortical surfaces and most probably originate from the same secondary formation which is not identified, no more accessible today due to neotectonic movements.

Among the six RMU of 123 type, we distinguished two main aspects: a first one identified by spicules abundance (123A; fig. 4, No 3), a second one by the presence of Orbulina (#123B; fig. 4, No 6). Within 124 type, the RMU differ from each other by the preservation of clasts (fig. 4, No 9).

Some cherts have a very low detrital component, only represented by radiolarian. They present major convergences with the upper Jurassic cherts of the Maiolica formation (114; fig. 4, No 10). We distinguished two RMU (with or without radiolarian), but this distinction is difficult to assess in absence of geological comparative samples. A last RMU is individualized. It is made of three small flakes of a reddish raw material with no evident clasts. It could originate from another formation of the Jurassic-Eocene sequence of the Apennines formations (maybe Scaglia Rossa), but this remains doubtful.

Among the undetermined cherts, two RMU are individualized (fig. 4, No 11). They correspond to sets showing a global homogeneity and each one comes from a specific source. They present the same cortical surfaces as local raw materials and most probably originate from the same sources, which we are not able to localize yet.

Lithic production *chaînes opératoires* by petrographic group

Cherts Group #124 (Oligocene-Paleocene)

Group MPALP #124 is made of 88 artefacts in chert rich in Nummulitidae from the "Decontra" Oligocene-

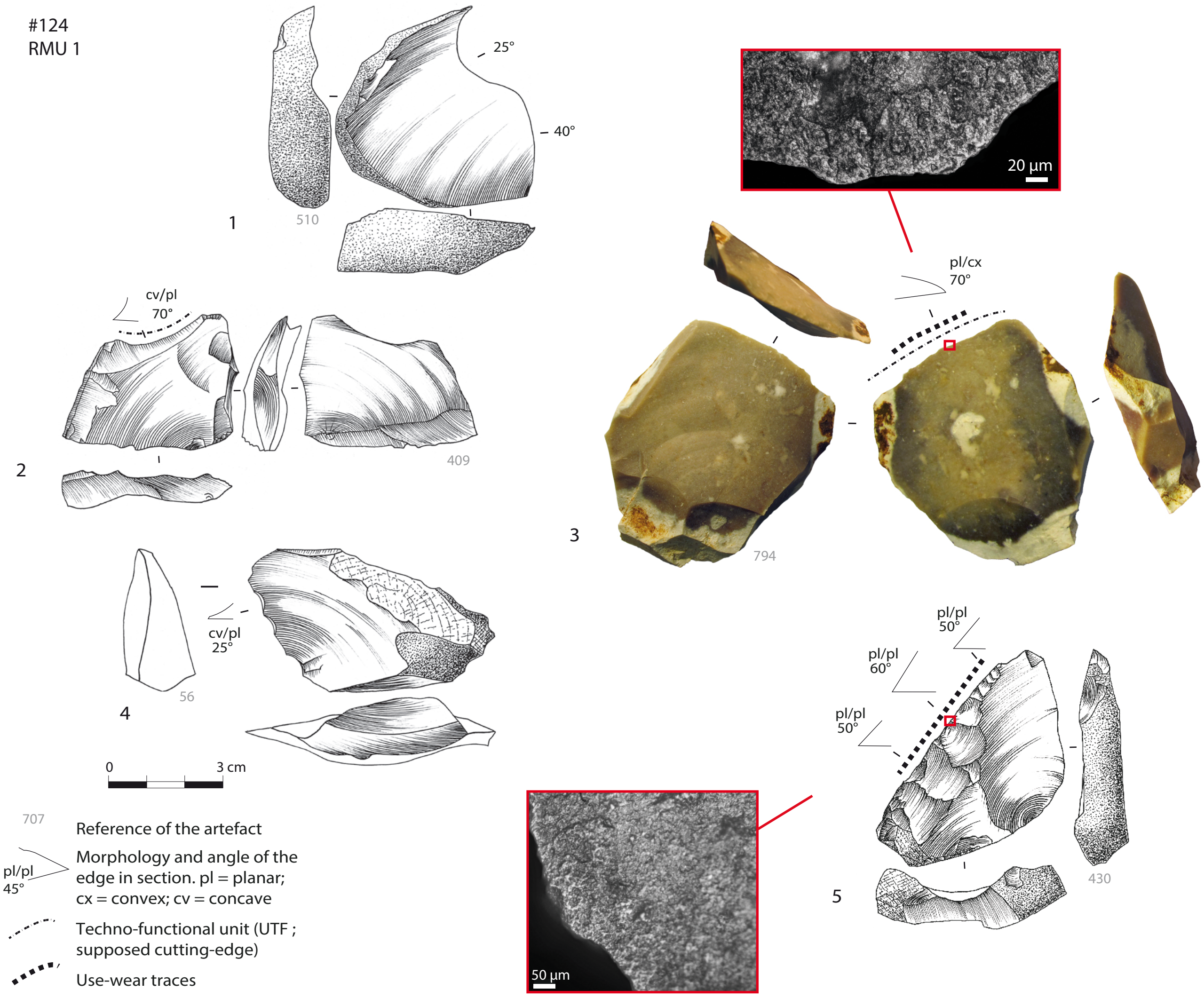


Fig. 11 – Flake industry from Valle Giumentina ALB-42 (RMU #124-1) : **1**, **2**, unretouched flakes with cortical back (1) and plain back (2) ; **3**, side-scrapper on transversal distal edge; lateral edges and butt form a back (wood processing attested); **4**, unretouched flake with thick plain butt; **5**, scrapper with cortical back (meat and hide processing) (ink drawings by M. Pagli; pictures and CAD: E. Nicoud).

*Fig. 11 – Industrie à éclats de Valle Giumentina ALB-42 (RMU #124-1) : **1**, **2**, éclats non retouchés à dos cortical (1) et à dos lisse (2) ; **3**, racloir transversal ; les bords latéraux et le talon forment un dos (travail du bois attesté) ; **4**, éclat non retouché à talon épais et lisse ; **5**, racloir à dos cortical (travail de boucherie et de la peau) (dessins à l'encre par M. Pagli ; clichés et DAO : E. Nicoud).*

Paleocene formation (M4-2). Four well-distinct RMU have been identified. There is no real concentration of artefacts within the excavation area but artefacts from RMU 2 including four refit groups (E, FG, M and H) are mainly located on few square meters in the western part of the site (fig. 8). Each RMU of #124 group show very different objectives.

RMU 1 regroups few notches flakes and four retouched flakes but no core (fig. 11). Tools are characterized by the presence of a cortical back opposite the cutting-edge, according to a "*tranches de saucisson*" flaking method. One flake with a peripheral cortical back (butt and two adjacent edges) has been used to scrap wood (No 794, fig. 11, No 3). Another backed flake worked on meat and hide. The gesture is undeterminable (No 430, fig. 11, nº 4). Small flakes coming from retouch are absent too. So, some unretouched blanks and some tools seem to have been produced outside and imported into the site.

RMU 2 does not count any core but many flakes. Refit groups FG and H suggest that the *débitage* took place on the site and that the core has been brought out (fig. 8 and 10, nº 6; table 2). Blanks of diverse morphologies are produced. Here, backs are absent but linear edges with 40° to 50° angles and slight convexo-concave section are recurrent (fig. 12). The number 381 is a raw flake used for cutting soft material. An imposing cortical flake (No 464) has an irregular retouch on the left edge that worked hide with an undeterminable gesture (fig. 12, No 4).

RMU 3 consists of a thick notched flake with double-patina suggesting the tool has been brought to the site already finished. It can result from the reuse of a core-flake (No 692; fig. 13, No 1).

RMU 9 is made of only eight flakes, among which a large plunging flake (134 x 93 x 64 mm; No. 65, fig. 13, No 3) carrying out a big part of the core. It wears removals negatives but no negative bulbs. The other flakes are thin and of small size. The core is absent. No refit occurs.

Refitting units	Group	RMU	Nombre pièces
F-G	124	2	8
H	124	2	2
M	124	3	2
C	123A	6	4
E	123A	7	2
N	123A	7	5
D	114	10	7
A	indet	12	3
B	indet	12	4
I	indet	13	3
JK	indet	13	10
L	123B	other	2
		total	52

Table 1 – Lithic refit groups from level ALB-42 of Valle Giumentina. Correspondence with raw material groups and RMU; number of artefacts in each refit group.

Tabl. 1 – *Unités de remontages lithiques du niveau ALB-42 de la Valle Giumentina. Correspondance avec les groupes de matières premières et les RMU ; nombre d'artefacts dans chaque remontage.*

Cherts Groups #123A and 123B (Senonian-Burdigalian)

Groups MPALP #123A and 123B are respectively made of 85 and 38 artefacts in chert from the « San Bartolomeo » Tortonian Burdigalian Formation (0-PC; fig. 4). Pieces from group #123A appear in many spots but we can see a higher density at north-east and a small cluster forming refit group N in square I9 (fig. 8). Pieces from #123B group are also scarce but appear in different spots than the artefacts from group #123A.

RMU 4 has only seven pieces, and show a production using the "*tranches de saucisson*" method and a flake illustrates the Kombewa method. Few centimeters linear and convex cutting-edges appear on various blanks with or without backs (fig. 14, Nos 1 and 2).

RMU 5 is only represented by a highly rounded core made on a cobble. It has two flaking surfaces showing short production sequences of irregular flakes (No 424, fig. 14, No 3). Crushing edges and well-marked incipient cones, added to its unusual rounded aspect, seem clues to consider this artefact a hammerstone. Hammerstone (pebbles) are very rare at Valle Giumentina. The only available stone, other than cherts in the surrounding is limestone but it is quite fragile and brittle.

RMU 6 of chocolate colour, with refit group C, shows that part of *débitage* has been made *in situ* as well as the direct and abrupt retouch of the transversal edge of a big cortical flake (No 649; fig. 15, No 4). Small retouch flakes coming from this edge are part of the refit. The core, as well as other flakes, have been brought away. Indeed, some small flakes and debris associated to this RMU do not refit. Spatial distribution shows that tool number 649 has been produced, retouched and use on the same spot (on the same m²). It wears traces of wood scraping on its distal edge. A broken thin flake with a sharp straight edge (No 27; fig. 15, No 1) cut hide in a dry state.

RMU 7 is made of a big core and flakes coming from it found into a cluster (refit group N, fig. 10, No 4). Some big flakes have been brought away. This parallelepiped core wearing four flaking surfaces, shows a SSDA method (see also fig. 16, Nos 1 and 2). Short production sequences of unipolar parallel removals with a 90° flaking angle are produced, without core preparation but with alternating platforms. Flakes are quite thin but of various sizes and morphologies. Two flakes from refit group E are also associated to this RMU. One of these flakes has been discovered 4 m far from the cluster, into the area with faunal remains. No use-wear traces have been observed on this flake.

RMU 8 is made of a core (fig. 16, No 6) and several flakes. They suggest an *in situ débitage* by the SSDA method but also the making of the tools, as shown by some small notches (No 150, fig. 16, No 5) and by two retouched flakes (Nos 145 and 440, fig. 16, Nos 3 and 4). Linear cutting-edges with a 30° to 40° angle are produced on thin blanks without any back. Some flakes have been brought out of the site, defined here as the excavation area. On the left edge of flake number 145, well developed polishes attributable to the contact with stone are detected. Their distribution and orientation suggest a transversal motion carried out with a quite perpendicular orientation of the tool on the contact surface. This action resulted in the complete blunting of the edge itself. This evidence could be interpreted as stone working or as the purposeful action of dulling the edge for griping. This latter hypothesis may be supported by the fact that the opposite right edge of the tool shows traces of hide processing.

Refit group L including two small retouch flakes (of which No 407, fig. 16, No 7) supports the idea of local tool making activity.

Undetermined cherts

Group of undetermined cherts correspond to three different RMU. A local origin is supposed because of the cortex and the matrix aspects but the absence of diagnostic fossils limits the interpretation.

RMU 12 includes 30 pieces and refit groups A and B mainly located at the northern corner of the excavation area (fig. 7). Refit group A (fig. 17, No 1) consists of three flakes from *plein débitage.* They come from two orthogonal flaking platforms. Two of them are elongated. Many previous thin removals on the butts could indicate a striking platform preparation. As preparations seem inexistent elsewhere on ALB-42 lithic material, this information must be taken with caution. Others thick flakes and debris (as in refit group B), few notches-flakes and the absence of cores suggest that cortex removal is made outside the site, then *plein débitage* flakes are produced on the spot. Tools or blank for tools have been mostly brought away but a hinged semi-corti-

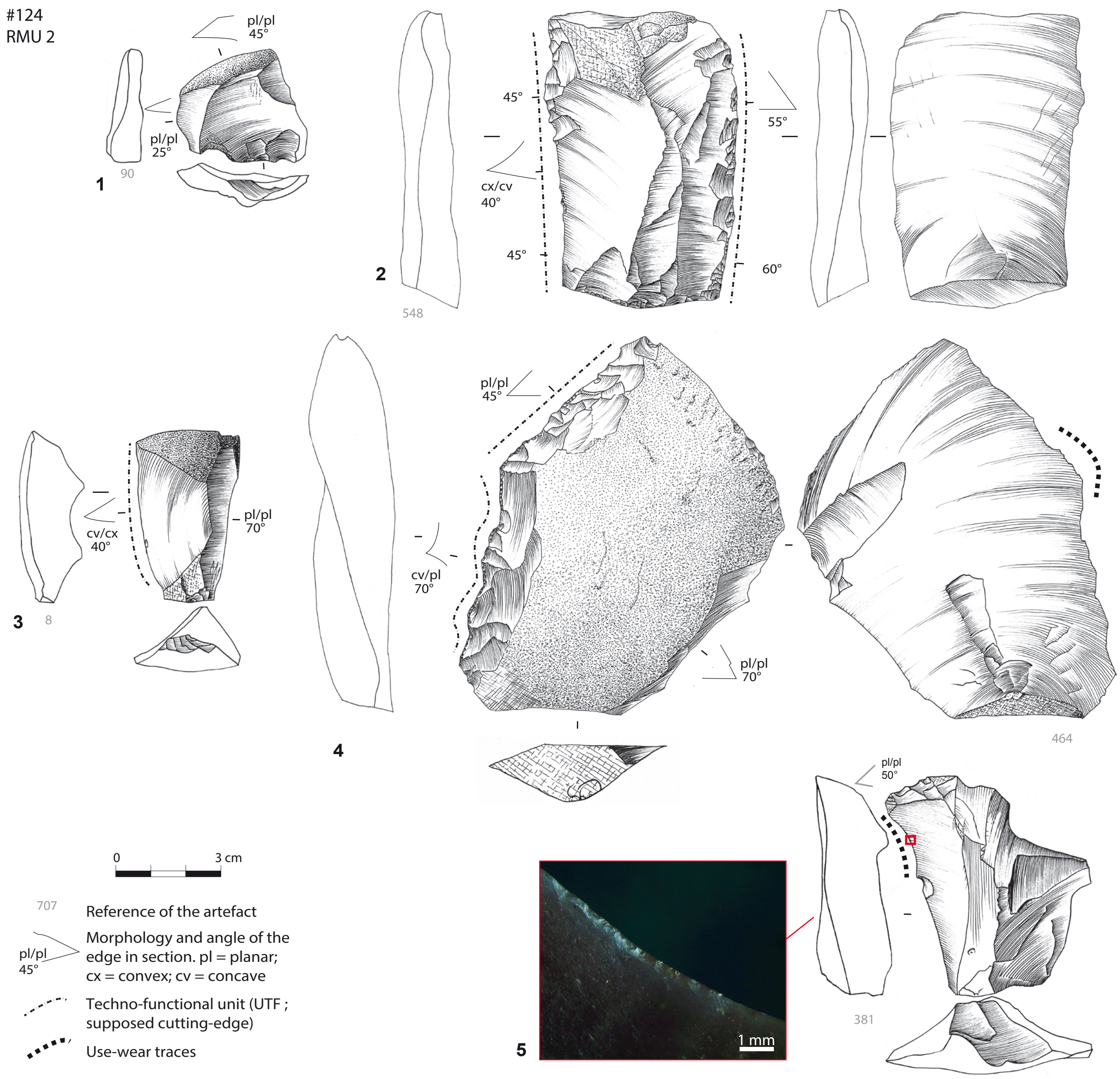


Fig. 12 – Flake industry from Valle Giumentina ALB-42 (RMU #124-2): **1**, notch; **2**, lateral scrapper; **3**, unretouched semi-cortical flake; **4**, thick cortical and denticulate flake (hide processing traces on left edge); **5**, flake with a sharp left edge (used on soft material) (ink drawings by M. Pagli; picture by C. Lemorini and CAD: E. Nicoud).

***Fig. 12 –** Industrie à éclats de Valle Giumentina ALB-42 (RMU #124-2) : **1**, coche ; **2**, racloir latéral ; **3**, éclat semi-cortical brut ; **4**, éclat épais cortical et denticulé (trace de travail de la peau sur le bord gauche) ; **5**, éclat au bord gauche fin (utilisé sur un matériau tendre) (dessins à l'encre par M. Pagli ; cliché par C. Lemorini et DAO : E. Nicoud).*

cal flake wearing one unipolar removal wears an irregular retouch on its left edge (No 488; fig. 17, No 2).

RMU 13 shows a diversity of products (fig. 18). It includes refit group JK which is made of small flakes from a sidescraper cutting-edge resharpening (fig. 8, No 7). The remaining tool has been brought away. Refit group I consists in an elongated flake maybe intentionally fractured in four parts. On one fragment, fresh hide and meat cutting traces have been observed (No 472; fig. 18, No 6). These occur also on the left edge of a cortical side-scraper (No 87; fig. 18, No 7). A big core with alternating platforms and no preparation that gave diverse flakes has been used in thrusting percussion on wood (No 533; fig. 19).

Cherts Group #114 Maiolica

Group #114 of Upper Jurassic cherts indicates an origin outside the Maiella mountain range. The raw material is brought into the site as a thick flake or as a retouched tool.

RMU 10 is made of refit group D and assimilated flakes (fig. 10, No 5). A thick flake has been brought to the site (No 808), then a deep notch and a split have been made on the lateral parts, creating in the meantime a nose (its distal part is No 67) opposite the cortical back. This action is repeated twice (notches Nos 809 and 784). Even a thin bladelet-like flake seems to accentuate the nose (No 820). Is this thick flake a tool or a core? The

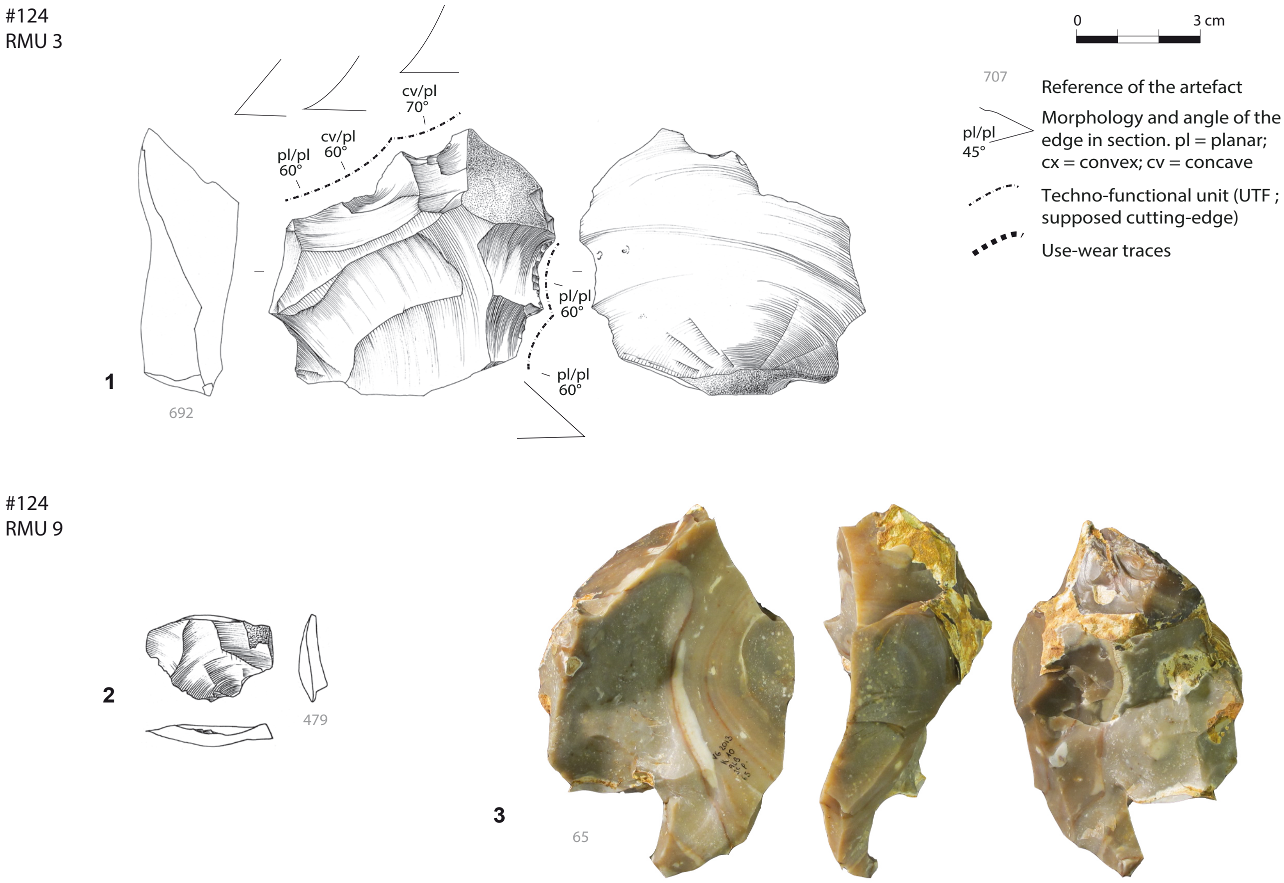


Fig. 13 – Flake industry from Valle Giumentina ALB-42 (RMU #124-3 and 9): **1**, thick flake with a notched edge; **2**, small retouch flake; **3**, thick plunging flake (ink drawings by M. Pagli; pictures and CAD: E. Nicoud).

Fig. 13 – *Industrie à éclats de Valle Giumentina ALB-42 (RMU #124-3 et 9) :* ***1****, éclat épais à bord encoché ;* ***2****, petit éclat de retouche ;* ***3****, éclat épais outrepassant (dessins à l'encre par M. Pagli ; clichés et DAO : E. Nicoud).*

question is still on as use-wear traces were not observed on it. The very small removals at the end of the nose are due to mechanic alteration.

RMU 11 has one flake retouched on the left side. Two convergent cutting edges with 45° and 70° angles form a tip (No 449; fig. 20). This piece wears both use-wear traces (fresh hide and meat cutting) and fatty acids salts residues (adipocere).

Scaglia Rossa cherts

RMU 14 regroups only three very small artefacts that could be in Scaglia Rossa chert, with an 80 km northern origin. The attribution remains doubtful.

Limestone pebbles

We found two limestone pebbles. A circular but flat pebble of very soft limestone from the Oligocene-Paleocene Formation (Decontra #124) may have been used as a hammer. It is altered but the edge is crushed on an extension of 6 cm and a big removal could be the result of percussion. However, the use of a soft rock hammer is hardly compatible with the very punctual stigmas of the percussion, observed on chert products.

Techno-functional features of Valle Giumentina ALB-42 lithic industry

General considerations on use-wear data

Use-wear traces have been identified on a total of 26 artefacts made of 1 core, 8 retouched flakes and 17 raw flakes or fragments (table 3; fig. 21). The eight retouched flakes show traces of use on their retouched edge, suggesting that the retouch is intended to model the active edge and not the grip area. Some of the artefacts with use-traces own cortical or backed areas that are suitable to grip (e.g. fig. 18, No 7).

Animal materials and wood have been worked. Seven flakes (e.g. fig. 11, No 4) document the process of butchering, testified by fresh hide and meat cutting. In a single case, the material processed by cutting is hide in a dry condition (fig. 15, No 1). The only vegetal material certainly processed at the site is wood (5 pieces), worked by scraping or thrusting percussion, preferably with large artefacts (e.g. fig. 19). The processing of plant materials other than wood was not recognized at the site. Two artefacts are used on hard material. One is used on mineral material (fig. 16, No 3) and for the other one (No 691;

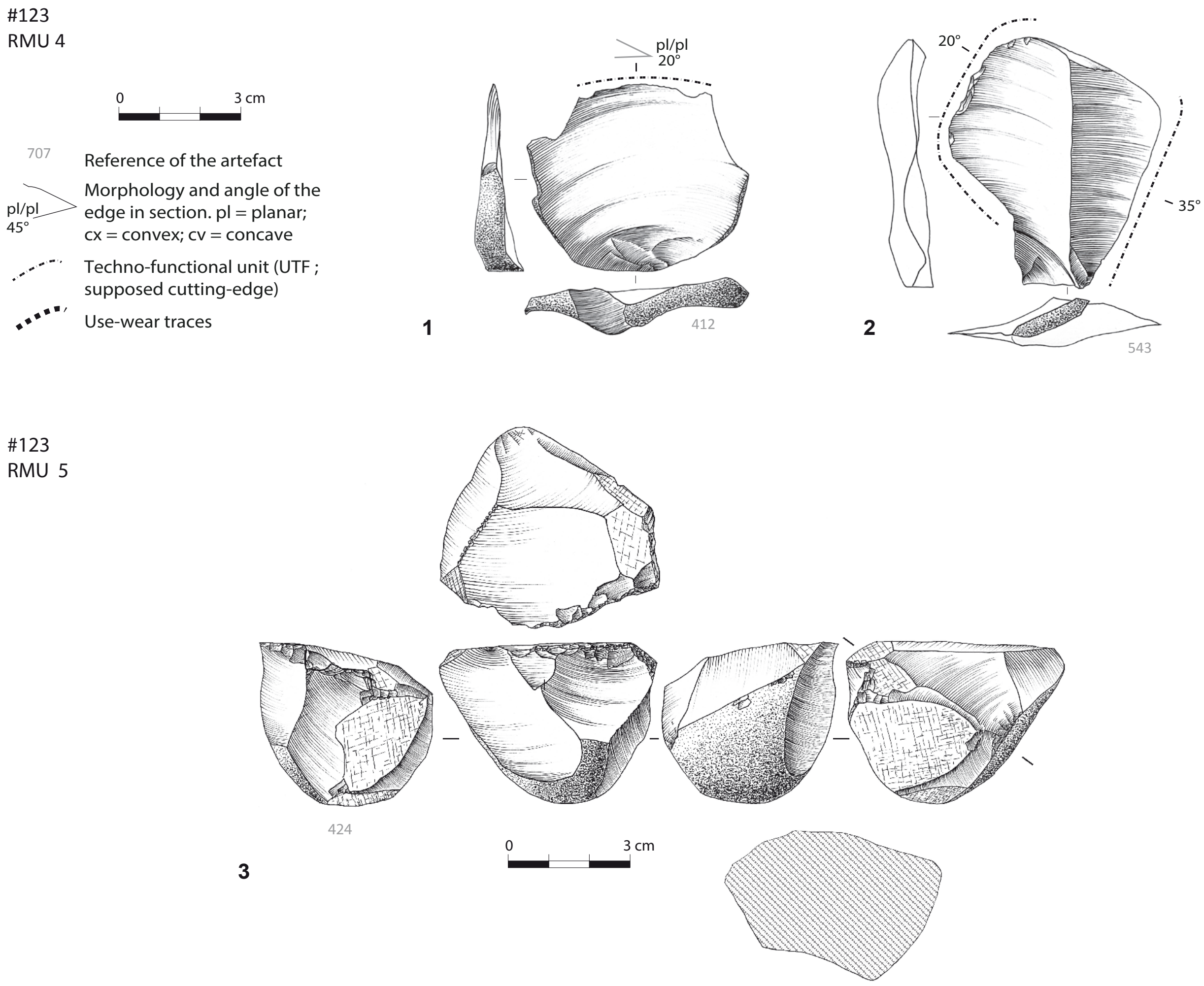


Fig. 14 – Flake industry from Valle Giumentina ALB-42 (RMU #123-4 and 5): **1**, flake with a cortical back; **2**, flake with sharp regular edges; **3**, core, maybe used as a hammerstone (ink drawings by M. Pagli; CAD: E. Nicoud).

Fig. 14 *– Industrie à éclats de Valle Giumentina ALB-42 (RMU #123-4 et 5) :* ***1****, éclat à dos cortical ;* ***2****, éclat à bords aigus et réguliers ;* ***3****, nucléus peut-être utilisé comme percuteur (dessins à l'encre par M. Pagli ; clichés et DAO : E. Nicoud).*

fig. 21, No 1), the hard material is undeterminable (possibly stone or hard animal material). The presence of objects with only diagnostic macro-traces of soft/medium materials cannot reveal anything more about the eventual material processed.

In addition, the traces observed on the butt of the very small flakes indicate that the tool is used prior to the detachment of these small flakes, which occurred during either retouch or use (Fig. 21, Nos 4 and 6).

Results of residues analysis by the FTIR technique

Sixteen artefacts have been sampled for FTIR analysis. In all spectra, an intense peak of the Si-O stretching mode shows a shoulder on its low frequency side (~ 913 cm^{-1}). This feature can be assigned to the P=O stretching mode of hydroxiapatire (Thompson *et al.*, 2013), the mineral component of bones or to the Si-O stretching mode of kaolinite [Al2Si2O5(OH)4] (Udvardi *et al.*, 2014). As the residues associated to this intense peak usually spread on the surface of the items, it is highly probable that they are related to particles of the sediments.

In addition, in all spectra, a very intense absorption band is observed at 1157 cm^{-1} and two medium intensity bands at 798 and 469 cm^{-1} attributed to Si-O stretching and O-Si-O and\or O-Si-Al bending modes, respectively, since cryptocrystalline silica is the principal constituent of the analysed items. All peaks show an up-down reversal due to the reststrahlen effect (Madejová, 2003; Vaculíková and Plevová, 2005).

Doublets of weak intensity at 2916 \2848 and 1575\ 1539 cm^{-1} are observed in the spectra of four items (Nos 449, 459, 473 and 808) and respectively attributable to the C-H and C-O stretching modes of fatty acids salts (palmitate and/or stearate; Hénichart *et al.*, 1982; Gönen *et al.*, 2010). The mentioned compounds are present both in vegetal (Raíces *et al.*, 2003; Woodfield *et al.*, 2017) and animal tissues. In the latter case, their presence is due to the transformation of animal body fat into a greasy lipid mixture called adipocere (Stuart *et al.*, 2005). These compounds are extremely resistant, and they can survive on flint surface strongly patinated (Venditti *et al.*, 2019). Thus, their presence on the patinated lithic tools of Valle Giumentina is very reliable.

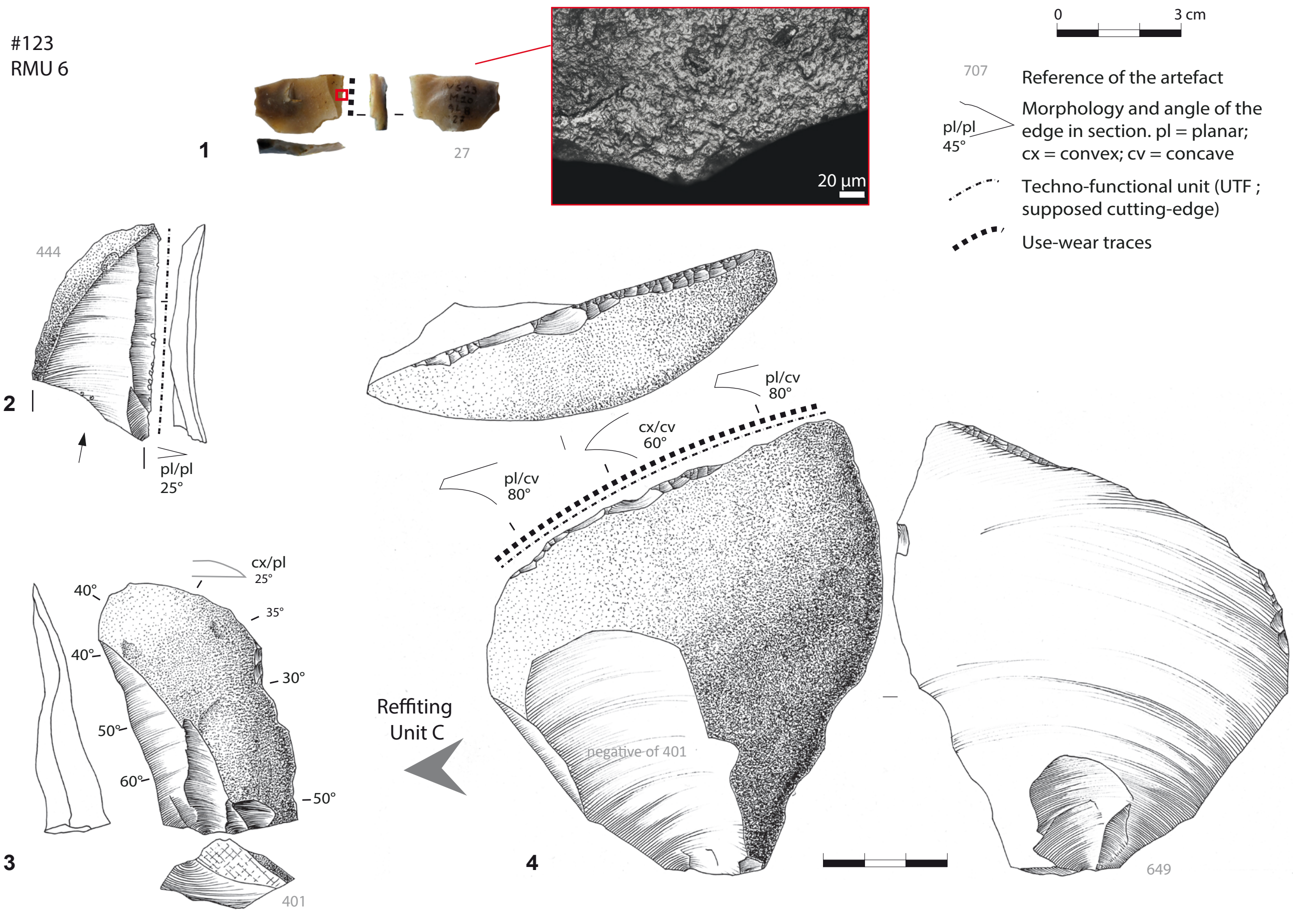


Fig. 15 – Flake industry from Valle Giumentina ALB-42 (RMU #123-6): **1**, thin flake fragment (dry hide cutting); **2**-**3**, partially-cortical flakes; **4**, distal scrapper (wood processing) (ink drawings by M. Pagli; pictures and CAD: E. Nicoud).

***Fig. 15 –** Industrie à éclats de Valle Giumentina ALB-42 (RMU #123-6) : **1**, fragment d'éclat fin (découpe de peau sèche) ; **2-3**, éclats partiellement corticaux ; **4**, racloir distal (travail du bois) (dessins à l'encre par M. Pagli ; clichés et DAO : E. Nicoud).*

In item 449 (fig. 22, No 1) the fatty acids salts residues match with use-wear of animal material processing, reinforcing the interpretation reached by the use-wear analysis. Item 459 does not show traces of use, but it is part of a refit group I (fig. 22, No 2) where item 472 shows localized traces of hide working. This combination of data (use-wear plus residues) suggests that the large artefact is used to process fresh animal material before its fragmentation in the refitted three pieces. A similar explanation is proposed for item 808, which does not show traces of use, but is part of refit group D (fig. 22, No 3).

Débitage technique*, methods and concept*

Preliminary results obtained on half of the lithic industry have been published earlier (Nicoud *et al.*, 2016b). They already highlighted the great number of tools (meaning retouched flakes), now established at 38 artifacts as well as the rarity of cores (n = 5). With this new exhaustive study, we also confirm that bifacial shaping is absent whereas the *débitage* is done according to different methods such as the "*tranches de saucisson*" and the "SSDA" (*Système par surface de débitage alternée*) intended as "orthogonal flaking" (Turq, 1989; Ashton *et al.*, 1992; Forestier, 1993; Ashton *et al.*, 1994). There is no preparation of the flaking surface nor of the striking platform. Percussion is direct and internal, with a hard hammerstone: bulbs can be prominent, butts are mainly plain and thick (table 4), flaking angles go from 90° to 110°. This kind of *débitage* can be related to the same concept of "Core volumetric structure", in this case "C type", according to the phylo-technic classification by Boëda (2013). It implies a short recurrence of removals using natural convex surfaces and the ridge left by previous removals in order to guide the shock wave. The morphology of the core is not discriminant: only an under-volume of the core is used. Rotating the core and choosing new flaking surfaces allows flaking to continue, when the flaking surfaces or the striking platform used so far no longer have the appropriate convexities or dimensions.

Blanks and cutting-edges morphologies

Sometimes a RMU show a recurrent production for a specific blank type (as RMU 1 producing backed flakes) or of a specific cutting-edges type (as RMU 2 producing linear edges), but mainly, one *débitage* provides blanks

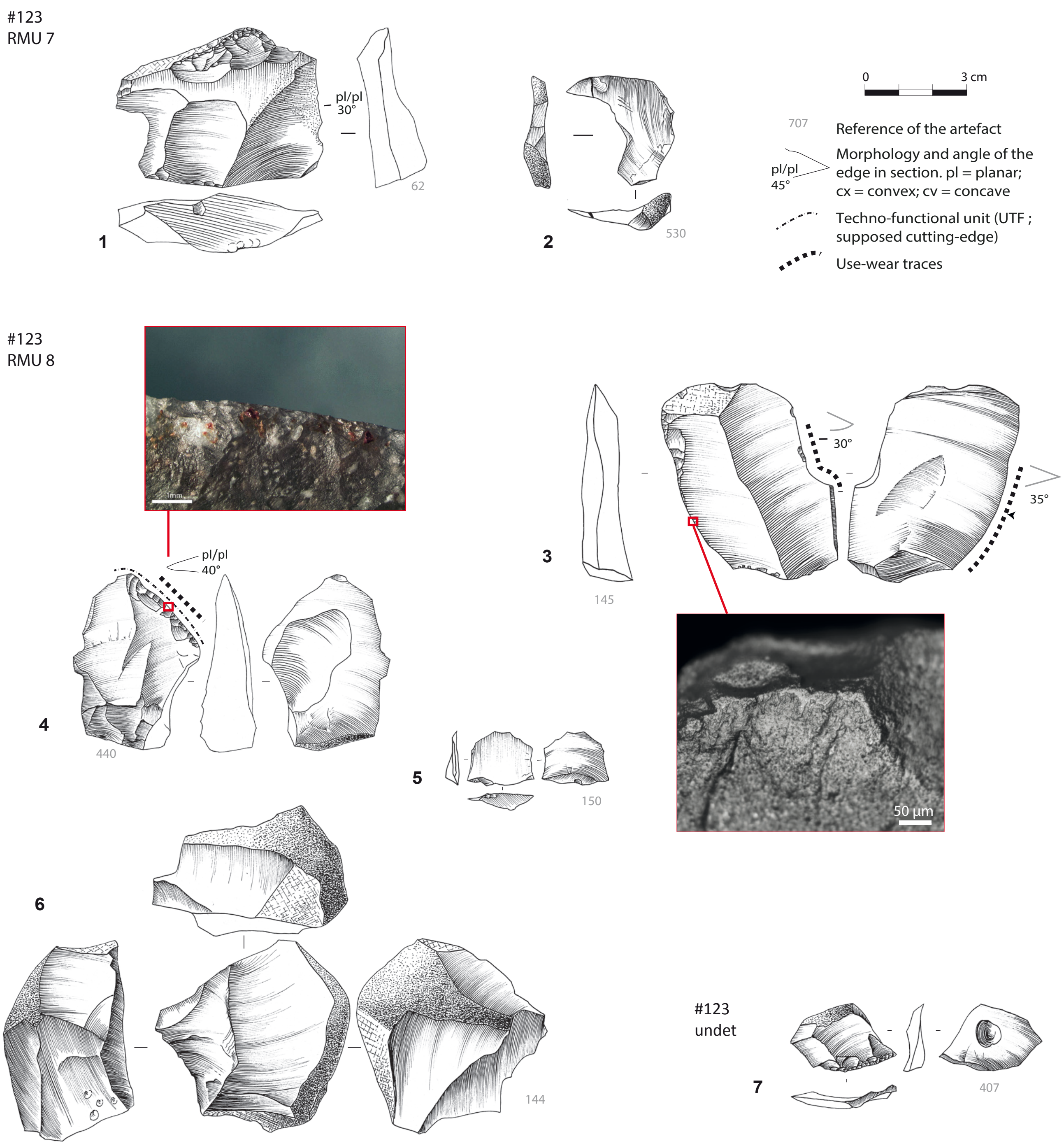


Fig. 16 – Flake industry from Valle Giumentina ALB-42 (RMU #123-7, 8 and undetermined) : **1**, flake from unipolar flaking sequence; **2**, fragment; **3**, flake with traces of mineral processing on its left edge and hide processing on the right edge; **4**, flake with distal retouch showing macro-traces related to soft material processing; **5**, small retouch flake; **6**, SSDA core; **7**, small retouch flake from refit group L (ink drawings by M. Pagli; pictures: C. Lemorini; CAD: E. Nicoud).

Fig. 15 – *Industrie à éclats de Valle Giumentina ALB-42 (RMU #123-7, 8 et indéterminé) :* ***1****, éclat issu d'une séquence unipolaire ;* ***2****, fragment ;* ***3****, éclat portant sur le bord droit des traces de contact avec un matériau minéral et sur le bord gauche, de traitement de la peau ;* ***4****, éclat à retouche distale avec des macro-traces liées au traitement de matériaux tendres ;* ***5****, petit éclat de retouche ;* ***6****, nucléus SSDA ;* ***7****, petit éclat de retouche (dessins à l'encre par M. Pagli ; clichés C. Lemorini ; DAO : E. Nicoud).*

and cutting edges of diverse morphologies. Flakes can be cortical or not (table 4). They can have a back made by the butt and/or one adjacent edge but it is not systematic.

Here, one major characteristic of the series is the presence of thick flakes, introducing once again the question of the function of these big artefacts: tools or cores (McPherron dir., 2007). The plain ventral surface is then the striking platform for flaking or retouch. The flaking/retouch occurs in the thickness of the flake (e.g. fig. 10, No 5). So, the removals have typical notches morphologies: they are short and often hinged, with thick and plain butts, and prominent bulbs. They create denticulate or

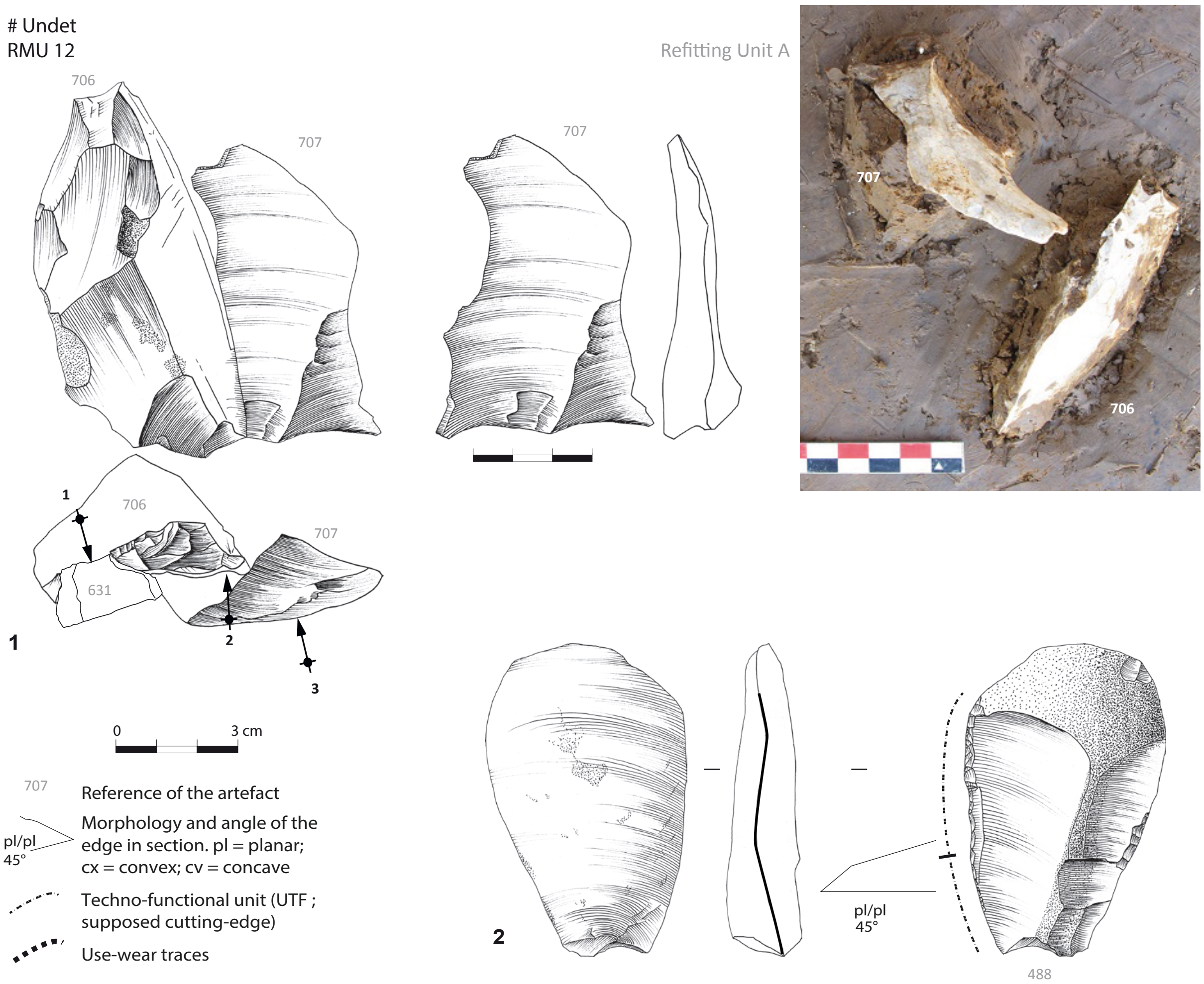


Fig. 17 – Flake industry from Valle Giumentina ALB-42 (RMU #Undet-12): **1**, drawings and picture of refit group A; **2**, semi-cortical flake with a retouched left edge (ink drawings by M. Pagli; pictures and CAD: E. Nicoud).

***Fig. 17** – Industrie à éclats de Valle Giumentina ALB-42 (RMU #Undet-12) : **1**, dessins et image de l'unité de remontage A ; **2**, éclat semi-cortical à bord gauche retouché (dessins à l'encre par M. Pagli ; clichés et DAO : E. Nicoud).*

notched edges delineations on the thick flake. Either the cutting-edge remains like this or a second row of short retouch regularize the cutting-edge, taking away the irregularities of the ridges ("candelabra retouch", Boëda, 2001; fig 12, No 4). In this second case, the retouch reinforces the idea of the thick flake being a tool, more than a core.

Other ways of retouching flakes appear. The retouch is always direct, affecting the upper face of the flake, but its other characteristics vary. They go from a low angle, continuous and parallel retouch (fig. 11, No 4), to a scalariform quite invasive retouch (fig. 12, No 4), to a marginal but abrupt retouch (fig. 15, No 4), to the making of notches, or to marginal discontinuous retouch (fig. 20). Typologically, tools are side-scrapers, denticulates and notches (fig. 13, No 1; fig. 18, No 2). In one case, as shown by refit group D (fig. 10, No 5), lateral notches produce a rostrum on a thick flake. Also, mostly on denticulates, the convergence of two cutting-edge segments creates a robust trihedral part (fig. 12, No 4). Thus, the retouch brings considerable changes in the cutting-edge morphology for denticulates but slightly regularize the edge in other cases. A fine description and a synthesis of cutting-edges morphotypes resulting from a techno-morpho-functional analysis, has already been exposed in Nicoud *et al.,* (2016b p. 187) and is still valid with the new data.

DISCUSSION: MAKING SENSE OF THE APPARENT SIMPLICITY OF LOWER PALAEOLITHIC INDUSTRIES

From tools to mobility pattern

Thus, at first glance, there is no normalization nor in the *débitage* methods nor in the retouching technique, nor in the flakes morphologies. Nevertheless, flaking methods used in Valle Giumentina ALB-42 are based on the same technical conception ("C Type") which is very common during Lower Palaeolithic in Europe (e.g. Ashton *et al.* 1992; Forestier, 1993; Boëda, 2013; Nicoud, 2013b; Rocca, 2016). This is quite an easy way of making a large diversity of flakes, as seen here at Valle

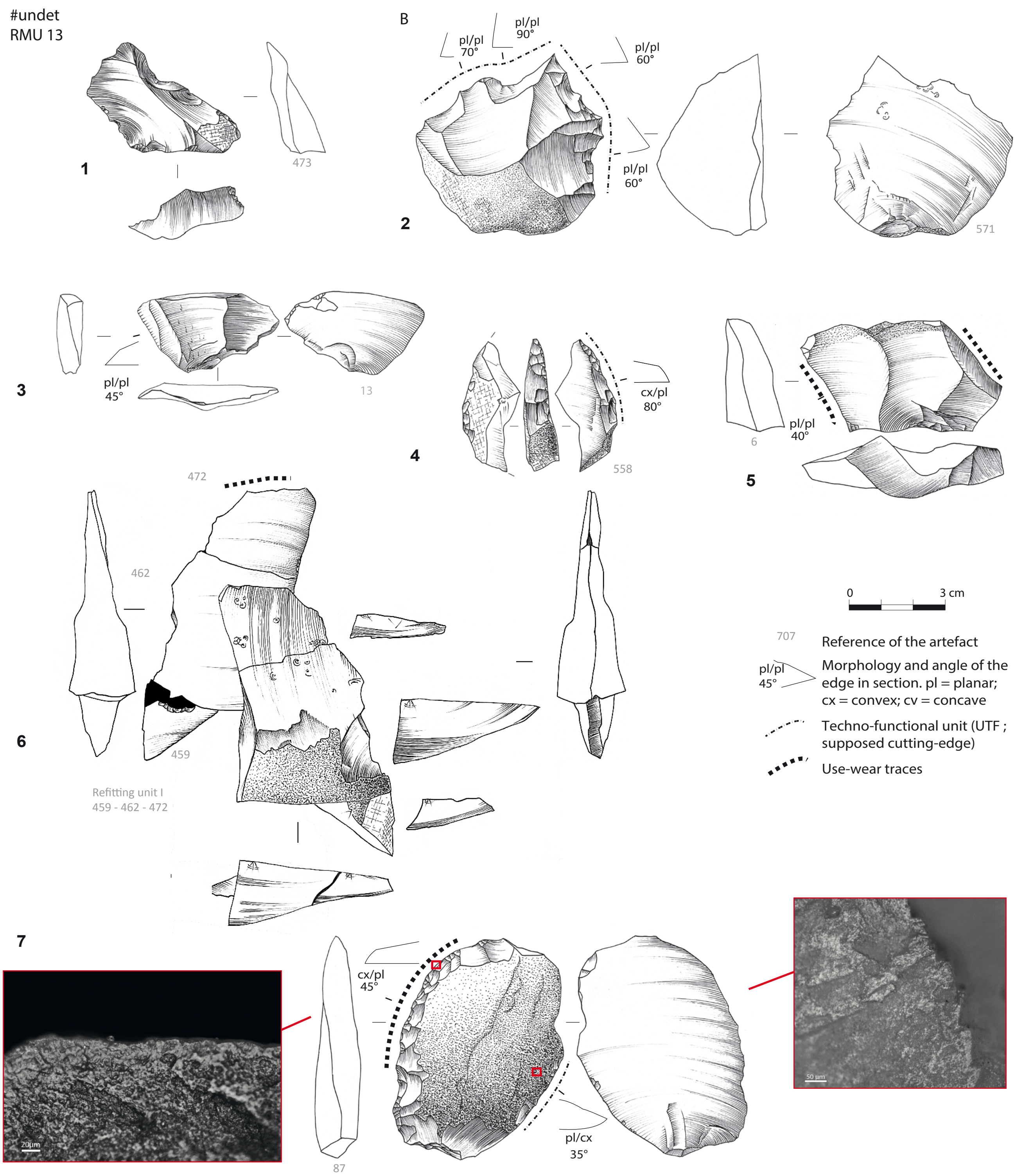


Fig. 18 – Flake industry from Valle Giumentina ALB-42 (RMU #Undet-13): **1**-**2**, notched flakes; **3**, small hinged flake; **4**, fragment of flake with abrupt retouch; **5**, flake from unipolar flaking sequence; **6**, elongated fractured flake forming Refit group I; **7**, lateral scraper on cortical flake with fresh hide and meat cutting traces (left edge) and gripping traces on the cortical face (ink drawings by M. Pagli; pictures: C. Lemorini; CAD: E. Nicoud).

Fig. 18 – *Industrie à éclats de Valle Giumentina ALB-42 (RMU #Undet-13) :* ***1****-****2****, éclats encochés ;* ***3****, petit éclat réfléchi ;* ***4****, fragment d'éclat à retouche abrupte ;* ***5****, éclat issu d'une séquence unipolaire ;* ***6****, éclat allongé fracturé formant l'unité de remontage I ;* ***7****, racloir latéral sur éclat cortical avec traces de découpe de peau fraîche et de viande (bord gauche) et traces de préhension sur la face corticale (dessins à l'encre par M. Pagli ; clichés : C. Lemorini ; DAO : E. Nicoud).*

Giumentina. Flaking only affects an under-volume of the core, there is no preparation. This is sometimes called an "opportunistic" behavior in the sense that the flaking method is adapted to the morphology of the initial block (Arzarello *et al.*, 2016). Here, the diversity of tools that are produced and the variety of methods employed better

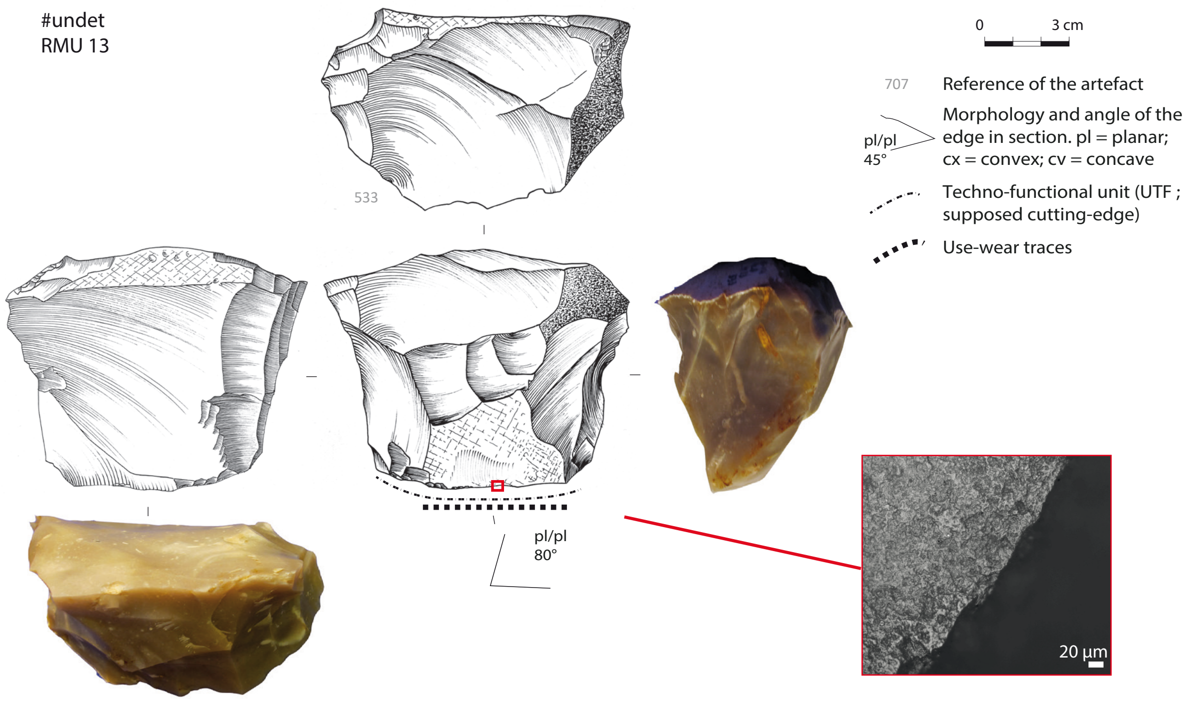


Fig. 19 – Flake industry from Valle Giumentina ALB-42 (RMU #Undet-13): partially cortical core with three main flaking surfaces and percussion traces on one edge (used on wood) (ink drawings by M. Pagli; pictures and CAD: E. Nicoud; picture of the edge: C. Lemorini).

***Fig. 19** – Industrie à éclats de Valle Giumentina ALB-42 (RMU #Undet-13) : nucléus partiellement cortical à trois surfaces de débitage principales portant des traces de percussion sur un bord (utilisé sur du bois) (dessins à l'encre par M. Pagli ; clichés et DAO : E. Nicoud).*

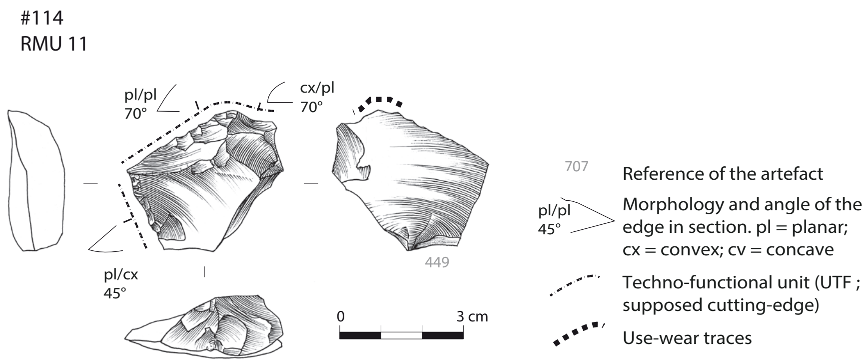


Fig. 20 – Flake industry from Valle Giumentina ALB-42 (RMU #114-11): retouched flake with a tip (ink drawings by M. Pagli; CAD: E. Nicoud).

***Fig. 20** – Industrie à éclats de Valle Giumentina ALB-42 (RMU #114-11) : éclat retouché à pointe (dessins à l'encre par M. Pagli ; clichés et DAO : E. Nicoud).*

reflect an organized strategy of raw material supply and an anticipation of needs as already shown for example at Isernia La Pineta in Molise (Gallotti et Peretto, 2015).

Indeed, we need to zoom out from the typo-technology of the artefacts in order to eventually apprehend the conceptual background and techno-economic patterns behind them. Sorting the artefacts according to raw material characteristics tells us more about the underlying mobility of human groups. A minimum of 14 different cherts RMU gathered in six groups of raw material are imported into the site. These RMUs entered the site in different forms and stages of *chaînes opératoires.* Most of the RMU comes from a potentially identical source, a conglomerate located on the slopes of the Maiella Mountain. Local cherts groups #123 and #124 are well represented and the cortex condition indicates the same supply source. The location of this conglomerate is impossible to know today because of strong tectonic upheavals. The presence of “extra-Maiella” chert (#114), even if it can be from a close source (around 40 km far from the site), helps us considering the fact that prehistoric groups came into Valle Giumentina with either the finished tools or a little stock of good quality raw material. So, they knew the potential good quality chert sources and traveled with a stock which consists of small blocks or thick flakes, never bigger than 15 cm long and with a maximum weight of

Chert	RMU	No	Technology	Worked material	Action	Gripping
#124	1	430	RF	Meat and hide	Undet.	
	1	794	RF	Wood	Scraping	
	2	381	RF	Soft Material	Cutting	
	2	464	RF	Hide	Undet.	Yes
	3	691	F Fgt	Hard material	Scraping	
	other	93	F Fgt	Soft Material	Cutting	
	other	666	F Fgt	Soft Material	Scraping	
#123	4	727	F Fgt	Soft Material	Cutting	
	6	27	F Fgt	Hide	Cutting	
	6	649	RF	Wood	Scraping	Yes
	6	444	F	Soft Material	Undet.	
	8	145	F	1-Edge Right Hard mineral material 2-Edge Left Meat	1-Scraping 2-Cutting	
	8	440	RF	Soft Material	Undet.	
	other	664	F > 1 cm²	Soft Material	Cutting	
	other	K8b	F > 1 cm²	Hide	Cutting	
Undet	12	M13b	F > 1 cm²	Soft Material	Cutting	
	13	87	RF	Hide overlapping wood	Cutting	Yes
	13	472	F	Hide	Undet.	
	13	6	F	Wood	Undet.	Yes
	13	533	Core	Wood	Thrusting Percussion	
	13	722	F	Medium material	Cutting	
	other	490	F Fgt	Soft Material	Cutting	
	other	679	F Fgt	Soft Material	Undet.	
114	10	67	F Fgt	Medium material	Scraping	
	11	449	RF	Meat and hide	Undet.	Yes
	11	M8a	F > 1 cm²	Soft Material	Cutting	

Table 3 – Lithic artefacts with use-wear traces of Valle Giumentina ALB-42, inferred materials worked and activities carried out: F = Flake; RF = retouched flake; F Fgt = Flake fragment. Undet = undeterminable.

Tabl. 3 – *Artefacts lithiques à traces d'utilisation de Valle Giumentina ALB-42, matériaux travaillés et activités réalisées. F = éclat ; RF = éclat retouché ; F Fgt = fragment d'éclat. Undet = indéterminable.*

800 g. This is corroborated by the fact that cores are very few and cannot be the providers of all the flakes. Hammers are very rare at Valle Giumentina, we can imagine people kept them while leaving the site. Some tools are made, then used and discarded within the site. Others are made or retouched within the excavated area before being carried away.

The fragmentation of the various production *chaînes opératoires* says a lot about anticipating the needs and knowing the territory around the site. Valle Giumentina ALB-42 is a specific site within a territory, dedicated to specific activities such as butchery (attested by use-wear and residues analysis) of medium size mammals (as attested by Red Deer remains), and recurrently used as such during the interstadial event of MIS 12b. It doesn't seem to be an isolated site where human groups bring raw material directly from primary sources, but as a site within a larger network of sites. This suggest that human groups move frequently, arriving with tools or parts of blocks, carrying out various activities, dropping off raw materials that can still be exploited, and leaving with other tools. Therefore, a more complex conception of the territory stems from these data, showing that pre-Neanderthal human groups had an articulated vision of the territory with a high degree of anticipation not only in the mobility of tools but maybe also in the reuse of waste from old occupations as a new source of raw material. Even in a well-preserved soil such as ALB-42, it is impossible to assess how many times or during how long the site was occupied. As A.M. Radmilli already found some remains hundred meters away from our excavation, we can imagine that the occupation of the Valle Giumentina area was often repeated during the many years of the soil formation.

Wood processing is also attested on lithic artefacts (scraping). The tools do not have very strong use-wear traces, suggesting for the main part either a use on soft materials and/or a brief use.

Fig. 21 – Example of small flakes and fragments from Valle Giumentina ALB-42 with use-wear traces (pictures: E. Nicoud).

***Fig. 21 –** Exemples de petits éclats et fragments d'éclats de Valle Giumentina ALB-42 portant des traces d'utilisation (clichés et DAO : E. Nicoud).*

Level ALB-42 within the Valle Giumentina sequence and the Lower Palaeolithic of Italy

Techno-economic data give the image of a perennial presence of the populations near the site. This idea is reinforced by the numerous archaeological levels of Valle Giumentina, with settlements occurring both in glacial and interglacial periods. When bifaces appear in the underlying MIS 12 levels SLM-37 and LABM-40, the chert still comes from the Maiella Mountain (Nicoud *et al.,* 2017, 2018). A future confrontation of the techno-economic behaviors in these levels will give us a better understanding of the choices made by prehistoric groups, depending to the site function and the environment. Although some differences are expected within the Valle Giumentina sequence, the site leads us to question continuity rather than change over the 150,000 years registered in the sequence.

Geomorphological context of ALB level is peculiar in the framework of Lower Palaeolithic Italian sites: most of Middle Pleistocene sites were found in alluvial or marsh contexts, while ALB level appears in a palaeosol. Does this original palaeotopographic context imply different characteristics in terms of the activities carried out at the site and the segmentation of the *chaîne opératoire* of lithic production? The deer remains found in the ALB are fragmentary and partial. Is this related to conservation biases, to the limits of the excavation area, or could it also be a consequence of import/export of certain anatomical parts?

The spatial analysis of the data shows that a specific area of the site at north, is probably used for processing the deer carcass. The distribution of tools with traces of use shows that woodworking is also present in the vicinity of the carcass. Tools for working hide appear a few meters away from the carcass. Are these different activities contemporary or unrelated and separate in time? There seems to be a simultaneous use of several spots of activities as shown by the refittings that relate them (Refitting unit E).

Since A.M. Radmilli used the term of "Clactonian of Valle Giumentina facies", Middle Pleistocene new discoveries in Italy have been few but confirm the originality of Valle Giumentina ALB-42 industry within the Italian panorama (e.g. Rocca *et al.*, 2020; Mutillo *et al.*, 2021, fig. 23). No handaxes but good quality cherts and large size flakes, this is far from the small tool industries, pebble industry or handaxes industries –sometimes with manufactured bones- discovered in the Latium area for example. These industries occur at Ficoncella, Fontana Ranuccio, Cava Pompi, Lademagne, Torre in Pietra, Castel di Guido, or even in Molise at Isernia La Pineta or Guado San Nicola, or in the South at Venosa Notarchirico, Loreto or Atella too (Aureli *et al.*, 2016; Pereira *et al.*, 2018; Nicoud, 2013b; Peretto, 2013; Peretto *et al.*, 2016; Piperno, 1999; Abruzzese *et al.*, 2016). Each site has its particularities: preservation, age, climate, environment, paleotopography, function or tools typology. In the lot, only Valle Giumentina is in the immediate vicinity of important good quality and great size chert nodules sources. This allows the production of large flakes that are mainly absent from the other sites. Clactonian refers to English sites (Clacton-on-Sea or High Lodge for example), within the Paris cretaceous basin where chert is abundant. The italian Lower Palaeolithic diversity echoes the one occurring during MIS 12 in whole Europe.

Valle Giumentina ALB-42 and MIS 12 European sites

ALB-42 can be related to the interstadial event of MIS 12b. Such a resolution is unique for this period. MIS 12 in Europe is spanning between 474-427 ka (Bassinot *et al.*, 1994) and corresponds to one of the most arid and longest glacial period of the Quaternary (Rohling *et al.*, 2014). Sites from glacial periods are very rare whereas they are frequent during interglacial periods at MIS 13, 11 and 9 (Nicoud, 2013a). Moreover, dating for most of them is often unprecise because of the dating wide error range (Villa *et al.,* 2016a). Archaeological levels in primary context also showing paleoenvironmental data (fauna, sediments) corroborating a MIS 12 dating are to

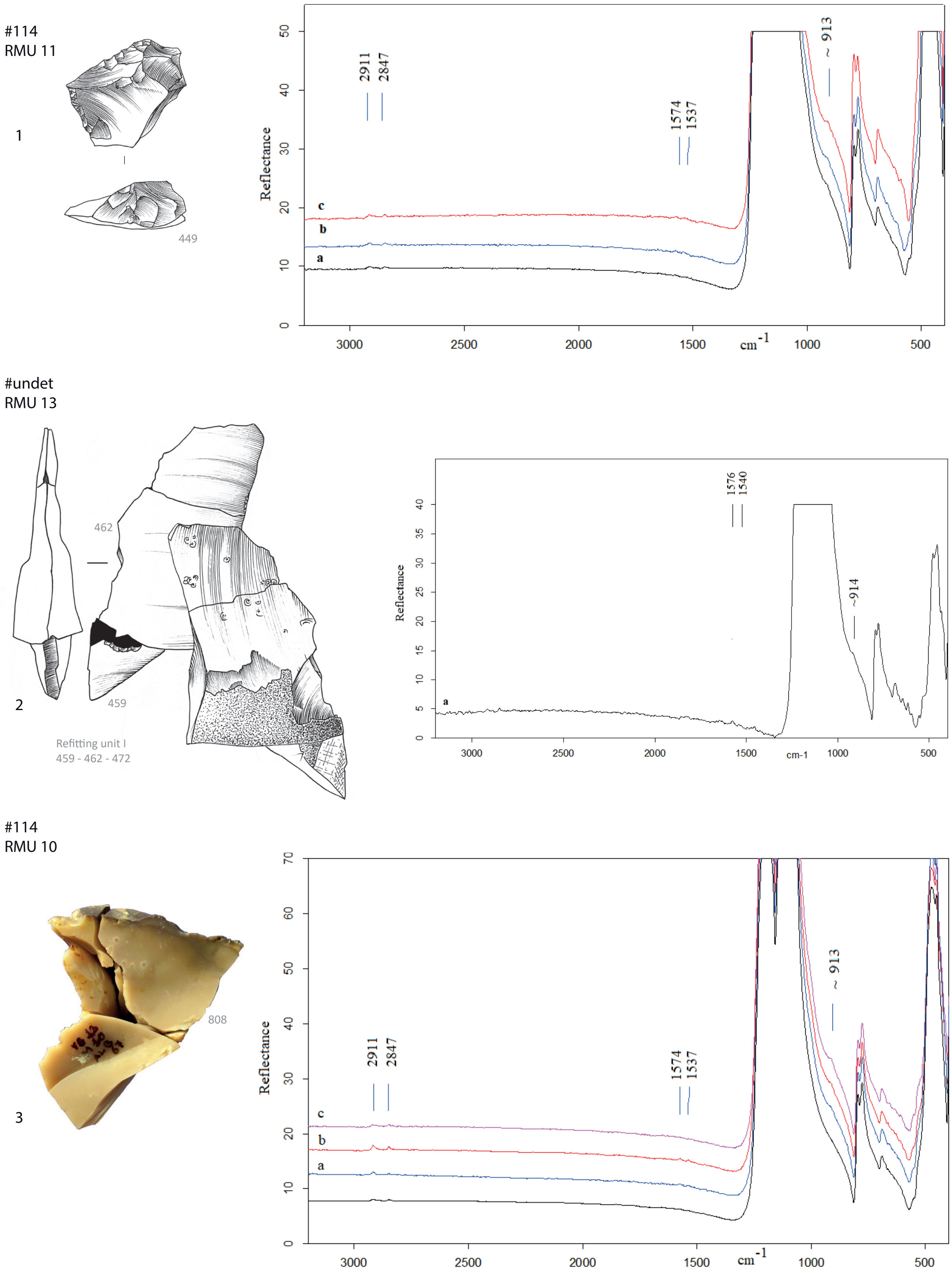


Fig. 22 – Adipocere residue observed by FTIR analysis on Valle Giumentina ALB-42 industry (ink drawings by M. Pagli; pictures and CAD: E. Nicoud).

Fig. 22 *– Résidus d'adipocire observés par l'analyse FTIR sur des industries de Valle Giumentina ALB-42 (dessins à l'encre par M. Pagli ; clichés et DAO : E. Nicoud).*

be found in a few sites: Caune de l'Arago, Visogliano, Valle Giumentina, Menez-Dregan, Cagny-La-Garenne I, Kärlich, (e.g. Villa *et al.*, 2016a; Rodríguez *et al.*, 2021). The first two are a cave and a rock shelter that have preserved important faunal records, while the others have little or no faunal remains.

Flakes and fragments of flakes			of which small flakes < 1 cm²		of which retouched flakes («tools»)	of which typical retouch flakes	of which cortical or semi-cortical	of which with a back
Butts :	nb	% of total	nb	% of total	nb	nb	nb	nb
Absent (fragment)	164	45,18	117	32,23	8	3	32	2
Plain	158	43,53	69	19,01	21	23	53	10
Cortical	22	6,06	2	0,55	8	1	12	3
Punctiform	14	3,86	5	1,38	0	4	2	1
Dihedral	2	0,55		0,00	1	0	0	
Linear	3	0,83	1	0,28	0	1	0	
Total	363	100	194	53,44	38	32	103	16

Table 4 – Flakes and fragments of flakes from level ALB-42 of Valle Giumentina. Butts characteristics, number of retouched pieces, retouch flakes, cortical pieces and pieces with a back (butt and/or edge). Typical retouch flakes are small flakes, with prominent bulb (« éclats de retouche »).

***Tabl. 4 –** Éclats et fragments d'éclats du niveau ALB-42 de la Valle Giumentina. Caractéristiques des talons, nombre de pièces retouchées, éclats de retouche, pièces corticales et pièces à dos (talon et/ou bord). Les éclats de retouche typiques sont de petits éclats, avec un bulbe proéminent.*

Caune de l'Arago Cave Middle Complex

The Middle stratigraphic complex of Arago Cave in Tautavel (France) covers MIS 14, 13 and 12 (Falguères *et al.*, 2010; Lebreton *et al.*, 2017). Lœss deposits and meso- and microfauna records show cold and dry climate at the bottom (level P to L with Reindeer or *Microtus gregalis* and *M. œconomus*) then a major warming (level J to G3, with *Dama*, *Cervus or Hystrix cristata*) and the return of cold climate (G2 to D, with Reindeer, Muskox or *P. priscus*). They are located under a stalagmitic floor dated >350 ka that could have formed during MIS 9 or during both MIS 11 and 9 (Falguères *et al.,* 2015). Also, G level mean age is 438 ± 31 ka according ESR/U-series ages on herbivorous teethes and corroborant with non-destructive gamma spectrometry directly done 40 years ago on Arago XXI fossil skull (Yokoyama and Nguyen 1981). Dating is less reliable and precise for the Lower levels (Falguères *et al.*, 2015). Thus, a MIS 12 (levels P to L), MIS 11 (J-G3) and MIS 10 (G2 to F) attribution cannot be totally excluded as well as a MIS 12 attribution for all the Middle complex (from P to F), mostly if we consider the climatic signature of MIS 14 both at global scale and around the Mediterranean Sea does not show a strong cold period (fig. 2).

In any case, Caune de l'Arago cave is particularly relevant regarding Valle Giumentina as it has a long stratigraphic sequence covering cold events from broadly the same period. The lithic industry is numerous (e.g. Barsky, 2013). It counts handaxes in various levels but also flakes produced by many methods of "*additional volumetric structures of Type-C' (Boëda, 2013), in which one or more useful sub-volumes of the blocks are exploited*" (Capellari *et al.*, 2021, p. 16). There is no preparation of the cores when *débitage* on anvil occurs, or centripetal flaking, and short series of recurrent unipolar removals. Discoïdal bifacial flaking is also present. Products are varied and tools typology covers the Lower Palaeolithic diversity. Differences in tool-kit are interpreted as depending on short or long stays (specific or diversified activities or hunting practices). Small typo-technic differences occur in the sequence mostly at the top of this Middle Complex (Level G and above): a size reduction of the industry, more core preparation (facetted butts), more intensive knapping sequences, decrease in the frequency of pebbles and pebble-tools or increase in the blade index. However, most of these differences also appear in P Level, which lies at the bottom of the sequence (Barsky, 2013). A site-function determinism is suggested to explain it.

Level L is characterised by a cold climate. It contains numerous remains of reindeer (49 individuals of *Rangifer tarandus*) and is correlated with the end of MIS 14 but a MIS 12 age is not excluded. It contains 4428 lithic remains. A recent techno-functional study on this flake production-oriented series shows many recurrences in the selection of blanks according to their volume but independently of the raw material (Capellari *et al.*, 2021). Quartz, quartzite, jaspe, lydite and flint from various distances are present. Some techno-functional objectives are the same: a natural gripping part seems to be searched in the first place and often opposites a linear 70° cutting-edge that is raw or retouched. The fragmentation of the *chaînes opératoires* testifies of some tool mobility patterns across the landscape. We can see a recurrence within the techno-functional objectives and thus, a repetition of the activities carried out in the cave, surely linked to the processing of Reindeer meat and skin. "*All of this implies hominin behaviours that are far from opportunistic*" (op. cit., p. 22).

What is particularly relevant for us here is this recurrence of techno-economic patterns. Indeed, no major changes are visible within the Caune de l'Arago

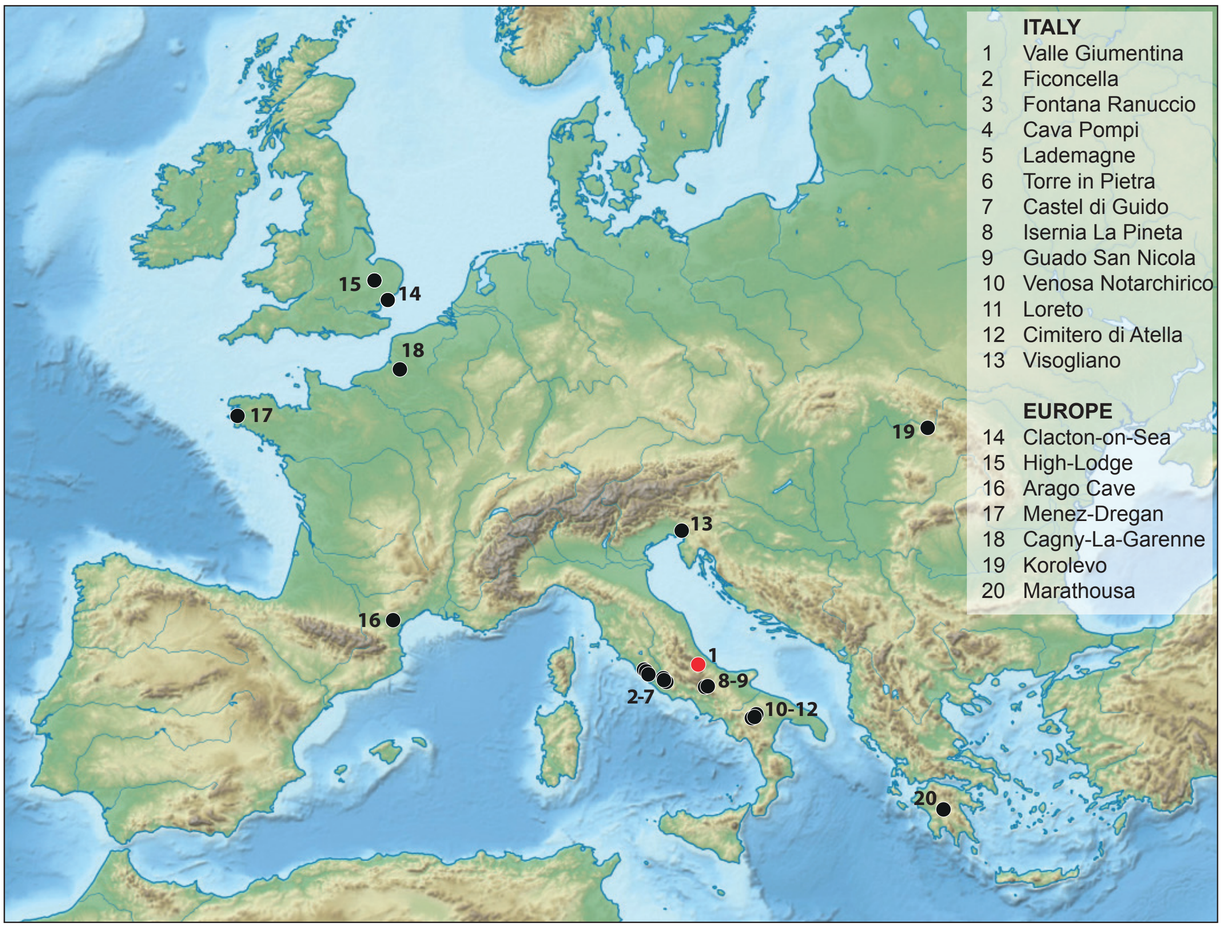


Fig. 23 – Map of sites mentioned in the text.

Fig. 23 – *Carte des sites mentionnés dans le texte.*

sequence in terms of raw material procurement and flaking methods. There, raw material determinism is invoked to explain this similarity (Barsky, 2013). Constraints linked to the morphology of the nodules, the tenacity of the rocks or the distance of supply would lead to flaking methods specific to each raw material: *"[the strategies] must be construed as rational adaptations to raw material availability, rather than as strategies grounded in cultural tradition*" (Byrne, 2004, p. 362; Barsky, 2013). This determinism would explain that "*with separate sites, differences in the lithic record are usually more pronounced between sites than between the different levels of multistratified sites*" (Byrne, 2004, p. 362). This possibility must be explored further in Valle Giumentina.

Visogliano Levels 46 to 13

In Northern Italy, near Trieste, Visogliano cold fauna is often compared with the one of Caune de l'Arago Cave. Locus A and breccia B levels 46 to 13 dating covers MIS 12 age range but also MIS 13 to 10 due to wide error range. Nevertheless, levels 46-40 show warm and humid condition (supposed MIS 13 by the authors) and levels 39-11 are contemporaneous of glacial events. Therefore, level 39 and upwards are related to MIS 12 according to the authors (Falguères *et al.*, 2008). They argue that such an accumulation cannot be made only during MIS 11 and 10. The lithic assemblage of the older levels have discoidal cores, choppers, flakes (few are retouched), and so-called "*protobifaces*" mainly made on local limestone. Flint (chert) is dominant from level 39 and upwards. The choppers disappear and tool-kits of levels 39–37 have many denticulates. So levels 39-37 are called "denticulate" in opposition to the lower (46-40) and upper levels (25–22, 13 and 12) called "Tayacian" (Grifoni et Tozzi, 2006). Valle Giumentina ALB-42 industry cannot find many similarities with Visogliano series. The absence of core preparation still brings technical manifestations closer together whereas they differ in tool typology or techno-economic behaviors.

Menez-Dregan level 9a

In Western France (Brittany), Menez-Dregan level 9a is famous for the occurrence of hearths assigned to MIS 12. ESR dating of this pedogenetic colluvium containing the remains gave an age of 465 ± 65 ka (Monnier *et al.*, 1994). The settlement appears older than the first part of the Holsteinien interglacial (MIS 11) and occurs during a marine regression (Laforge and Monnier, 2011; Ravon *et al.*, 2016) thus assigned to MIS 12. The industry is made on pebbles (the site is close to the ocean) and the raw material mainly used is flint, then quartz, sandstone, microgranite and quartzite. Every stages of flint and quartz production are found *in situ* whereas flakes are imported for other rocks. *Débitage* technique is direct, rarely on anvil. Cores are flaked bifacially but with short series of removals and no preparation. Tools are mainly denticulates, notches and few scrapers occur (Ravon, 2017). "*The site of Menez-Dregan I is an example of the variability of the lithic industries in the Lower Palaeolithic, and highlights the importance of the environment on technical traditions*" (Ravon *et al.*, 2016, p. 142).

Cagny-La-Garenne I CXV, CXB, Lj and CA series

Cagny-La-Garenne I (Northern France) has yielded many archaeological layers within the MIS 12 alluvial silts, sands and gravels interbedded with debris derived from the chalk talus (Tuffreau *et al.*, 1997; Lamotte, 2001). Levels CXCA and CA are considered to be in a primary context and Levels Lj, Lg, CXB and CXV derived from the hillslope. The first two levels correspond to workshop sites where local flint have been used to make bifaces, core and flake, notches and denticulates. This combination is quite typical of Acheulian series from the Paris Basin of which Cagny is a historic site. Among the 1821 artefacts recovered in Levels CXV, CXB, Lj and CA, 141 cores appear, most of them with unipolar *débitage*. Also, 5 cores are ascribed to a Levallois-like technology (Moncel *et al.*, 2020). This early appearance of the Levallois technology in Europe has been discussed including few ancient occurrences as Cagny-La-Garenne II and Guado San Nicola (MIS 11-10), Purfleet and Orgnac 3 (MIS 9) and Cava dell'Olio (>MIS 9). In Cagny-La-Garenne I, the 5 cores selected show a volume made by two asymmetric surfaces, the exploitation of one preferential slightly convex surface, a local preparation of the striking surface and an "*angle de chasse*" inferior to 90°. Very few flakes have facetted butts. Some flakes are *"debordant"* flakes (core-edge flakes). Re-preparation is not attested. Even if good quality cherts are available here too, it is hard to find many convergences with Valle Giumentina ALB-42 first, because of the absence of handaxes and levallois-like technology.

Kärlich H

Kärlich, in west-central Germany in the Neuwied basin, is a complex of open-air sites within a stratified context. The stratigraphy consists of alluvial gravels and sands of ancient Rhine terraces, followed by interbedded loess, paleosols and tephras, and lacustrine deposits. Kärlich is mostly famous for its interglacial sequence containing archaeological remains at Kärlich-Seeufer (Gaudzinski, 1997). Older than this interglacial sequence is Kärlich thick level H, typical of a glacial period. At the bottom of Level H, a rescue excavation carried out in 1983 on 1 m² yielded 26 artefacts of quartz and quartzite of which pebble tools, two cores and small flakes (Würges, 1994). It is first attributed to the beginning of a cold stage due to its lithostratigraphic position and the presence of a steppe mammoth tusk. It is then assigned to MIS 12 thanks to its position between two $^{40}Ar/^{39}Ar$-dated tephra even though the base of the H level is closer to the older tephra (618 ± 13 ka and 452 ± 8 ka; Van Den Bogaard *et al.*, 1989; Bosinski, 1992; Haidle et Pawlik, 2010).

Korolevo level VI

In Ukraine (Transcarpatia), Korolevo level VI has been assigned to MIS 14 thanks to correlation with other stratigraphic sequences in Central Europe (Haesaerts et Koulakovskaia, 2006; Koulakovska *et al.*, 2010; Nawrocki *et al.*, 2016). A MIS 12 age cannot be totally excluded as the first TL dating above level VI gave 360 ± 50 ka. It occurs at the top of a forest grey soil. Near 1500 artefacts have been found in many pits and excavation areas in the andesite quarry. This local raw material is used by prehistoric groups and the remains have a strong patina (Rocca, 2016). Cores indicate that only an under-volume is flaked in order to produce short series of removals, with no preparation. « *The aim of the production is to obtain large backed flakes, elongated/convergent flakes and medium quadrangular flakes. Only a few products are flaked on every core, using the lateral convexities and following the ridges of the previous removal* » (Rocca *et al.*, 2016, p. 215). Retouched tools are rare (denticulates). Many flakes wear a back opposite the cutting-edge. Early convex removals both open a striking platform and create adequate convexities. In sum, the production system of Korolevo based on selection, recurrence, and slight preparation tends to ascribe it at a « C and rarely D system » (according Boëda, 2013). No clear resemblances appear with Valle Giumentina ALB-42, beyond the volumetric conception of the *débitage* (System C), a flake-aimed system and the importance of retouch phase.

CONCLUSION: GOOD QUALITY SITES ARE REQUIRED TO ACCUMULATE RELIABLE DATA

From all this fast inventory two main aspects of Lower Paleolithic are brought to light. The scarcity of MIS 12 sites and more broadly of glacial period settlements are a major issue as well as dating approximations. For now, we are aware of a maximum of five sites during 50 000 years within circa 10 million km²: how relevant are they to represent human societies at this time? The Valle Giumentina ALB-42 somewhat fills the void thanks to a precise chronostratigraphic context and a well-preserved archaeological level. It seems to be the first occurrence of a MIS 12b site in Europe.

ALB-42 fits well into its technological atmosphere "between originality and banality" (Rocca, 2016). Indeed, the absence of core preparation is the norm also called "C system" even if it occurs sometimes (Korolevo VI, Cagny-La-Garenne I and II, Guado San Nicola, etc. "D or E systems"). It is easier to define these sites regarding what changes next, this is the appearance of more integrated technological concept: Levallois, Discoïde, Laminar, etc. During Lower Paleolithic, techno-functional needs seem less constrained by flaking schemes. However, this kind of technical trend can be seen in handaxes manufacture mainly since MIS 11 (Nicoud, 2013b). The "Levallois-like" *débitage* (preferential flaking surface and management of core convexities) appears anciently but does not last until hundreds of thousands years. This indicates technical convergences which can also be considered for handaxe manufacture or for every other production.

Reconstructing the whole lithic production system, using the *chaîne opératoire* concept, from raw material supply, to tools use, discard and export from the site tell us that, at Valle Giumentina ALB-42, a same techno-economic and mobility patterns guides the production. The use of local raw material is clearly the norm for Lower Paleolithic, until 35 km for Caune de l'Arago Cave (De Lumley *et al.*, 2004). There is always exception, like the "Maiolica chert" recognized in ALB-42, but techno-economic patterns seem identical.

Typo-technologically, ALB-42 appears to be just one expression of the "amazing richness" of the Lower Paleolithic package (Otte, 2001). Here techno-economic data show how people came many times during MIS 12b on the spot, gathering good quality chert mostly in a nearby conglomerate, bringing tools already done, or thick flakes or small blocks as a raw material stock, then they used or retouched tools on the spot, abandoned them or bring them away. The recurrence of mobility pattern in this level indicates a well-known and functionally fragmented territory and an anticipation of needs.

Functional studies show wood processing and butchery activities on a large panel of tool morphotypes. The presence/absence of certain tools (such as denticulate, handaxes, backed flakes) or flaking methods is still hard to strictly correlate with determined factors such as activity, raw material availability, but also climate, environment, technical flexibility and adaptation, or culture. Maybe sometimes it is one factor, and elsewhere it is another. For example, it is still not clear if bifaces have a special functional role (Guibert--Cardin *et al.*, 2021).

This conclusion relativizes the cultural value of the typology of the artefacts. Bifaces, large flakes, small tools: these industries make up the whole Lower Paleolithic. In the state of the art, they presage neither a particular activity, nor a determinism of the raw material. So how can we imagine they represent particular cultural traits? We absolutely need more sites in order to precise for each occurrence, what looks alike and what is different. It would be particularly useful at a regional scale or within one site before doing intercontinental comparisons. New discoveries, such as Marathusa I in Greece or Ficoncella in Italy, or re-entering old sites such as Cimitero di Atella or Valle Giumentina in Italy, are fundamental to enrich the ongoing debate (e. g. Aureli *et al.*, 2016; Tourloukis *et al.*, 2018; Rocca and Aureli, 2019; Nicoud, Aureli, Pagli 2015; Rocca *et al.*, 2020). The multidisciplinary work led at Valle Giumentina, the multiplicity of the archaeological layers occurring between c. 585 and 450 ka, as well as the quality of their preservation, encourages us to obtain a better chronological, environmental and techno-economic resolution of the Human settlements.

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SUPPLEMENTARY DATA

ALB-m101 Sanidine - single grains **Flux standard**		Lab #N1484-01/N1484-09 **ACs-2**	Irradiation #119 **1.194 Ma**	J value = 0.00035100 ± 0.00000176				reactor OSIRIS, CEA Saclay		**$^{40}Ar/^{39}Ar$ CEA-LSCE Facility ; Analysts : A. Pereira & S. Nomade**								
N	^{40}Ar (moles)	^{36}Ar V	$\pm s_{36}$ V	^{37}Ar V	$\pm s_{37}$ V	^{38}Ar V	$\pm s_{38}$ V	^{39}Ar V	$\pm s_{39}$ V	^{40}Ar V	$\pm s_{40}$ V	D[1]	$\pm\% s_D$	$\%^{40}Ar^*$	Age (ka)	±s (ka)	K/Ca	± 1s
N1484-01	2,35E-15	5,54E-7	5,85	2,79E-5	4,60	3,28E-5	0,38	2,17E-3	0,18	1,71E-3	0,16	1,009	0,07	90,49	**452,5**	**± 3,0**	33,37	1,54
N1484-02	2,15E-15	4,18E-7	5,54	4,21E-5	5,47	3,17E-5	0,65	2,03E-3	0,14	1,57E-3	0,13	1,009	0,07	92,33	**452,5**	**± 2,3**	20,77	1,14
N1484-03	1,37E-15	3,59E-8	75,35	3,08E-5	4,89	2,05E-5	0,66	1,36E-3	0,14	9,97E-4	0,18	1,009	0,07	99,23	**460,5**	**± 3,9**	19,00	0,93
N1484-04	1,36E-15	2,89E-8	87,92	3,05E-5	2,78	2,18E-5	0,76	1,36E-3	0,12	9,92E-4	0,20	1,009	0,07	99,44	**458,0**	**± 3,7**	19,23	0,53
N1484-05	1,18E-15	1,00E-8	191,28	1,92E-5	3,05	1,28E-5	0,87	8,04E-4	0,17	8,59E-4	0,24	1,009	0,07	99,88	**675,3**	**± 4,9**	18,02	0,55
N1484-06	8,48E-16	2,32E-7	12,17	1,35E-5	3,45	1,16E-5	1,03	7,56E-4	0,22	6,19E-4	0,24	1,009	0,07	89,03	**461,7**	**± 7,2**	24,02	0,83
N1484-07	2,58E-15	3,86E-6	0,70	2,79E-5	2,15	1,69E-5	0,63	1,01E-3	0,13	1,88E-3	0,16	1,009	0,07	38,90	**458,9**	**± 5,4**	15,54	0,33
N1484-08	1,40E-15	7,86E-7	3,26	9,46E-6	3,11	1,56E-5	0,63	1,10E-3	0,18	1,02E-3	0,16	1,009	0,07	77,02	**452,7**	**± 4,6**	49,85	1,55
N1484-09	9,97E-16	1,60E-7	13,40	1,45E-5	5,18	1,44E-5	0,67	9,31E-4	0,18	7,28E-4	0,17	1,009	0,07	93,64	**463,6**	**± 4,5**	27,58	1,43

Results	40Ar*/39Ark	± 1s	Age (Ka)	± 1s	MSWD	39Ar(k) (n)	K/Ca	± 1s
Weighted mean	0,72	0,00 ± 0,33%	455,7	± 2,7 ± 0,60%	1,35	1,09 8	19,1	± 2,4
			Full External Error	± 6,2	1,00	Statistical T ratio		
			Analytical Error	± 1,5				
Results		40(a)/36(a)	± 1s	40(r)/39(k)	± 1s	Age (Ka)	± 1s	
								MSWD
Inverse Isochron		199,50	± 3,010 ± 1,00%	0,72	0,00 ± 0,44%	455,5	± 2,9 ± 0,64%	1,55
Full External Error							± 6,3	
Analytical Error							± 1,8	
Statistics		Statistical F ratio	1,12		Convergence	0,00		
		Error Magnification	1,246		Number of Iterations	3		
		Number of Data Points	9		Calculated Line	Weighted York-2		

Background corrections ALB-m101										
N	^{36}Ar	±s36	^{37}Ar	±s37	^{38}Ar	±s38	^{39}Ar	±s39	^{40}Ar	±s40
	V	V	V	V	V	V	V	V	V	V
N1484-01	1,78E-07	2,20E-08	1,00E-08	5,00E-09	3,09E-8	3,09E-08	2,68E-07	4,74E-08	4,55E-05	3,14E-07
N1484-02	1,78E-07	2,20E-08	1,00E-08	5,00E-09	3,09E-8	3,09E-08	2,68E-07	4,74E-08	4,55E-05	3,14E-07
N1484-03	1,78E-07	2,20E-08	1,00E-08	5,00E-09	3,09E-8	3,09E-08	2,68E-07	4,74E-08	4,55E-05	3,14E-07
N1484-04	1,98E-07	1,63E-08	2,10E-08	1,05E-08	1,01E-8	1,01E-08	1,65E-07	1,00E-07	3,93E-05	5,97E-07
N1484-05	1,98E-07	1,63E-08	2,10E-08	1,05E-08	1,01E-8	1,01E-08	1,65E-07	1,00E-07	3,93E-05	5,97E-07
N1484-06	1,98E-07	1,63E-08	2,10E-08	1,05E-08	1,01E-8	1,01E-08	1,65E-07	1,00E-07	3,93E-05	5,97E-07
N1484-07	1,26E-07	1,03E-08	1,00E-08	5,00E-09	1,84E-8	1,84E-08	1,11E-06	6,42E-08	3,00E-05	3,42E-07
N1484-08	1,05E-07	1,98E-08	1,50E-08	7,50E-09	1,81E-8	1,81E-08	5,34E-07	5,28E-07	3,19E-05	3,83E-07
N1484-09	1,05E-07	1,98E-08	1,50E-08	7,50E-09	1,81E-8	1,81E-08	5,34E-07	5,28E-07	3,19E-05	3,83E-07

Annex 1 – F40Ar/39Ar analytical data for level ALB-42 of Valle Giumentina (sample m101).

Annexe 1 – *Données analytiques 40Ar/39Ar du niveau ALB-42 of Valle Giumentina (échantillon m101).*

BIBLIOGRAPHICAL REFERENCES

Abruzzese C., Aureli D., Rocca R. (2016) – Assessment of the Acheulean in Southern Italy: New study on the Atella site (Basilicata, Italy), *Quaternary International*, 393, p. 158-168.

Arzarello M., de Weyer L., Peretto C. (2016) – The first European peopling and the Italian case: Peculiarities and “opportunism”, *Quaternary International*, 393, p. 41-50.

Ashton N., Lewis S.G., Parfitt S. (dir.) (1998) – *Excavations at the Lower palaeolithic site at East Farm, Barnham, Suffolk 1989-94*, vol. 125, British Museum Press (British Museum Occasional Paper), 305 p.

Ashton N., Cook J., Lewis S. G., Rose J. éds (1992) – *High Lodge, excavations by G. de G. Sieveking 1962-1968 and J. Cook 1988*, British Museum press, 260 p.

Ashton N., McNabb J., Irving B., Lewis S., Parfitt S. (1994) – Contemporaneity of Clactonian and Acheulian flint industries at Barnham, Suffolk, *Antiquity*, 68, 260, p. 585-589.

Aureli D., Rocca R., Lemorini C., Modesti V., Scaramucci S., Milli S., Giaccio B., Marani F., Palombo M.R., Contardi A. (2016) – Mode 1 or mode 2? “Small tools” in the technical variability of the European Lower Palaeolithic: The site of Ficoncella (Tarquinia, Lazio, central Italy), *Quaternary International*, 393, p. 169-184.

Bahain J.-J., Voinchet P., Vietti A., Shao Q., Tombret O., Pereira A., Nomade S., Falguères C. (2021) – ESR/U-series and ESR dating of several Middle Pleistocene Italian sites: Comparison with 40Ar/39Ar chronology, *Quaternary Geochronology*, 63, p. 101151.

Barsky D. (2013) – The Caune de l’Arago stone industries in their stratigraphical context, *Comptes Rendus Palevol*, 12, 5, p. 305-325.

Bassinot F., Labeyrie L., Vincent E., Quidelleur X., Schackleton N., Lancelot Y. (1994) – The astronomical theory of climate and the age of the Brunhes-Matuyama magnetic reversal, *Earth and Planetary Science Letters*, 126, 1-3, p. 91-108.

Bertola S. (2016) – Southern Alpine (Trento Plateau) and Northern Apennine flints: Ages, Distribution and Petrography, *in Tomasso, A., Binder, D., Martino, G., Simon, P., Porraz, G., Naudinot, N. (Eds.),* Ressources Lithiques, Productions et Transferts Entre Alpes et Méditerranée, *Les séances de la SPF*, 5, p.55-75.

Binder D. (1998) – Silex blond et complexité des assemblages lithiques dans le Néolithique liguro-provençal, *in* A. D’Anna et D. Binder (dir.), *Production et identité culturelle : actualité de la recherche : Rencontres méridionales de préhistoire récente, actes de la deuxième session, Arles (Bouches-du-Rhône), 8 et 9 novembre 1996*, Antibes, APDCA, p. 111-128.

Boëda E. (1991) – Approche de la variabilité des systèmes de production lithique des industries du Paléolithique inférieur et moyen : Chronique d’une variabilité attendue, *Techniques et culture*, 17-18, p. 37-79.

Boëda E. (2001) – Détermination des Unités Techno-Fonctionnelles de pièces bifaciales provenant de la couche acheuléenne C’3 base du site de Barbas I, *in Actes de la table-ronde internationale organisée à Caen (France, 14 et 15 octobre 1999)*, Liège, ERAUL, p.51-75.

Boëda E. (1997) – *Technogénèse de systèmes de production lithique au Paléolithique inférieur et moyen en Europe occidentale et au Proche-Orient*, Thèse de doctorat, Université de Paris X - Nanterre, France, 173 p.

Boëda E. (2013) – *Techno-logique & Technologie. Une Paléo-histoire des objets lithiques tranchants*, @rchéo-éditions, France, Prigonrieux (Dordogne): @rchéo-éditions (Préhistoire au Présent), 264 p.

Bosinski G. (1992) – Die ersten Menschen in Eurasien, *Jahrbuch des Römisch-Germanischen Zentralmuseums Mainz*, 39, 1, p. 131-184.

Breuil H. (1932) – Les industries à éclats du paléolithique ancien, I, le Clactonien, *Préhistoire*, 1, 2, p. 125-190.

Brewer R. (1964) – *Fabric and Mineral Analysis of Soils.*, New York, Wiley, 470 p.

Bullock P., Fedoroff N., Jongerius A., Stoops G., Tursina T. (1985) – *Handbook for soil thin section description*, Waine Research Publications, 152 p.

Byrne L. (2004) – Lithic tools from Arago cave, Tautavel (Pyrénées-Orientales, France): behavioural continuity or raw material determinism during the Middle Pleistocene? *Journal of Archaeological Science*, 31, 4, p. 351-364.

Cancellieri E. (2015) – *Over the Hills and Far Away: Last Glacial Maximum Lithic Technology around the Great Adriatic Plain*, Oxford, Archaeopress

Capellari F., Grégoire S., Lumley H. de (2021) – Lower Palaeolithic Core-Flake Industries in Western Europe: Techno-Functional Study of Layer « L» of Caune de l’Arago Cave (Tautavel, France), *Journal of Paleolithic Archaeology*, 4, 3, p. 1-35.

Chacón, M. G., Bargalló, A., Gabucio, M. J., Rivals, F., Vaquero, M. (2015) – Neanderthal behaviors from a spatio-temporal perspective: An interdisciplinary approach to interpret archaeological assemblages, in Conard, N. J., Delagnes, A., éds., *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age IV*, p. 253-294.

Chevrier B. (2012) – Ni espace ni temps en Préhistoire ancienne : « Out of Africa » ou le paradigme de la flèche, *M@ppemonde* 106, 19 p. [en ligne].

D’Agostino N., Jackson J.A., Dramis F., Funiciello R. (2001) – Interactions between mantle upwelling, drainage evolution and active normal faulting: an example from the central Apennines (Italy), *Geophysical Journal International*, 147, 2, p. 475-497.

Degeai J.-P., Villa V., Chaussé C., Pereira A., Nomade S., Aureli D., Pagli M., Nicoud E. (2018) – Chemical weathering of palaeosols from the Lower Palaeolithic site of Valle Giumentina, central Italy, *Quaternary Science Reviews*, 183, p. 88-109.

Demangeot J., Radmilli A.M. (1966) – Le gisement paléolithique de Valle Giumentina (Appennin central) et ses problèmes, *Eiszeitalter und Gegenwart*, 17, p. 159-199.

Demangeot J., Radmilli A.M. (1953) – Le gisement quaternaire de la Valle Giumentina (Abruzzes adriatiques), Stratigraphie et Palethnologie, *Contributi di Scienze Geologiche, suppl. à la Ricerca Scientifica*, 3, p. 11-123.

Falguères C., Bahain J.-J., Duval M., Shao Q., Han F., Lebon M., Mercier N., Perez-Gonzalez A., Dolo J.-M., Garcia T. (2010) – A 300–600 ka ESR/U-series chronology of Acheulian sites in Western Europe, *Quaternary International*, 223-224, p. 293-298.

Falguères C., Bahain J.-J., Tozzi C., Boschian G., Dolo J.-M., Mercier N., Valladas H., Yokoyama Y. (2008) – ESR/U-series chronology of the Lower Palaeolithic palaeoanthropological site of Visogliano, Trieste, Italy, *Quaternary Geochronology*, 3, 4, p. 390-398.

Falguères C., Shao Q., Han F., Richard M., Perrenoud C., Moigne A.-M., Lumley de H. (2015) – New ESR and U-series dating at Caune de l'Arago, France: A key-site for European Middle Pleistocene, *Quaternary Geochronology*, 30, p. 547-553.

Fernandes P. (2012) – *Itinéraires et transformations du silex : une pétroarchéologie refondée, application au Paléolithique moyen*, thèse de doctorat, Université de Bordeaux 1, Bordeaux, 623 p.

Fiers G. (2020) – *The characteristics and alteration of flint: a multi-methodological approach and significance for archaeological research*, PhD thesis, Ghent University, 235 p.

Forestier H. (1993) – Le Clactonien : mise en application d'une nouvelle méthode de débitage s'inscrivant dans la variabilité des systèmes de production lithique du Paléolithique ancien, *Paléo, Revue d'Archéologie Préhistorique*, 5, 1, p. 53-82.

Gallotti R., Peretto C. (2015) – The Lower/Early Middle Pleistocene small débitage productions in Western Europe: New data from Isernia La Pineta t.3c (Upper Volturno Basin, Italy), *Quaternary International*, 357, p. 264-281.

Gaudzinski S. (1997) – Über die komplexe Genese mittelpleistozäner archäologischer Fundstellen am Beispiel des Platzes Kärlich-Seeufer (Mittelrhein), *E&G Quaternary Science Journal*, 47, 1, p. 1-27.

Geneste J.-M. (1991) – Systèmes techniques de production lithique. Variations techno-économiques dans les processus de réalisation des outillages paléolithiques, *Techniques & Culture. Revue semestrielle d'anthropologie des techniques*, 17-18, p. 1-35.

Giaccio B, Arienzo I, Sottili G, Castorina F., Gaeta M., Nomade S., Galli P., Messina P. (2013) – Isotopic (Sr–Nd) and major element fingerprinting of distal tephras: an application to the Middle-Late Pleistocene markers from the Colli Albani volcano, central Italy, *Quaternary Science Reviews,* 67, p. 190–206.

Girone A., Maiorano P., Marino M., Kucera M. (2013) – Calcareous plankton response to orbital and millennial-scale climate changes across the Middle Pleistocene in the western Mediterranean, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 392, p. 105-116.

Gönen M., Öztürk S., Balköse D., Okur S., Ülkü S. (2010) – Preparation and Characterization of Calcium Stearate Powders and Films Prepared by Precipitation and Langmuir−Blodgett Techniques, *Industrial & Engineering Chemistry Research*, 49, 4, p. 1732-1736.

Gonzalez G., Pépin D. (1996) – Le cerf (*Cervus elaphus*) en milieu montagnard et nordique. 1. Paléontologie, occupation de l'espace, utilisation du temps et des ressources, *Gibier Faune Sauvage*, 13, p. 27-52.

Grifoni R., Tozzi C. (2006) – L'émergence des identités culturelles au Paléolithique inférieur : le cas de l'Italie, *Comptes Rendus Palevol*, 5, 1-2, p. 137-148.

Guibert--Cardin J., Capellari F., Lhomme V., Connet N., Nicoud E., Beyries S. (2021) – Lower Palaeolithic stone tools: a techno-functional study of the Soucy 3P assemblage (France), *in* S. Beyries, C. Hamon, et Y. Maigrot (dir.), *Beyond use-wear traces: going from tools to people by means of archaeological wear and residue analyses*, Sidestone Press, p.101-116.

Haesaerts P., Koulakovskaia L. (2006) – La séquence pédosédimentaire de Korolevo (Ukraine Transcarpatique) : contexte chronostratigraphique et chronologique, *in* Koulakovskaia, L. éd., *The European Middle Palaeolithic*, p. 21-37.

Haidle M.N., Pawlik A. (2010) – The earliest settlement of Germany: Is there anything out there? *Quaternary International*, 223-224, p. 143-153.

Hénichart J.P., Bernier J.P., Roman M., Roussel P. (1982) – Identification of calcium palmitate in gallstones by infra-red spectroscopy, *International Journal of Clinical Chemistry*, 118, 2-3.

Inizan M.-L., Reduron M., Roche H., Tixier J. (1995) – *Préhistoire de la pierre taillée*, vol. Tome 4 : Technologie de la pierre taillée, France, Meudon, CREP, 199 p.

Koppers A.A.P. (2002) – ArArCALC – software for Ar-40/Ar-39 age calculations, *Computers & Geosciences*, 28, 5, 605-619.

Koulakovska L., Usik V., Haesaerts P. (2010) – Early Paleolithic of Korolevo site (Transcarpathia, Ukraine), *Quaternary International*, 223-224, p. 116-130.

Laforge M., Monnier J.-L. (2011) – Contribution à la chronostratigraphie du gisement paléolithique inférieur de Menez-Dregan 1 (Plouhinec, Finistère, France). Corrélations avec les dépôts pléistocènes de la falaise de Gwendrez., *Quaternaire*, 22, 2, p. 91-104.

Lamotte A. (2001) – *Les industries à bifaces de l'Europe du Nord-Ouest au Pléistocène moyen. L'apport des données des gisements du bassin de la Somme, de l'Escaut et de la baie de Saint-Briene* (BAR International Series 932), 187 p.

Lebreton L., Desclaux E., Hanquet C., Cuenca-Besco G., Moigne A.-M., Perrenoud C., Grégoire S. (2017) – Variations paléoenvironnementales au sein de l'Unité Archéostratigraphique G (UA G) de la Caune de l'Arago (Tautavel, France) : apport des paléocommunautés de rongeurs, *Quaternaire. Revue de l'Association française pour l'étude du Quaternaire*, vol. 28/3, p. 313-321.

Lee J.Y., Marti K., Severinghaus J.P., Kawamura K., Yoo H.S., Lee J.B., Kim J.S. (2006) – A redetermination of the isotopic abundances of atmospheric Ar, *Geochimica et Cosmochimica Acta*, 70, 17, p. 4507-4512.

Lemorini C. (2000) – *Reconnaître des tactiques d'exploitation du milieu au Paléolithique moyen : la contribution de l'analyse fonctionnelle : Etude fonctionnelle des industries lithiques de Grotta Breuil (Latium, Italie) et de La Combette (Bonnieux, Vaucluse, France)* (BAR International Series 858), 142 p.

Lepot M. (1993) – *Approche techno-fonctionnelle de l'outillage lithique moustérien : essai de classification des parties actives en termes d'efficacité technique : application à la couche M2e sagittale du Grand abri de la Ferrassie (fouille Henri Delporte)*, Mémoire de maîtrise, Nanterre, université de Paris X, 170 p.

Leroi-Gourhan A. (1945) – *Évolution et technique 2, Milieu et technique,* 2e éd. 1973, Paris, Albin Michel (coll. Sciences d'aujourd'hui).

Lhomme V. (2007) – Tools, space and behaviour in the Lower Palaeolithic: Discoveries at Soucy in the Paris Basin., *Antiquity*, 81, p. 536-554.

Limondin-Lozouet N., Villa V., Pereira A., Nomade S., Bahain J.-J., Stoetzel E., Aureli D., Nicoud E. (2017) – Middle Pleistocene molluscan fauna from the Valle Giumentina(Abruzzo, Central Italy): Palaeoenvironmental, biostratigraphical and biogeographical implications, *Quaternary Science Reviews*, 156, p. 135-149.

Lisiecki L.E., Raymo M.E. (2005) – A Pliocene-Pleistocene stack of 57 globally distributed benthic $\delta^{18}O$ records: Pliocene-Pleistocene benthic stack, *Paleoceanography*, 20, 1, p. PA1003.

de Lumley H., Grégoire S., Barsky D., Batalla G., Bailon S., Belda V., Briki D., Byrne L., Desclaux E., El Guenouni K., Fournier A., Kacimi S., Lacombat F., de Lumley M.-A., Moigne A.-M., Moutoussamy J., Paunescu C., Perrenoud C., Pois V., Quiles J., Rivals F., Roger T., Testu A. (2004) – Habitat et mode de vie des chasseurs paléolithiques de la Caune de l'Arago (600 000–400 000 ans), *L'Anthropologie*, 108, 2, p. 159-184.

Machado, J., Mayor, A., Hernández, C. M., Galván, B. (2019) – Lithic refitting and the analysis of Middle Palaeolithic settlement dynamics: a high-temporal resolution example from El Pastor rock shelter (Eastern Iberia). *Archaeological and anthropological sciences*, *11*(9), p. 4539-4554.

Madejová J. (2003) – FTIR techniques in clay mineral studies, *Vib Spectrosc*, 31, p. 1-10.

Marciani, G., Spagnolo, V., Aureli, D., Ranaldo, F., Boscato, P., Ronchitelli, A. (2016) – Middle Palaeolithic technical behaviour: Material import- export and Levallois production at the SU 13 of Oscurusciuto rock shelter, Southern Italy, *Journal of Lithic Studies* 3, p. 1-24.

Marreiros J.M., Bao J.F.G., Bicho N.F. (dir.) (2015) – *Use-Wear and Residue Analysis in Archaeology*, Manuals in Archaeological Method, Theory and Technique series, Springer International Publishing, 223 p.

McPherron S. (2007) – *Tools versus cores: alternative approaches to stone tool analysis*, Cambridge Scholars Publishing, Newcastle, 280 p.

Moncel M.-H., Ashton N., Arzarello M., Fontana F., Lamotte A., Scott B., Muttillo B., Berruti G., Nenzioni G., Tuffreau A., Peretto C. (2020) – Early Levallois core technology between Marine Isotope Stage 12 and 9 in Western Europe, *Journal of Human Evolution*, 139, p. 102735.

Monnier J.-L., Hallegouët B., Hinguant S., Falguères C., Laurent M., Yokoyama Y., Auguste P., Bahain J.-J., Marguerie D., Molines N., Morzadec H. (1994) – A New Regional Group of the Lower Palaeolithic in Brittany (France) Recently Dated by Electron Spin Resonance, *Comptes Rendus de l'Academie des Sciences*, 319, 2, p. 155-160.

Mutillo B., Lembo G., Gallotti R. (2021) – Lithic productions during the first half of the Middle Pleistocene (MIS 19-12) in the Italian Peninsula: an overview, *Alpine and Mediterranean Quaternary*, 34, 1, p. 1-21.

Nawrocki J., Łanczont M., Rosowiecka O., Bogucki A.B. (2016) – Magnetostratigraphy of the loess-palaeosol key Palaeolithic section at Korolevo (Transcarpathia, W Ukraine), *Quaternary International*, 399, p. 72-85.

Nicoud E. (2013a) – Complexité des stratigraphies régionales et nouveau modèle d'apparition et de diffusion du phénomène Acheuléen en Europe de l'Ouest, *Quaternaire*, 24, 4, p. 407-417.

Nicoud E. (2013b) – *Le paradoxe acheuléen*, Paris, Comité des travaux historiques et scientifiques (coll. Documents préhistoriques 32, Bibliothèque des Ecoles Françaises d'Athènes et de Rome 356), 309 p.

Nicoud E., Pagli M., Aureli D., Agostini S., Boschian G., Chaussé C., Degeai J.-P., Fusco F., Kuzucuoglu C., Mazza P., Villa V. (2013) – Valle Giumentina (Abruzzes, Italie). Étude des comportements techno-économiques au Pléistocène moyen, Italie centrale, *Chronique des activités archéologiques de l'École française de Rome* [en ligne] http://cefr.revues.org/902

Nicoud E., Aureli D., Pagli M., Agostini S., Boschian G., Chaussé C., Colalelli U., Degeai J.-P., Fusco F., Hernandez M., Kuzucuoglu C., Lahaye C., Lemorini C., Mazza P., Mercier N., Robert V., Rossi M.A., Villa V., Virmoux C., Zupancich A. (2014) – Valle Giumentina (Abruzzes, Italie). Deuxième mission : étude des comportements techno-économiques au Pléistocène moyen, *Chronique des activités archéologiques de l'Ecole française de Rome* [en ligne] http://cefr.revues.org/1081

Nicoud E., Aureli D., Pagli M. (2015) –Valle Giumentina (Abruzzes, Italie). Troisième mission : étude des comportements techno-économiques au Pléistocène moyen, *Chronique des activités archéologiques de l'École française de Rome* [en ligne] http://cefr.revues.org/1306

Nicoud E., Aureli D., Pagli M. (2016a) – Valle Giumentina (Abruzzes, Italie). Quatrième mission : étude des comportements techno-économiques au Pléistocène moyen, *Chronique des activités archéologiques de l'Ecole française de Rome* [en ligne] https://doi.org/10.4000/cefr.1507

Nicoud E., Aureli D., Pagli M., Villa V., Chaussé C., Agostini S., Bahain J.-J., Boschian G., Degeai J.-P., Fusco F., Giaccio B., Hernandez M., Kuzucuoglu C., Lahaye C., Lemorini C., Limondin-Lozouet N., Mazza P., Mercier N., Nomade S., Pereira A., Robert V., Rossi M.A., Virmoux C., Zupancich A. (2016b) – Preliminary data from Valle Giumentina Pleistocene site (Abruzzo, Central Italy): A new approach to a Clactonian and Acheulian sequence, *Quaternary International*, 409, p. 182-194.

Nicoud E., Aureli D., Pagli M. (2017) – Valle Giumentina (Abruzzes, Italie), Cinquième mission : étude des comportements techno-économiques au Pléistocène moyen. *Chronique des activités archéologiques de l'École française de Rome* [en ligne], Italie centrale, mis en ligne le 13 février 2017, consulté le 06 mars 2022. http://journals.openedition.org/cefr/1656

Nicoud E., Villa V., Davtian G., Guibert-Cardin J. (2018) – Valle Giumentina (Abruzzes). Sixième mission : étude des comportements techno-économiques au Pléistocène moyen. Italie centrale. *Chronique des activités archéologiques de l'École française de Rome* [en ligne] https://journals.openedition.org/cefr/1891

Niespolo E., Rutte D., Deino A.L., Renne P.R. (2017) – Intercalibration and age of the Alder Creek sanidine $^{40}Ar/^{39}Ar$ standard., *Quaternary Geochronology*, 39, p. 205-213.

Nomade S., Gauthier A., Guillou H., Pastre J.-F. (2010) – $^{40}Ar/^{39}Ar$ temporal framework for the Alleret maar lacustrine sequence (French Massif Central): volcanological and Paleoclimatic implications, *Quaternary Geochronology*, 5, p. 20-27.

Nomade S., Renne P.R., Vogel N., Deino A.L., Sharp W.D., Becker T.A., Jaouni A.R., Mundil R. (2005) – Alder Creek sanidine (ACs-2): A Quaternary $^{40}Ar/^{39}Ar$ dating standard tied to the Cobb Mountain geomagnetic event. *Chemical Geology*, 218, 3-4, p. 315-338. DOI: 10.1016/j.chemgeo.2005.01.005

Otte M. (2001) – Recension of Lamotte A. 2001, *Bulletin de la Société préhistorique française*, 98, 4, p. 746.

Pereira A. (2017) – *Apport de la datation $^{40}Ar/^{39}Ar$ à la compréhension de l'évolution culturelle des pré-néanderthaliens en Italie centrale et méridionale entre 750 et 250 ka*, Muséum national d'Histoire naturelle de Paris, Università degli Studi di Ferrara et l'Ecole française de Rome, 434 p.

Pereira A., Nomade S., Moncel M.-H., Voinchet P., Bahain J.-J., Bidittu I., Falguères C., Giaccio B., Manzi G., Parenti F., Scardia G., Scao V., Sottili G., Vietti A. (2018) – Integrated geochronology of Acheulian sites from the southern Latium (central Italy): Insights on human-environment interaction and the technological innovations during the MIS 11-MIS 10 period, *Quaternary Science Reviews*, 187, p. 112-129.

Peretto C. (2013) – *Isernia La Pineta*, Cosmo Iannone Editore, 493 p.

Peretto C., Arzarello M., Bahain J.-J., Boulbes N., Dolo J.-M., Douville E., Falguères C., Frank N., Garcia T., Lembo G., Moigne A.-M., Muttillo B., Nomade S., Pereira A., Rufo M.A., Sala B., Shao Q., Thun Hehenstein U., Tessari U., Turrini M.C., Vaccaro C. (2016) – The Middle Pleistocene site of Guado San Nicola (Monteroduni, Central Italy) on the Lower/Middle Palaeolithic transition, *Quaternary International*, 411, p. 301-315.

Pierre C., Belanger P., Saliège J.F., Urrutiaguer M.J., Murat A. (1999) – Paleoceanography of the western Mediterranean during the Pleistocene oxygen and carbon isotope records at Site 975, *in Proceedings of the Ocean Drilling Program. Scientific Results*, p.481-488.

Piperno M. (1999) – *Notarchirico. Un sito del Pleistocene medio iniziale nel bacino di Venosa*, Venosa, Edizioni Osanna, 624 p.

Pizzi A. (2003) – Plio-Quaternary uplift rates in the outer zone of the central Apennines fold-and-thrust belt, Italy, *Quaternary International*, 101, p. 229-237.

Porraz G. (2008) – Middle palaeolithic mobile toolkits in short-term human occupations. Pié Lombard rockshelter (Provence, France) and Broion cave (Venetia, Italy): two case studies, *Eurasian Prehistory*, 6, p. 33-56.

Radmilli A.M. (1965) – *Abruzzo Preistorico. Il Paleolitico inferiore-medio abruzzese*, Florence, Sansoni, 117 p.

Radmilli A.M. (1982) – Il Paleolitico inferiore in Abruzzo, *in Atti della XIII Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria*, Florence p.165-176.

Raíces M., Gargantini P.R., Chinchilla D., Crespi M., Téllez-Iñón M.T., Ulloa R.M. (2003) – Regulation of CDPK isoforms during tuber development, *Plant Molecular Biology*, 52, 5, p. 1011-1024.

Ravon A.-L. (2017) – *Originalité et développement du Paléolithique inférieur à l'extrémité occidentale de l'Eurasie : le Colombanien de Menez-Dregan (Plouhinec, Finistère)*, Thèse de doctorat, Université de Rennes 1, 402 p.

Ravon A.-L., Gaillard C., Monnier J.-L. (2016) – Menez-Dregan (Plouhinec, far western Europe): The lithic industry from layer 7 and its Acheulean components, *Quaternary International*, 411, p. 132-143.

Regattieri E., Giaccio B., Galli P., Nomade S., Peronace E., Messina P., Sposato A., Boschi C., Gemelli M. (2016) – A multi-proxy record of MIS 11–12 deglaciation and glacial MIS 12 instability from the Sulmona basin (central Italy), *Quaternary Science Reviews*, 132, p. 129-145.

Renne P.R., Mundil L.R., Balco G., Min K., Ludwig K.R. (2011) – Joint determination of 40K decay constants and 40Ar/40K for the Fish Canyon sanidine standard, and improved accuracy for $^{40}Ar/^{39}Ar$ geochronology. Response to the comment by W.H. Schwarz *et al.* Geochem. Cosmochim. Acta 75, 5097-5100., *Geochimica et Cosmochimica Acta*, 75, p. 5097-5100.

Rightmire P.G. (2001) – Patterns of hominid evolution and dispersal in the Middle Pleistocene, *Quaternary International*, 75, p. 77-84.

Rocca R. (2016) – First settlements in Central Europe: Between originality and banality, *Quaternary International*, 409, p. 213-221.

Rocca R., Abruzzese C., Aureli D. (2016) – Europeans Acheuleans: Critical perspectives from the East, *Quaternary International*, 411, p. 402-411.

Rocca R., Abruzzese C., Aureli D., Nicoud E., Pagli M. (2020) – L'Italia circa 500.000 anni fa: centro o periferia nel Mediterraneo?, *in Rivista di Scienze Preistoriche*, LXX S1, p.7-17.

Rocca R., Aureli D. (2019) – Cimitero di Atella. Résultats de la mission 2018, *Chronique des activités archéologiques de* *l'École française de Rome*, http://journals.openedition.org/cefr/3329 [consulté le 25 juin 2021].

Rocca, R., Bodin, E. (2010) – Quelles dynamiques de peuplement en eurasie. Les industries lithiques en europe centrale et en chine au paléolithque inférieur, *The Earliest inhabitants of the caucasus and hominid dispersals at Eurasia*, p. 250-262.

Rodríguez J., Willmes C., Mateos A. (2021) – Shivering in the Pleistocene. Human adaptations to cold exposure in Western Europe from MIS 14 to MIS 11, *Journal of Human Evolution*, 153, p. 102966.

Roebroeks W. (1988) – A study of Middle Palaeolithic riverside settlements at Maastricht-Belvedere (The Netherlands), *Analecta Praehistorica Leidensia*, Thesis at the University of Leiden.

Rohling E.J., Foster G.L., Grant K.M., Marino G., Roberts A.P., Tamisiea M.E., Williams F. (2014) – Sea-level and deep-sea-temperature variability over the past 5.3 million years, *Nature*, 508, 7497, p. 477-482.

Rottländer R. (1975) – The formation of patina on flint, *Archaeometry*, 17, 1, p. 106-110.

Serradimigni M. (2013) – *L'industria litica dei livelli epigravettiani di Grotta Continenza (Trasacco, AQ): studio, revisione e inquadramento nell'ambito delle coeve industrie dell'Italia adriatica centro-meridionale*, Thèse de doctorat, Università degli studi di Siena, 666 p.

Soressi M., Geneste J.-M. (2011) – The History and Efficacy of the Chaîne Opératoire Approach to Lithic Analysis: Studying Techniques to Reveal Past Societies in an Evolutionary Perspective, *PaleoAnthropology*, Special Issue: Reduction Sequence, Chaîne Opératoire, and Other Methods: The Epistemologies of Different Approaches to Lithic Analysis, p. 334-350.

Stapert D. (1976) – Some natural surface modifications on flint in the Netherlands, *Paleohistoria*, 18, p. 8-41.

Steiger R.H., Jaeger E. (1977) – Subcommission on geochronology: convention on the use of decay constants in geo- and cosmochronology, *Earth and Planetary Science Letters*, 6, p. 359-362.

Stoops G. (dir.) (2003) –*Guidelines for analysis and description of soil and regolith thin sections*, Soil Science Society of America, Inc. Madison, Wisconsin, USA, 184 p.

Stuart B.H., Craft L., Forbes S.L., Dent B.B. (2005) – Studies of adipocere using attenuated total reflectance infrared spectroscopy, *Forensic Science, Medicine, and Pathology*, 1, 3, p. 197-201.

Thompson T.J.U., Islam M., Bonniere M. (2013) – A new statistical approach for determining the crystallinity of heat-altered bone mineral from FTIR spectra, *Journal of Archaeological Science*, 40, 1, p. 416-422.

Tixier J., Dawson M.-C., Gravina B. (2012) – *A Method for the study of stone tools / Méthode pour l'étude des outillages lithiques*, MNHA / CNRA, Luxembourg (coll. Archéo-Logiques, 4), 197 p.

Tomasso A., Binder D., Fernandes P., Milot J., Léa V. (2019) – The Urgonian chert from Provence (France): the intra-formation variability and its exploitation in petro-archeological investigations, *Archaeological and Anthropological Sciences, 11,* p. 253–269.

Tourloukis V., Harvati K. (2017) – The Palaeolithic record of Greece: A synthesis of the evidence and a research agenda for the future, *Quaternary International*, 466, p. 48-65.

Tourloukis V., Thompson N., Panagopoulou E., Giusti D., Konidaris G., Karkanas P., Harvati K. (2018) – Lithic artifacts and bone tools from the Lower Palaeolithic site Marathousa 1, Megalopolis, Greece: Preliminary results, *Quaternary International*, 497, p. 47-64.

Tuffreau A., Lamotte A., Marcy J.-L. (1997) – Land-Use and Site Function in Acheulean Complexes of the Somme Valley on JSTOR, *World Archaeology*, 29, 2, p. 225-241.

Turq A. (1989) – Approche technologique et économique du faciès Moustérien de type Quina : étude préliminaire, *Bulletin de la Société préhistorique française*, 86, 8, p. 244-256.

Tzedakis P.C., Hooghiemstra H., Pälike H. (2006) – The last 1.35 million years at Tenaghi Philippon: revised chronostratigraphy and long-term vegetation trends, *Quaternary Science Reviews*, 25, 23-24, p. 3416-3430.

Udvardi B., Kovács I.J., Kónya P., Földvári M., Füri J., Budai F., Falus G., Fancsik T., Szabó C., Szalai Z., Mihály J. (2014) – Application of attenuated total reflectance Fourier transform infrared spectroscopy in the mineralogical study of a landslide area, Hungary, *Sedimentary Geology*, 313, p. 1-14.

Vaculíková L., Plevová E. (2005) – Identification of clay minerals and micas in sedimentary rocks, *Acta Geodynamica et Geomaterialia*, 2, 1, p. 67-175.

Vaissié E., Caux S., Faivre J.-P. (2021) – Supply distances and territories in south-west France through the Middle and Upper Palaeolithic: a petro-techno-economic approach, *Bulletin de la Société préhistorique française*, 118, 3, p. 7-32.

Vaquero M. (2008) – The history of stones: behavioural inferences and temporal resolution of an archaeological assemblage from the Middle Palaeolithic, *Journal of Archaeological Science*, 35, p. 3178-3185.

Van Den Bogaard C., Van Den Bogaard P., Schmincke H.-U. (1989) – Quartärgeologisch-tephrostratigraphische Neuaufnahme und Interpretation des Pleistozänprofils Kärlich, *E&G Quaternary Science Journal*, 39, 1, p. 62-86.

Vaquero, M. (2008) – The history of stones: behavioural inferences and temporal resolution of an archaeological assemblage from the Middle Palaeolithic, *Journal of Archaeological Science*, 35, p. 3178-3185.

Veall M-A., Matheson C. (2014) – Improved molecular and biochemical approaches to residue analysis in C. Lemorini & S. Nunziante Cesaro, *An integration of use-wear and residues analysis for the identification of the function of archaeological stone tools*, BAR (IS) 2649, p. 9-25.

Venditti F., Cristiani E., Nunziante-Cesaro S., Agam A., Lemorini C., Barkai R. (2019) – Animal residues found on tiny Lower Paleolithic tools reveal their use in butchery, *Scientific Reports*, 9, 13031, p. 14.

Vezzani L., Ghisetti F. (1998) – *Carta Geologica dell'Abruzzo, Scala 1:100.00, Foglio 2*, Regione Abruzzo.

Villa V. (2017) – *Environnements et occupations Paléolithiques d'Italie centrale : la longue séquence Pléistocène moyen de Valle Giumentina*, Thèse de doctorat, Université Paris 1 Panthéon-Sorbonne et Università di Pisa, 400 p.

Villa V., Chaussé C., Nicoud E., Aureli D., Pagli M. (2015) – Valle Giumentina (Abruzzes, Italie). Nouvelles observations de la stratigraphie, *Mélanges de l'École française de Rome - Antiquité*, 127-1 [en ligne]. http://journals.openedition.org/mefra/2658

Villa V., Pereira A., Chaussé C., Nomade S., Giaccio B., Limondin-Lozouet N., Regattieri E., Degeai J.-P., Robert V., Kuzucuoglu C., Boschian G., Agostini S., Aureli D., Pagli M., Bahain J.J., Nicoud E. (2016a) – A MIS 15-MIS 12 record of environmental changes and Lower Palaeolithic occupation from Valle Giumentina, central Italy, *Quaternary Science Reviews*, 151, p. 160-184.

Villa V., Virmoux C., Chaussé C., Degeai J.-P., Kuzucuoglu C., Boschian G., Agostini S., Aureli D., Pagli M., Nicoud E. (2016b) – The long sedimentary succession of the Valle Giumentina basin (Abruzzo, central Italy): new evidence from stratigraphic studies and electrical resistivity tomography (ERT), 29, 2, p. 193-199.

Villa V., Nicoud E., Fusco F. (2021a) – Valle Giumentina (Abruzzes, Italie). Neuvième mission : étude paléoenvironnementale des occupations humaines du Pléistocène moyen, *Bulletin archéologique des Ecoles françaises à l'étranger,* [En ligne]. https://doi.org/10.4000/baefe.1247

Villa V., Nicoud E., Fusco F., Pereira A., Nomade S., Guibert--Cardin J., Chaussé C. (2021b) – Palaeoenvironmental high-resolution studies at Valle Giumentina archaeological site (Central Italy, ABF and LAC layers): new evidence of a cold and dry event during MIS 13b in the Adriatic region, *in Nicoud E., Balasse M., Desclaux E., Théry I. (eds), Actes des 41e Rencontres internationales d'Archéologie et d'Histoire de Nice Côte d'Azur*, APDCA-CEPAM, p. 151-168.

Yokoyama, Y., Van Nguyen H.V. (1981) – Datation directe de l'Homme de Tautavel par la spectrométrie gamma, non destructive, du crâne humain fossile Arago XXI. *Comptes Rendus des Séances de l'Academie des Sciences, série 2, 292, 12*, p. 927-930.

Woodfield H.K., Sturtevant D., Borisjuk L., Munz E., Guschina I.A., Chapman K., Harwood J.L. (2017) – Spatial and temporal mapping of key lipid species in *Brassica napus* seeds, *Plant Physiology*, 173, 4, p. 1998.

Würges K. (1994) – Altpaläolithische Funde aus der Tongrube Kärlich (Schicht H, unten), Kreis Mayen-Koblenz/Neuwieder Becken, *Archäologisches Korrespondenzblatt*, 14, p. 17-22.

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