Accepted Manuscript

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PII: S1040-6182(09)00361-9

DOI: 10.1016/j.quaint.2009.10.013

Reference: JQI 2152

To appear in: *Quaternary International*

Received Date: 2 June 2009

Revised Date: 8October2009

Accepted Date: 14 October 2009

Please cite this article as: Limondin-Lozouet, N., Nicoud, E., Antoine, P., Auguste, P., Bahain, J.-J., Dabkowski, J., Dupéron, J., Dupéron, M., Falguères, C., Ghaleb, B., Jolly-Saad, M.-C., Mercier, N. Oldest evidence of Acheulean occupation in the Upper Seine valley (France) from an MIS 11 tufa at La Celle, Quaternary International (2009), doi: 10.1016/j.quaint.2009.10.013

Oldest evidence of Acheulean occupation in the Upper Seine valley (France) from an MIS 11 tufa at La Celle

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Abstract

The tufa deposit of La Celle, located in the Upper Seine valley (Northern France), has been known for more than a century and extensive collections of shells and leaf impressions exist. These fossils led earlier authors to recognize the tufa as evidence of an old temperate phase of the Pleistocene. New studies have recently been undertaken at the site in order to reappraise its palaeontological potential and to improve its dating. Recent investigations are based on the analysis of a new series of stratified samples, coupled with a revision of material in several old collections. The new work shows that the tufa accumulated under interglacial conditions and demonstrates the progressive development of forest biotopes culminating in the climatic optimum. In the upper levels the reopening of the landscape is registered by both molluscan communities and plant remains. The tufa at La Celle has been correlated with MIS 11, based on the geomorphological context of the site, together with the occurrence of 'the *Lyrodiscus* fauna', a malacological assemblage characteristic of tufa deposits of this period in Northwest Europe. This correlation is supported by radiometric measurements (U-series and ESR/U-series,) which have produced a mean age of ~400 ka. Mammalian remains are also preserved and include *Macaca* and *Hippopotamus*, which are the first well-provenanced records of these species from this region. An archaeological horizon with flint artefacts demonstrates human

occupation during the interglacial optimum. Analysis of the lithic artefacts confirms their similarity with the Acheulean assemblage collected at the end of the 19th century. La Celle therefore represents one of the best dated Acheulean occupation sites in Northern France and one where the palaeoenvironmental context can be described in great detail.

Keywords: *Acheulean, MIS 11, Northern France, Tufa, Middle Pleistocene*

1. Introduction

The tufa at La Celle lies on the right bank of the Seine, 2.5 km upstream of the confluence with the River Loing. This calcareous formation occurs at the top of the fluvial deposits of a middle terrace of the Seine (15 m above the modern alluvial plain) up to the lower part of the calcareous slope (Eocene) (Figure 1). The tufa has been exploited as building material probably since the Middle Ages, as blocks of tufa appear in the church porches of some neighbouring villages. It is mentioned in the scientific literature of the 19th century for its palaeontological richness (molluscs and leaf impressions) and was the subject of several studies (Saporta, 1876; Tournouër, 1874, 1877), before new work was undertaken in the middle of the 20th century (Bourdier et al., 1969). This work allowed firm allocation of the tufa to an interglacial phase of the Pleistocene but resulted in incomplete palaeontological inventories and ambiguous dating (Alimen, 1957; Bourdier, 1961, 1969). In the most recent regional syntheses of the Quaternary of the Seine valley, the tufa at La Celle is attributed to marine isotope stage (MIS) 11 on the basis of palaeontological and geomorphological considerations (Rousseau, 1992; Lautridou et al., 1999).

New investigations initiated in 2003 aimed to improve knowledge of stratigraphy, palaeoenvironmental development and dating. Several stratigraphical profiles were created in order to locate the best preserved sequence through the tufa to enable detailed multidisciplinary sampling. In 2005 a borehole survey was conducted to determine the precise extent of the tufa and in 2006 an excavation was undertaken of an archaeological level previously found to contain flint artefacts and vertebrates. A preliminary synthesis reconstructing the palaeoenvironment with details of its dating has been published (Limondin-Lozouet et al., 2006). The present paper reiterates the main findings and supplements them by reviewing additional results obtained subsequently. However, its main focus is on the archaeological data resulting from the excavations carried out in 2006, together with a revision of the old collections of lithic artefacts. The archaeological importance of La Celle is discussed in a regional and European context.

2. Revised stratigraphy

Recent investigations showed that the best preserved tufa occurred in the western part of the site, along the face of the old quarry that cuts the slope (Figure 2). Behind this section, westwards, boreholes reveal that the tufa does not extend beyond a few tens of metres. Towards the east of profile 3 a palaeogully, filled by loess, truncates the tufa.

The stratigraphy of the tufa shows a succession made up of more or less coarse grained levels in which several grey horizons with finer granulometry have developed (Figure 3). The stratigraphical observation of the long section created along the slope allows the description of the following deposits from top downwards:

Unit 0: brown grey calcareous sandy silt horizon with tufa blocks , modern soil.

Unit 1: light yellow soft tufa with discontinuous bedding including several granulometrical facies: TFH, fine homogeneous tufa; TGS, sandy granular tufa with oncoliths ; LTC, indurated tufa with leaf impressions.

Unit 2: fine grey tufa, dense and homogeneous with small concretions included within a sandy matrix.

NB1: unconformable level of reworked indurated tufa blocks and calcareous blocks (Eocene), heterogeneous in size (few centimetres up to 35 cm).

Unit 3: light brown to orange layers of silty tufa including detrital material (silt and fine sand) reworked from the slope, well visible on figure 3. The whole tufa mass has been affected by a network of reversed faults created by compaction. These faults often remained open, and some are coated with secondary re-precipitation due to pseudomycelia. Facies variations are related to changes in texture and density: 3a, very light granular tufa; 3b, granular tufa, denser than 3a; 3c, sandy silty tufa with calcareous granules; 3d, dense silty tufa with lateral variations of gleying (3d') and platty structure (3d''). The last includes two facies: TFG, light grey fine dense tufa and TS, fine to coarse sandy tufa beds.

Unit 4: compact fine grey tufa. A sample from this level has yielded a malacological fauna very similar to molluscan assemblages from unit 7 that contain the archaeological artefacts (Zone 3).

Unit 5: light yellow granular tufa characterized by a high amount of secondary carbonates.

Unit 6: light grey fine tufa, compact with oxidized spots from 9 m to 27 m. Lateral variations in granulometry from 12 m: 6' including a granular grey tufa facies (TGG) and little beds of dense fine grey tufa (LFG).

NB2: continuous level of heterogeneous tufa blocks from 1 up to 50 cm in a fine matrix.

TOC facies: tufa with oncoliths infilling a palaeochannel structure and overlying unit 7. Granular tufa with fine sandy matrix, tiny organic elements and flint artefacts.

Unit 7: grey fine tufa including reworked tufa granules and little heated tufa fragments, shells, charcoal. This horizon has developed as an upbuilding soil in which colluvial sedimentation, pedogenesis and bioturbation are contemporaneous (Almond and Tonkin, 1999). This unit corresponds to the "lgt" facies including archaeological artefacts and large mammals remains, described in Limondin-Lozouet et al., 2006.

NB3: discontinuous level of large calcareous and tufa blocks under unit 7, encrusted into the upper part of unit 8.

Unit 8: clear fine sandy-granular tufa with lateral variation (8a to 8c) in colour (light yellow to white) and texture.

Unit 9: light yellow sandy-silty tufa with indurated tufa blocks (≥ 10 cm). Lateral variations, 9a, abundant sandy-silty matrix with scattered blocks; 9b, abundant blocks.

Unit 10: light orange silty tufa with fragments of blocks and in situ blocks 10 to 40 cm.

Unit 11: light orange brown sandy tufa, coarse at the top and finer at its base.

Unit 12: homogeneous dense grey silty to sandy tufa, with fragments of heated tufa. Malacofaunas from this horizon appear similar to assemblages from the beginning of zone 2 corresponding to the spread of forest habitats (Limondin-Lozouet et al., 2006). Lateral variations, 12a, silty to sandy tufa with some indurated blocks ; 12b, greenish tufa with shell fragments.

Unit 13: yellow grey tufa, sandy-silty, homogeneous.

Unit 14: white fine silty tufa, with scattered gravels and flints at its base.

Unit 15: greenish grey fluvial sandy silts with sub-horizontal laminations (overbank deposits).

Unit 16: coarse fluvial sands with sub-horizontal beddings, scattered gravels and coarse sandy beds.

Unit 17: limestone and flint angular detrital stones in a silty tufa matrix and weathered limestone bedrock.

The excavation of this section has recently been undertaken down to the bedrock. The first stratigraphical profiles showed that upslope, the tufa rests on chalky mud (20 cm thick) described as unit 17 in the long section, which overlies the calcareous bedrock. In the lower part of the slope the tufa lies at the top of a fluvial sequence with coarse gravels, then fine sands (unit 16) and silts (unit 15). In these profiles (numbered 2, 5 and 1), the tufa is 4 - 5 m thick (Figure 4). The first correlations resulting from the recent malacological works

(Limondin-Lozouet et al., 2006) demonstrated that the tufa started to form in the upper part of the slope, and then developed downslope at the top of the fluvial terrace deposits (unit 15). This means that the total thickness of the tufa sequence is almost 9 m (Figure 4). The malacological correlations have been subsequently confirmed by the stratigraphical record revealed in the large section. These findings are consistent with the observations of earlier authors who suggested that the tufa reached 11 m in thickness in the eastern part of the site close to the current cemetery (Tournouër, 1874; Lapparent, 1900; Munier-Chalmas, 1903).

3. Palaeoenvironmental and chronological context: New Results

Shells and leaf impressions are the most important and common fossils in the tufa at La Celle. The recent investigations are based on the analysis of a new series of stratified samples, coupled with a revision of material in several old collections (Jolly-Saad et al., 2006; Limondin-Lozouet et al., 2006). Ostracods were also analysed from the samples taken for molluscs (Carbonel in Limondin-Lozouet et al., 2006). No micromammals were recovered despite extensive sieving. Attempts to extract meaningful pollen assemblages from unit 7 were unsuccessful.

3.1 Malacofaunas

Mollusc shells are abundant and well preserved throughout all the units of the tufa. Combining the new faunal analyses with the revisions of the old collections, a total of 92 species are now known from La Celle, including 71 terrestrial, of which 40 are forest taxa. These proportions are particularly high compared to other interglacial or modern molluscan faunas. Thus, the tufa at La Celle has yielded one of the richest malacofaunas in Northwest Europe. Richness and diversity of these faunas imply that the tufa deposit precipitated under fully temperate conditions corresponding to an interglacial. However, not all the species became established at the same time and the analyses reveal a clear succession. This faunal development reflects the environmental changes and in particular the gradual expansion of forest biotopes. Four mollusc zones were defined (Limondin-Lozouet et al., 2006) (Figure 4). In the earliest tufa, which occurs only in profile 2 at the top of the slope, mollusc assemblages that constitute zone 1 are already diversified in comparison to those of the preceeding cold climatic phase but they also indicate open environments, characterized by marsh. Molluscan populations subsequently become more diverse and the number of shells increases. Appearance of the first forest species characterizes the transition to zone 2. This occurs in the main part of profile 2, but downslope the transition appears more subdued Zone 3 corresponds

to the maximum development of forest species in both frequency and diversity. In this zone total number of species reach its highest values for the site up to 38 species in unit 7, from which 22 are forest species. These assemblages reflect closed forest habitats and indicate the interglacial optimum. The archaeological level occurs in zone 3. In zone 4, present only in the two lower profiles (5 and 1 in Figure 4), the molluscan assemblages show a dramatic reduction of forest species and an increase of those typical of an open landscape.

The malacological succession from La Celle includes a few extinct taxa or species that occur far beyond their modern range. In this respect the assemblages of zone 3 are highly distinctive because they belong to the "*Lyrodiscus* assemblage" named after a sub-genus of land snail now confined to the Canary islands. The *Lyrodiscus* assemblage is a land snail fauna characteristic from tufas of MIS 11 age in Northwest Europe (Rousseau et al., 1992; Limondin-Lozouet and Antoine, 2006; Preece et al., 2007). This malacological assemblage reflects a particular biotope of temperate and wet forest. The extremely high diversity of the molluscan fauna might also reflect weak seasonal contrasts, which allow the development of some species with narrow ecological ranges.

3.2 Leaf impressions

Few leaf impressions were recovered during the recent excavations, but new information on the flora has resulted from the revision of the Munier-Chalmas Collection (housed at the University of Paris VI, Jussieu). The beds with the most frequent plant remains were observed in the eastern part of the site, near the cemetery, where the thick upper levels of the tufa were indurated (Munier-Chalmas, 1903; Jodot, 1907) (Figure 5). These levels have long been exploited for building, for example the wall of the current cemetery includes many blocks with leaf impressions. The old studies of the flora of La Celle made the site famous because of the range of temperate taxa recorded (Saporta, 1874 and 1876). Among the most exotic listed was the Canary Island laurel (*Laurus canariensis*) and the Tree of Judaea (*Cercis siliquastrum*), which led earlier authors to infer that the contemporary climate must have been milder than today. However, re-examination of these specimens in the old collection showed that they had been misidentified (Jolly-Saad et al., 2006). Conversely, the presence of certain species of Mediterranean origin could be confirmed. This is the case with *Buxus sempervirens, Ficus carica, Celtis australis*. Beside, several additional taxa as *Fagus silvatica, Cornus, Quercus, Viburnum lantana,* and *Ligustrum vulgare* have been identified. Other plant species quoted in the old publications such as *Clematis vitalba, Osmunda regalis, Scolopendrium officinale, Pinus austriaca,* could not be found, although there is no reason to

doubt their identications. *Pinus austriaca* in particular was represented by beds of abundant leaves and cones, which are impossible to confuse with other species (Munier-Chalmas, 1903; Jodot, 1907). This suggests that certain samples were lost during the removal of the collection. The floristic list of La Celle consists of 24 taxa, which confirm the temperate climate deduced from the malacology although the precise stratigraphical context that is specified for most of the samples is not taken in account in the recent revision of the collection (Jolly-Saad et al., 2006). In the old publications (Munier-Chalmas, 1903) the bed with *Pinus austriaca* is described within the lower levels of soft tufa, whereas Mediterranean taxa came from higher indurated tufa layers (Figure 5). At the top of the tufa formation the most southern plants seem to disappear (Bourdier, 1961), which suggests that an optimum in the middle part of the tufa was followed by a less temperate phase, which is consistent with the evidence derived from the recent malacological data.

3.3 The "*Lyrodiscus* biome"

The assemblages containing this peculiar malacofauna that included extinct taxa and species beyond their modern range, associated with various southern tree species is known from several Pleistocene sites in France, Britain and Germany. This is the so-called "*Lyrodiscus* biome", which reflects forest development during MIS 11 when the climate was both milder and wetter than present (Rousseau et al., 1992). The recent revision of the malacological, floristic and chronological data of the European Pleistocene sites with *Lyrodiscus* resulted in the revision of the lists of taxa thought to be characteristic of this biome confirming its restriction to the Atlantic area of Northwest Europe during MIS 11 (Limondin-Lozouet and Antoine, 2006). The tufa at La Celle is one of the main reference sites for this biome but the elimination of certain trees, such as the Canary Island Laurel and the Tree of Judaea, which were recorded only from La Celle, necessitates a reinterpretation of the climate reconstructed from the site.

3.4 Dating

The context of the tufa within the terrace system of the River Seine (Lautridou et al., 1999) together with biostratigraphical data (Limondin-Lozouet et al., 2006) led to a correlation of La Celle with MIS 11.

Four radiometric measurements have now been carried out by U-series (α-spectrometry and TIMS) on indurated tufa and by a combined ESR/U-series method on a horse tooth (Limondin-Lozouet et al., 2006; Bahain et al., in press). These analyses (Table 1) give an

average age of 400 ka, consistent with an MIS 11 correlation. The dated samples come from the studied section in the western part of the site (horse tooth from the archaeological unit 7 and indurated tufa of the NB3 blocks level at the base of the archaeological layer, Figure 3) and from the indurated tufa from the eastern part of the old quarry. This last facies, mentioned by early authors as the upper part of the deposit, was sampled in profile 4 created near the cemetery during the first field trip (Figure 2). The consistency of the ages confirm the suggestion based on the fossils that the different facies between the western and eastern sequences are contemporaneous and represent lateral variations within the tufaceous deposit. Further dating based on ESR on quartz from the basal alluvial sand, TL on heated flint and amino-acids on shells are still underway and should provide additional evidence of the age of the tufa.

4. Archaeological data

4.1 Lithic industry

In the early 1890s before the construction of the railway, about thirty handaxes were discovered in a small quarry located south of the cemetery at La Celle (Collin et al., 1895). They occurred 3 or 4 m below the top of the quarry, under a thick tufa layer the base of which appeared indurated. The flint artefacts occurred at several levels, some recovered as groups. A tufa layer devoid of archaeology separated levels yielding handaxes and the Seine alluvial sheet. One artefact was encrusted with tufa on one of its faces, and all the flints had fresh unworn edges (Collin et al., 1895). There is no doubt about the in situ provenance of handaxes in the tufa. Several archaeological horizons were reported within a thickness of approximately 1 m. Holocene tufa accumulation rates demonstrate that this can represent a relatively short duration of about a few hundred years (Limondin-Lozouet and Preece, 2004). The approximate stratigraphical position reported for these levels is consistent with the recent data, as unit 7, which yielded the archaeology, lies at 4 m below the modern soil (Figure 3). Moreover, the indurated level yielding the handaxes was rich in exotic southern tree species, suggesting that human occupation of the site was contemporary with the climatic optimum, a finding confirmed by the recent work.

Most of these handaxes cannot be traced but two are illustrated by Collin et al. (1895) (Figure 6). Their dimensions are said to vary from 17 to 7 cm in length but all are rather thick (3 to 5 cm). The raw material appears to be local Cretaceous flint, although a few could have been worked from Tertiary flint (silex de Brie), which outcrops near the site (Collin et al., 1895). All have a white patina. Most recent lithic analyses have highlighted their similarity to the

Acheulean industries of Cagny-la-Garenne and Saint-Acheul in the Somme valley (Bourdier, 1961). However two handaxes from La Celle preserved in the collections of the "Musée des Antiquités Nationales" at Saint-Germain-en-Laye were analysed in detail (Figures 7 and 8). These two bifacial pieces were made following different modalities but share a similar cortical basis or back, on the opposite side of a straight cutting edge. In both cases, the distal part is very thin and consists of two flat surfaces (Figures 7 and 8) similar to some bifaces from Boxgrove (from MIS 13) (Roberts and Parfitt, 1999). For this type of biface, the shaping is a means of obtaining standardised blanks. From these various tools can be produced by means of successive retouch -the "pièces bifaciale-support d'outils" (sensu Boëda et al., 1990). This mode can be separated from those recognised at Soucy 3P or Torre in Pietra (MIS 9) (Lhomme, 2007, Malatesta, 1978) where bifacial shaping creates a specific tool which is part of a tool kit , composed of other tools (retouched flakes, pebble-tools). The making of the blanks cannot be separated from tool production - the "pièce bifaciale-outil" (sensu Boëda et al, 1990; Soriano, 2000; Lhomme et al., 2004).

A small number of lithic artefacts were recovered during the 2003 and 2006 excavations at La Celle (57 flakes and 15 indeterminate chips). The assemblage was similar to the historical material, being primarily local Cretaceous flint,with subordinate numbers made from Tertiary flint also available in the area. The flakes are soft-hammer thinning flakes produced during biface manufacture which possess characteristic obtuse flaking angles, lipped butt and curved profiles (Figure 6). The new finds are consistent with older discoveries (Connet and Lhomme in Limondin-Lozouet et al., 2006). These sequences are also observable on the handaxes collected at the end of the 19th century (Collin et al., 1895). Thus, La Celle has yielded a lithic industry which is produced by a "façonnage chaîne opératoire".

4.2 Mammal fauna

Most of the vertebrate remains from unit 7 are bones of large mammals. A total of 145 bones were recovered and five taxa were recognized (Auguste in Limondin-Lozouet et al., 2006). Red deer dominates the assemblage followed by bones of horse. Macaque, hippopotamus and a small carnivore were identified from single specimens. The minimum number of individuals estimated from this assemblage is 5, since all the deer bones might belong to a single adult animal. Some fragments of long bones provide evidence of dynamic fracturing carried out on fresh bone, possibly indicative of butchery involving the extraction of marrow.

The deer from La Celle is similar to modern red deer (*Cervus elaphus).* The horse is an animal with a rather strong stature with typical caballine teeth. It is similar to the horses from

the British Hoxnian (MIS 11) interglacial (Eisenmann, 1991) but it is impossible to identify the specimens to species. Macaque is represented by a single tooth, identical to those of *Macaca sylvanus* present in Western Europe since the Pliocene and found during the temperate phases of the Middle Pleistocene (Lanèque, 1996). Its last occurrence in Northwest Europe is thought to be from deposits correlated with MIS 9 in England (Schreve et al., 2002; Roe et al., 2009). The single hippopotamus metatarsal recovered at La Celle is allocated to *Hippopotamus incognitus* after its morphology and morphometry. This animal appears during the Cromerian and disappears before the beginning of the Weichselian (Faure, 1985). *H. amphibius* , the modern African hippopotamus, is sometimes put in synonymy with this species however the validity of *H. incognitus* first described from Barrington (England) has been demonstrated (Faure, 1984). A lower canine of a small carnivore is not sufficiently diagnostic to allow a taxonomic allocation.

The mammal fauna indicates a temperate and wet period and a landscape dominated by forest. Two elements of the mammal fauna from La Celle are noteworthy; the record of macaque is the first from Northern France, and the hippopotamus represents the only secure record from MIS 11 in NW Europe (Auguste in Schreve et al., 2007). The remaining mammal fauna from La Celle is similar to that from Cagny-la-Garenne II (Auguste, 1995a, b, in press).

4.3 Evidence of fire at La Celle

Among the flint artefacts discovered during October 2006 were four small burnt fragments. Another heated flint fragment (Figure 9 A) was discovered during the cleaning of the cutting in the archaeological layer (unit 7). This piece exhibited cracks and a large potlid (~1 cm in diameter) suggesting that it had been heated to a high temperature. In order to test this hypothesis, the flint was cut with a diamond saw and a few milligrams were crushed and prepared according to Valladas (1992). The powder was analyzed with a thermoluminescence (TL) reader between 20 and 500°C, at a heating rate of 5°/sec. The glow curve exhibits TL peaks whose amplitude is dependent on the radiation dose accumulated by the piece during its burial and on the temperature experienced by the flint in the past. Figure 9b shows the "natural" TL signal, induced by the archaeological dose, and the "natural + 150 Gy" signal recorded after another natural aliquot had received an additional 150 Gy dose, delivered artificially in the laboratory. The comparison of these glow curves shows a significant increase of the signal around the main TL peak (~380 °C) suggesting that the TL signal had been erased before the flint piece was abandoned. This erasure indicates that this piece had reached a temperature of about 350-400 °C. These measurements do not necessarily imply

human use of fire but perhaps demonstrate contemporaneity of archaeological occupation and the occurrence of fire at La Celle.

Three blocks levels occurring at the base of fine grey tufa layers are identified in the stratigraphy (NB1 to NB3, Figure 3). This position appeared questionable as the block movement along the slope implies an opening of the landscape whereas the fine grey deposits correspond to more stable environmental phases characterized by the development of closed vegetation. Moreover, unit 7 appears to have formed in woodland of the interglacial optimum. Detailed inspection of the fine sediments revealed many nodules of indurated grey tufa that appear to have been burnt. Interestingly, despite its strong grey color unit 7 contains only 0.26% organic carbon. It is assumed that local fires temporarily destroyed the vegetation and initiated movement of limestone and indurated tufa blocks downslope by colluvial processes. Careful examination of the precise stratigraphical position of artefacts and faunal remains indicate that they occurred at the base of unit 7, above the block level NB3 as demonstrated by presence of articulated deer bones (Figure 10). This suggests that Acheulean occupation occurred contemporaneously with the fire episode, which explains the presence of some heated flints. During subsequent periods when vegetation recolonized, the blocks became covered by fine sediments, which included a large proportion of burnt indurated tufa fragments and ash, which were largely responsible for the grey colour. Fossil remains from the grey layers such as shells do not show any trace of heating but compositional changes in the molluscan fauna are evident in later horizons. Three blocks levels overlained by fine grain size layers representing successions of fire and forest phases are observed on the section (Figure 3), but only unit 7 yielded archaeological artefacts. This suggests that the fire was more likely to have resulted from natural phenomenon, although a direct relationship with hominin populations cannot be excluded.

5. Discussion

Acheulean occupation horizons that are well dated and tied into the regional stratigraphy are scarce in Northern France (Figure 11). The oldest bifacial industries with secure contexts occur in the terrace system of the Middle Somme River in the Garenne alluvial formation. At Cagny-la-Garenne Acheulean industries have been recovered from coarse slope deposits with interstratified fluvial calcareous silts from an early glacial climatic context i.e. MIS 12 (Antoine et al., 2007). This is confirmed by an ESR/U-series age of 448 ± 68 ka obtained on a horse tooth recovered from the sandy archaeological layer and an ESR date of 443 ± 43 ka on quartz extracted from overlying green sands (Bahain et al., 2007). Mammal fauna associated

with the flint industry suggests occurrence of Acheulean occupation in an early cold stage context (MIS 12) and at the boundary of MIS 12 and MIS 11 (Lamotte and Tuffreau, 2001; Auguste, in press). At Cagny-la-Garenne II fine alluvial deposits overlying the coarse slope deposits yielded malacofaunas representative of the beginning of an interglacial, and are assigned to MIS 11 (Antoine et al., 2003; Limondin-Lozouet, 2001a). This allowed to precise a first age estimation after an ESR date of 400 ± 100 on quartz which was obtained from the same fine alluvial sequence in a green sand unit (Laurent et al, 1994). At Cagny-Cimetière, located at a few hundred metres from La Garenne, in the same alluvial formation, most of the Acheulean industry has been recovered from the basal gravels but a few artefacts came from the overlying sands and silts (Tuffreau and Lamotte, 2001). This suggests that the main period of human occupation occurred at the end of the cold stage i.e. MIS 12 (Antoine, 2001). Recent malacological analyses carried out on the fine alluvial deposits also indicate a cold climatic context. Snail assemblages suggest a correlation of these layers with the upper part of Cagny-la-Garenne II sequence (Limondin-Lozouet, 2001 b). No radiometric dating could be undertaken at Cagny-Cimetière, but comparison of stratigraphy and fossil evidence from both Cagny sites indicate a hiatus corresponding to the interglacial climatic optimum and main human occupations during early MIS 12.

A few kilometres downstream Cagny, the same alluvial formation was recently studied at the famous Saint-Acheul locality (Antoine and Limondin-Lozouet, 2004). There, a thin tufa layer yielded a land snail community belonging to the "*Lyrodiscus* assemblage", which indicates forest development during full temperate climatic condition, characteristic of MIS 11 tufa formations in North-West Europe (Limondin-Lozouet and Antoine, 2006). This attribution is consistent with an ESR date of 403 ± 73 ka undertaken on quartz extracted from the underlying fluvial silts and sands (Laurent et al., 1998). A single handaxe with a white patina was recovered at the top of the tufa layer, the only well-provenanced specimen from this MIS 11 deposit (Antoine and Limondin-Lozouet, 2004).

In the northern part of the Paris basin, drained by the Somme, Seine and Yonne rivers, Acheulean occupation is apparent during the MIS 11/MIS 10 transition at Saint-Pierre-les-Elbeuf in the Lower Seine (Lautridou, 2003 ; Cliquet et al., 2009), MIS 9 at Soucy in the Lower Yonne (Chaussé et al. 2004, Lhomme, 2007), and MIS 9 at Cagny-l'Epinette in the Somme valley (Tuffreau et al., 1995 , Bahain et al., 2007). At La Celle, the main part of the Palaeolithic site has been destroyed by exploitation of the modern tufa quarry. However despite the scarcity of artefacts the archaeological evidence recovered from this site is important to understand the context of this Palaeolithic industry in Western Europe. The

prehistoric occupation of La Celle, which took place during the interglacial optimum, is amongst the oldest in Northern France, but much older Acheulean sites occur in southern Britain (Roberts and Parfitt, 1999; Cook and Jacobi, 1998; Wenban-Smith et al., 2000) and central France (Despriée et al., 2007 and this issue). Preliminary work in the Somme valley (Antoine et al., this issue), suggests that Acheulean occupation may well have occurred in the Paris Basin before MIS 12.

An MIS 11 age for La Celle is now supported by various lines of evidence and results from other dating methods are imminent. Comparison with other sites also strengthens the chronological interpretation. The malacological "*Lyrodiscus* assemblage" recovered in the archaeological level is known from various sites in Northwest Europe (Rousseau et al., 1992; Limondin-Lozouet and Antoine, 2006; Preece et al., 2007). Among these is the Saint-Pierre-lès-Elbeuf tufa which pre-dates the Acheulean occupation. The stratigraphical position of this tufa is securely dated within a thick loess sequence containing several paleosols. This sequence has yielded several IRSL dates among which those of 396 ± 32 ka from the white sand and 475 ± 38 ka from the Elbeuf IV palaeosol, both levels laying underneath the tufa, support an MIS 11 attribution for the tufa (Cliquet et al., 2009). In Britain the same malacological assemblage occurred in a tufa at Beeches Pit, West Stow (Suffolk), a site also yielding evidence of primary context Palaeolithic archaeology (Preece et al., 2006 and 2007). Interestingly Beeches Pit is one of the rare European sites where evidence for the use of fire by humans during the Lower Palaeolithic has been demonstrated, including burnt areas interpreted as hearths (Gowlett, 2006; Preece et al., 2006). This suggests that the evidence for fire at La Celle might have some connection to the human occupation of the site.

Finally it is important to highlight that at La Celle, Acheulean occupation occurred during the interglacial optimum, the first observation of this kind from Northern France. At contemporary sites, such as Cagny, as well as more recent sites, such as Soucy, the malacofaunas indicate climatic contexts corresponding to the beginning or the end of interglacial periods (Limondin-Lozouet, 2001a and c). Repeated discoveries of human occupations during these transitional climatic phases have led to the suggestion that during Middle Pleistocene interglacial optima human populations preferred relatively open habitats that existed within a regional forested landscape (Roebroeks et al., 1992). The Acheulean occupation in forest habitats at La Celle, like that at Beeches Pit in England, invalidates this assumption. Recent investigations in the Somme valley have shown that Neandertals also was able to adapt their survival strategy to interglacial forest biotopes (Antoine et al., 2006).

6. Conclusion

The tufa succession at La Celle is a critical sequence for the characterization of environments in North West Europe during MIS 11 as well as an important Lower Palaeolithic site. The evidence of a bifacial industry in a well dated stratigraphical and palaeoenvironmental context constitutes a basis for a discussion of the origin and development of bifacial industries in northern Europe. The evidence from La Celle demonstrates the ability of prehistoric humans to colonize forested environments, which developed during the temperate phases of the Middle Pleistocene. Evidence for fire at La Celle might contribute to debate about possible use of fire by Lower Palaeolithic populations as early as 400 ka.

Acknowledgments

This work is a contribution to SITEP project (Signature climatique des Interglaciaires dans les Tufs Européens, réponse des Environnements et impact sur le Peuplement paléolithique - Programme CNRS-INSU : Eclipse II). We are grateful to the Mairie de Vernou-La-Celle, to the Conseil Général de Seine et Marne and the DRAC Ile-de-France for help in organizing and funding field work. Authors are indebted to an anonymous reviewer for comments on the manuscript and improvement of the English.

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Figure captions

Table 1 : Radiometric dates from La Celle.

Figure 1: Geographical location (A) and morphological position (B) of the tufa at La Celle in the terrace system of the River Seine (modified after Bourdier, 1969).

Figure 2: Site map of La Celle with location of i) the first surveys of 2003, carried out along the old face of the quarry, ii) the great cut along the slope, and iii) the boreholes demonstrating the maximum westward extent of the tufa.

Figure 3: Stratigraphy of La Celle tufa described from the long section along the slope.

Figure 4: Malacological zonation of La Celle tufa versus the stratigraphy. The malacological succession shows that the tufa formed downslope and that the total thickness of the tufa is about 9 metres.

Figure 5: Stratigraphic location of the levels rich in leaf impressions.

Stratigraphical synthesis and palaeontological contents of the tufa formation in the eastern part of the site according to Tournouër (1877) and Munier-Chalmas (1903).

Figure 6: Lithic industry of La Celle, A and B handaxes collected in the quarry located at the south of the cemetery in 1893-1894 (modified according to Collin et al., 1895), C and D bifacial flakes collected during the 2003 excavation.

Figure 7: Structural analysis of bifacial piece n°1 from La Celle, housed in the collections of the Musée des Antiquités Nationales de Saint-Germain-en-Laye (France).

Figure 8: Structural analysis of a bifacial piece n°2 from La Celle, housed in the collections of the Musée des Antiquités Nationales de Saint-Germain-en-Laye (France).

Figure 9: A. Heated flint from La Celle, B. Curves of heating tests. Nat = natural TL signal, induced by the archaeological dose ; Nat + 150 Gy = signal recorded after another natural aliquot had received an additionnal 150 Gy dose delivered artificially in the laboratory ; Regen. (150 Gy) = regenerative signal induced by a 150 Gy dose delivered to an aliquot previously heated at 420°C ; Bgd = Background signal generated by the thermal emission of the heating plate and the dark noise of the photomultiplier tube.

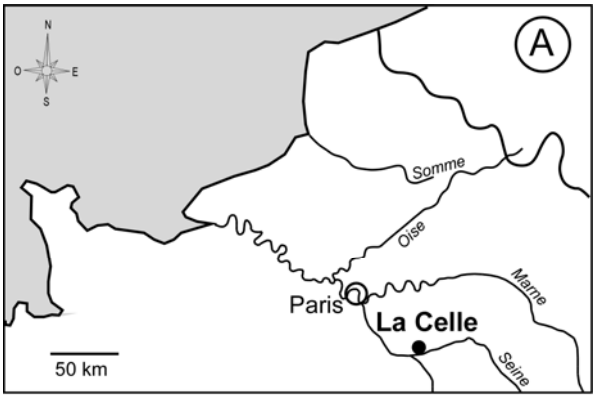
The comparison of the Nat. and Nat. + 150 Gy glow curves indicates a significant increase of the TL signal with the accumulated dose allowing to conclude that this flint has been heated in the prehistoric times at a high temperature. However, the shape in the 400-480°C interval of the Regen. glow curve, obtained by a 150 Gy dose delivered after the TL signal had been zeroed at 420°C, demonstrates that the temperature reached in the past did not likely exceed 350-400 °C.

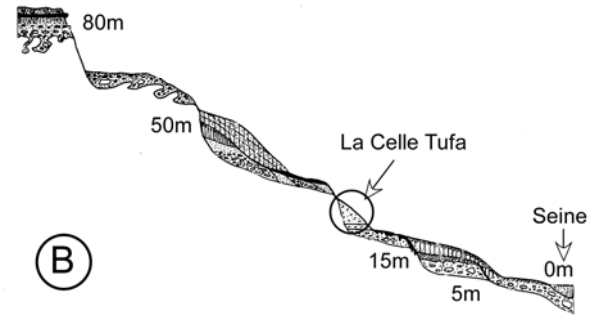
Figure 10: Articulated deer bones from the base of unit 7 above NB3 block level.

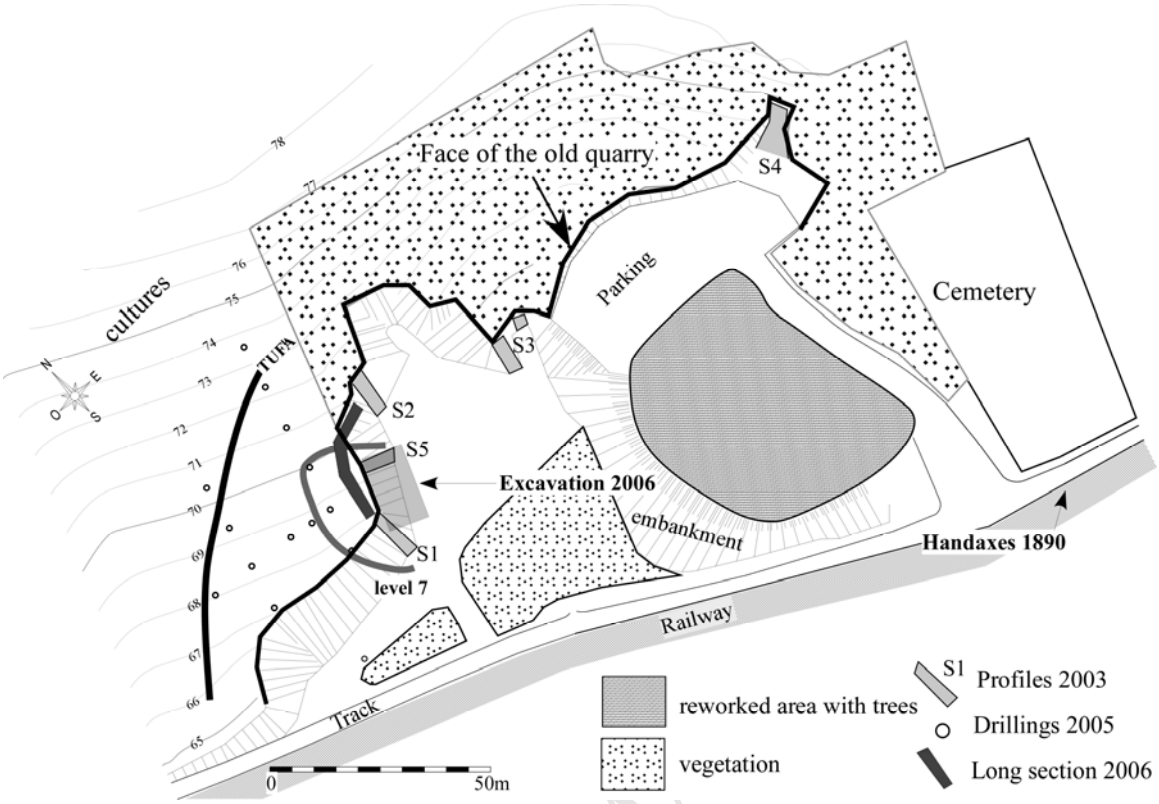
Figure 11: Map of some of the critical Acheulean sites in Northwest Europe mentioned in the text.

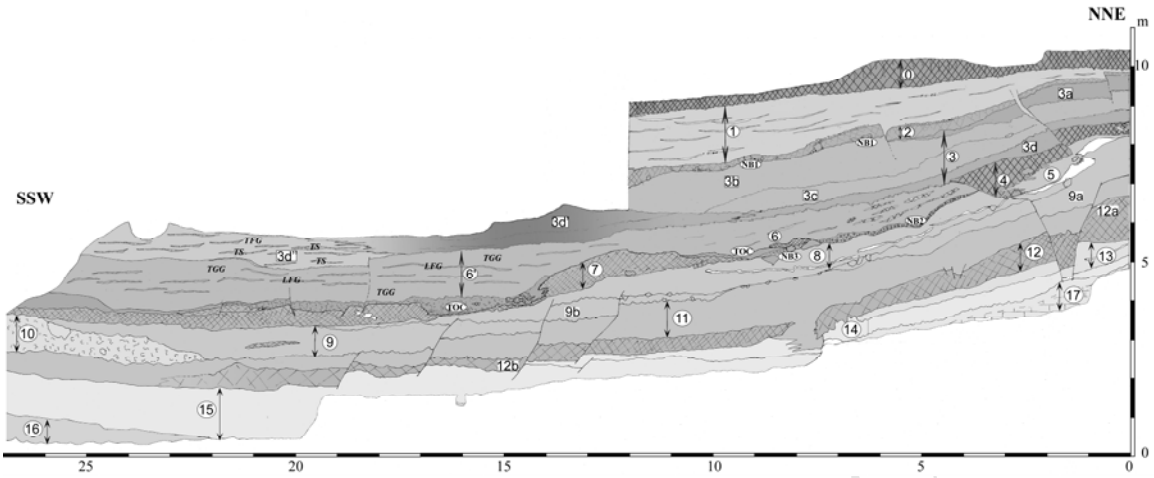
Method	Laboratory	Sample
U-series Spectrometry alpha	MNHN Paris, France	Tufa S4
U-series TIMS	GEOTOP Montréal, Canada	Tufa S4
U-series TIMS	GEOTOP Montréal, Canada	Tufa 2007: NB3 level
ESR - U-series	MNHN Paris, France	Horse tooth: level 7, 2003

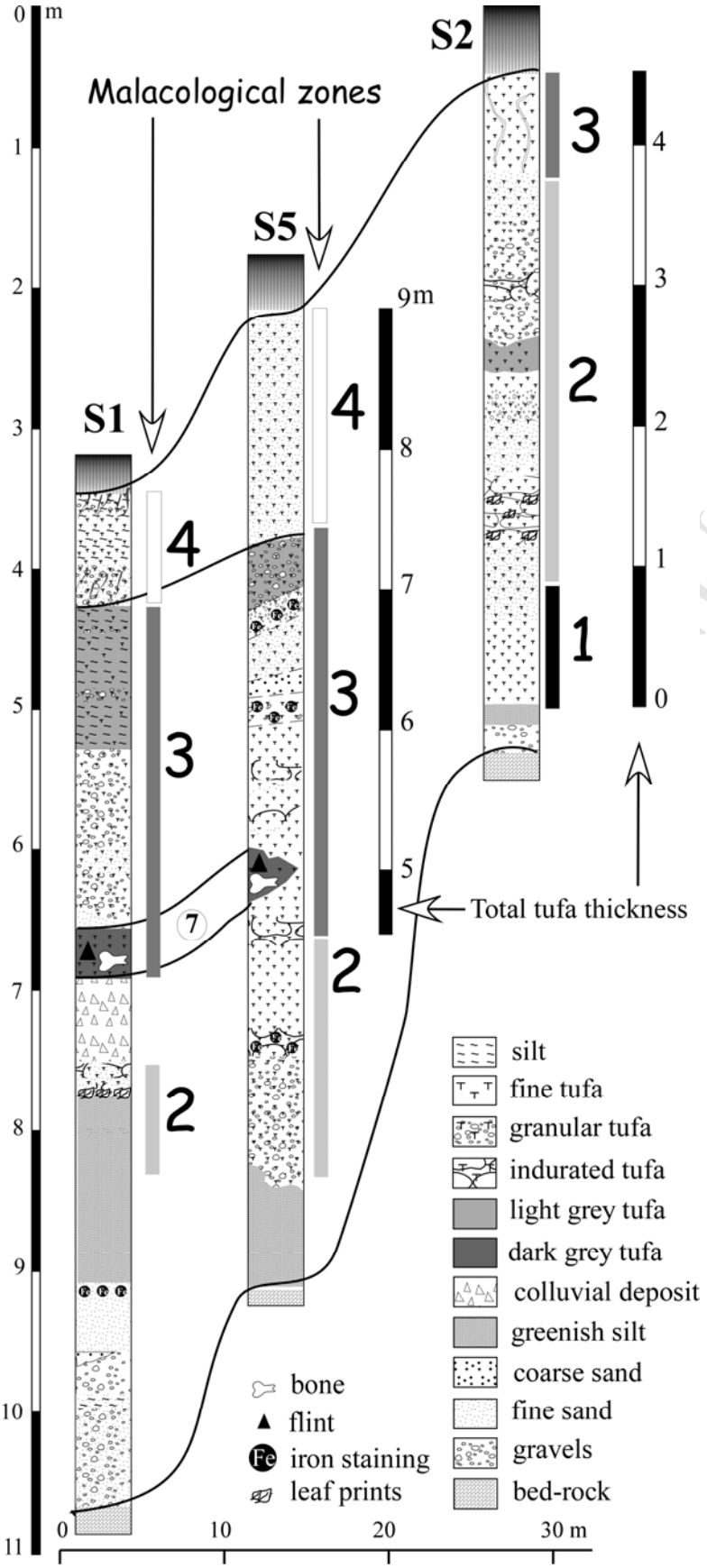
Age ka
>350
387 + 88 - 48
388 + 51 - 34
424 +- 38

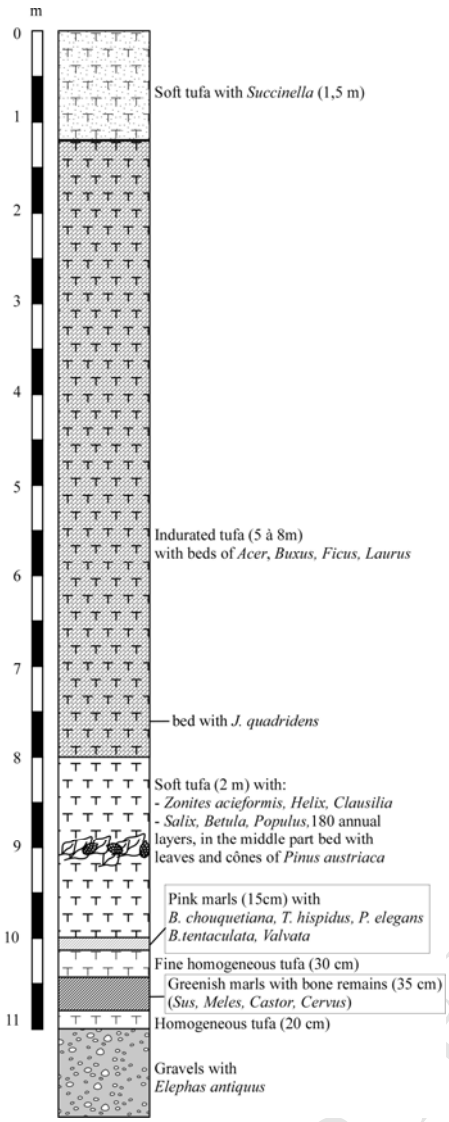


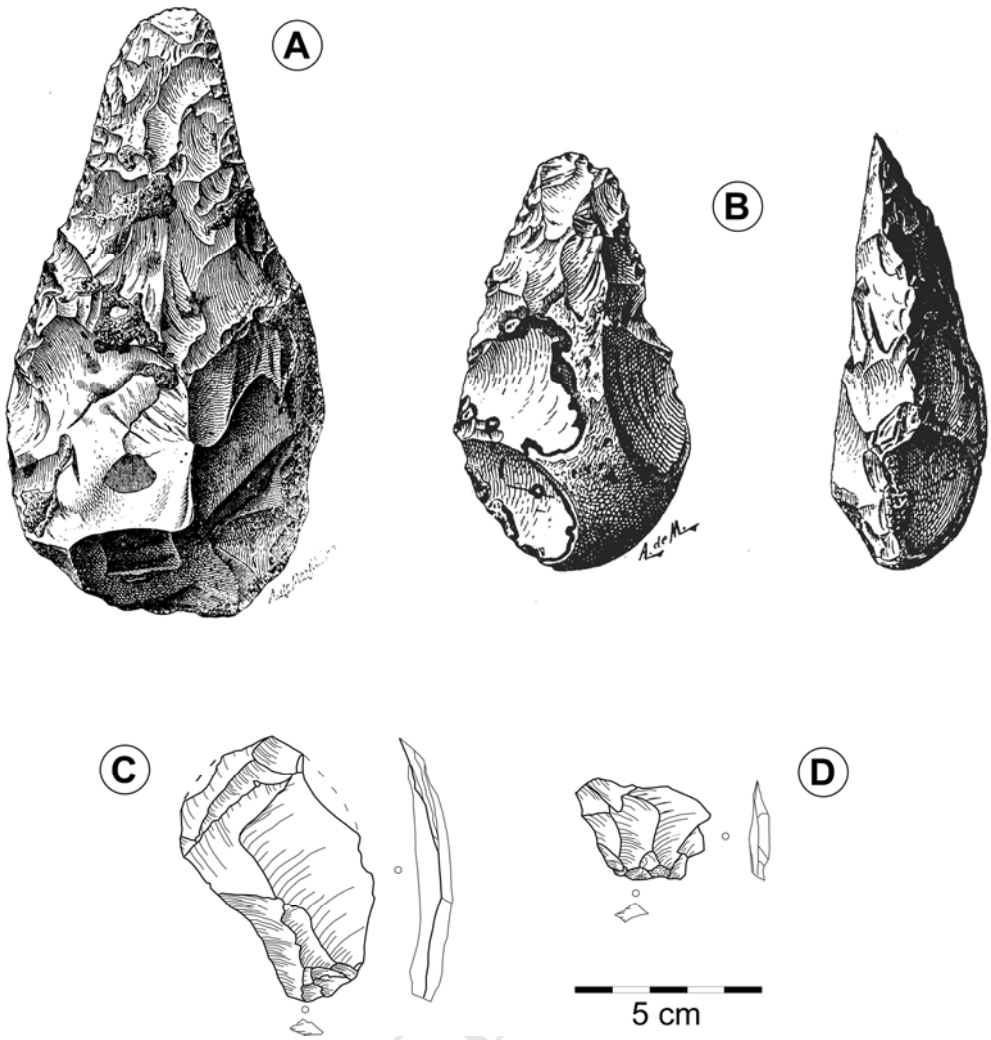


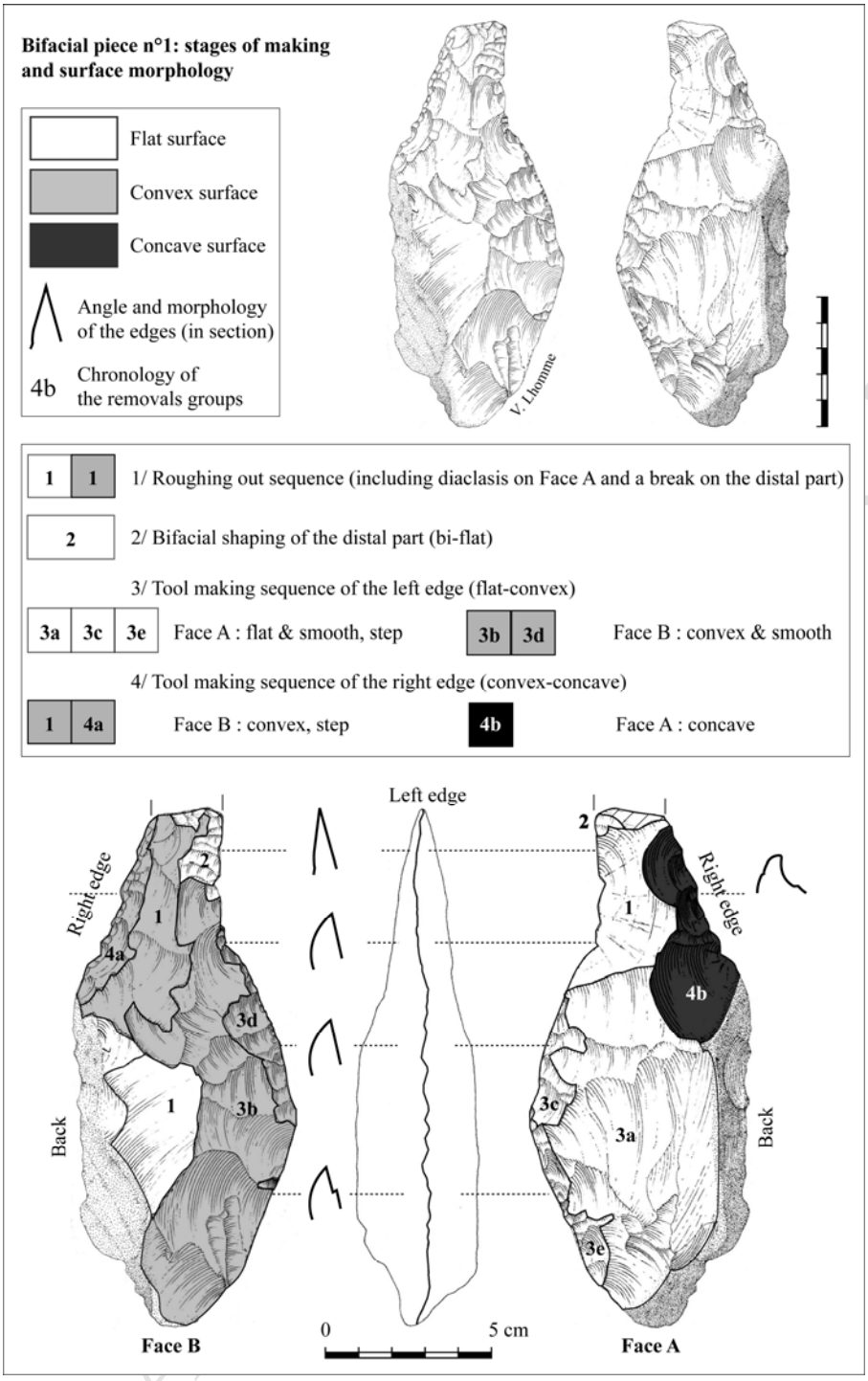





m
Malacological zones
S1
S2
S5
9m
Total tufa thickness
silt
fine tufa
granular tufa
indurated tufa
light grey tufa
dark grey tufa
colluvial deposit
greenish silt
coarse sand
fine sand
gravels
bed-rock
bone
flint
iron staining
leaf prints
0
10
20
30 m






Bifacial piece n°1: stages of making and surface morphology
Flat surface
Convex surface
Concave surface
Angle and morphology of the edges (in section)
4b Chronology of the removals groups
V. Lhomme
1 1 1/ Roughing out sequence (including diaclasis on Face A and a break on the distal part)
2 2/ Bifacial shaping of the distal part (bi-flat)
3/ Tool making sequence of the left edge (flat-convex)
3a 3c 3e Face A : flat & smooth, step
3b 3d Face B : convex & smooth
4/ Tool making sequence of the right edge (convex-concave)
1 4a Face B : convex, step
4b Face A : concave
Left edge
Right edge
Back
Face B
Face A
0
5 cm