Middle Paleolithic Geomorphological and Paleoenvironmental Setting of the Alsace Region: State of the Art and New Data

Patrice Wuscher[1,2], Olivier Moine[3], Agnès Gauthier[3], Frank Preusser[4]

1 Archéologie Alsace, Sélestat

2 Laboratoire Ville, UMR7362 CNRS-ULP, Strasbourg

3 Laboratoire de Géographie Physique: Environnements Quaternaires et Actuels, UMR 8591 CNRS-Univ. Paris1-UPEC, Meudon cedex

4 University of Freiburg, Institute of Earth and Environmental Science

ABSTRACT

The Upper Rhine Plain is part of a Cenozoic graben, which is approximately 40 km wide and 300 km long. This geological structure determines the geometry and the thicknesses of the Quaternary sediments, with a subsiding central zone and loess-covered alluvial terraces on its margins. In Alsace, most of the recorded Paleolithic remains are concentrated on the margins while the central area appears to be devoid of occupation. Recent investigations have been carried out in the region within the framework of the PaleoEls Project, and in the course of rescue excavations. They indicate that the sedimentary deposits, which are locally very thick, pose an obstacle for studying archaeological sites and are partly responsible for the observed distribution pattern. However, they also provide a chronological and palaeoenvironmental framework for the Middle Paleolithic. For the Upper Pleistocene, loess sequences attest to the establishment of pine forests during the first half of the period (from approximately 100,000 to 70,000 years ago), phases of erosion around the middle of the period (from approximately 100,000 to 30,000 years ago) and significant levels of deposition which fossilize tundra gleys over the course of the second half of the period (from approximately 30,000 to 20,000 years ago). Loess sequences also indicate environmental conditions that were dryer and richer in biodiversity than those in northern France. Around Strasbourg, alluvial clayey loams, more than 20 m deep, indicate the existence of a flood plain occupied by wet meadowlands and few trees during Pleistocene interstadial or interglacial times that was conducive to human occupation. While these deposits are currently only accessible through coring, Late Glacial and Holocene formations, which are easy to study, can serve as a model for studying the more discontinuous records from the earlier periods. They show the tendency for shrinkage in that part of the plain submitted to flooding from the Pleniglacial to the recent Holocene, leading us to envisage a situation where the plain was easy to cross during the Middle Paleolithic. Thus, from a geomorphological point of view, there is no reason to believe that the Rhine River acted as a boundary or posed an obstacle to human movement.

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RÉSUMÉ

La plaine du Rhin supérieur emprunte un graben d'âge cénozoïque large d'environ 40 kilomètres et long d'environ 300 kilomètres. Cette structure géologique conditionne la géométrie et les épaisseurs des sédiments quaternaires, avec une zone centrale subsidente et des terrasses alluviales couvertes de loess sur les bordures. En Alsace, la plupart des indices paléolithiques recensés sont concentrés sur les bordures et la plaine apparait comme un vaste secteur plus ou moins vierge de vestiges. Les observations récentes menées dans la région dans le cadre du projet PaleoEls et lors d'opérations d'archéologie préventive montrent que les dépôts sédimentaires, localement très épais, constituent une difficulté pour étudier les sites archéologiques et sont en partie responsables de cette répartition. Ils offrent en revanche un cadre chronologique et paléoenvironnemental pour le Paléolithique moyen. Pour le Weichselien, les formations loessiques témoignent ainsi de l'installation de forêts de pins durant la première partie de la période (environ entre 100 000 et 70 000 ans avant le Présent) et d'importants dépôts qui fossilisent des gleys de toundra durant sa dernière partie (environ entre 30 000 et 20 000 ans avant le Présent). Ils témoignent surtout d'environnements plus secs et plus riche en termes de biodiversité que ceux du nord de la France. Autour de Strasbourg, des alluvions limono-argileuses à plus de 20 m de profondeur témoignent d'une plaine d'inondation occupée par une prairie humide et par quelques arbres, dans un environnement interstadiaire ou interglaciaire, propice à des occupations humaines. Si ces dépôts sont accessibles aujourd'hui uniquement par carottages, les formations tardiglaciaires et holocènes étudiées en surface pourraient servir de modèle pour étudier les périodes plus anciennes. Ils confirment la tendance au rétrécissement de la bande active du Pléniglaciaire à l'Holocène récent, ce qui incite à imaginer une plaine plus facilement franchissable au cours du Paléolithique moyen que durant les périodes récentes. Ainsi, d'un point de vue géomorphologique, le Rhin ne semble pas constituer une frontière.

ZUSAMMENFASSUNG

Die Oberrheinische Tiefebene ist Teil eines känozoischen Grabens, der etwa 40 km breit und 300 km lang ist. Diese geologische Struktur bestimmt die Geometrie und die Mächtigkeit der Sedimente aus dem Quartär, mit einer absinkenden zentralen Zone und Löss-bedeckten Alluvial-Terrassen an ihren Rändern. Im Elsass konzentrieren sich die meisten paläolithischen Funde auf die Randgebiete, während das Zentrum offenbar unbesiedelt war. Rezente Untersuchungen wurden in der Region im Rahmen des PaleoEls-Projekts und im Zuge von Rettungsgrabungen durchgeführt. Sie weisen darauf hin, dass die lokal sehr mächtigen Sedimentablagerungen ein Hindernis für die Untersuchung archäologischer Stätten darstellen und teilweise für das beobachtete Verteilungsmuster verantwortlich sind. Diese Sedimentablagerungen bieten jedoch auch einen chronologischen und paläoökologischen Rahmen für das Mittelpaläolithikum. Für das Oberpleistozän belegen Lößsequenzen die Entstehung von Kiefernwäldern in der ersten Hälfte des Zeitraums (vor ca. 100 000 bis 70 000 Jahren), Erosionsphasen in der Mitte des Zeitraums (vor ca. 100 000 bis 30 000 Jahren) und massive Lössablagerungen, die Tundra-Gleye in der zweiten Hälfte des Zeitraums (vor ca. 30 000 bis 20 000 Jahren) fossilieren. Diese Lösssequenzen deuten zudem auf eine Umgebung hin, die trockener und artenreicher war als in Nordfrankreich. In der Umgebung von Straßburg weisen lehmige Alluvialböden mit einer Tiefe von mehr als 20 m, feuchten Wiesen und wenigen Bäumen auf eine Überschwemmungsebene hin, die während der pleistozänen Interstadial- oder Interglazialzeit von Menschen besiedelt wurde. Während diese Ablagerungen heute nur durch die Entnahme von Bohrkernen zugänglich sind, können spätglaziale und holozäne Formationen, die dahingegen leichter zu untersuchen sind, als Modell für die

Untersuchung der diskontinuierlicheren Aufzeichnungen aus den früheren Perioden dienen. Sie zeigen die Tendenz zur Schrumpfung des Teils der Ebene, der vom Pleniglazial bis zum jüngsten Holozän überflutet wurde, und lassen auf eine Situation schließen, in der die Ebene während des mittleren Paläolithikums leicht zu durchqueren war. Aus geomorphologischer Sicht gibt es demnach keinen Grund zu der Annahme, dass der Rhein eine Grenze bildete oder ein Hindernis für die menschliche Bewegung darstellte.

CONTEXT AND CURRENT STATE OF KNOWLEDGE

The Upper Rhine Plain is a Cenozoic intraplate rift that formed a graben, with a width of 35 to 40 km between the Vosges and the Black Forest and a length of about 300 km between the Jura and the Rhennish Massif. This geological structure, and the associated tectonic movements, have determined the geometry/geology and the thicknesses of surficial formations during the Quaternary (e.g., Gabriel et al. 2013; Ménillet and Wuscher 2017), with a central subsiding zone and systems of loess-covered alluvial terraces on the flanks of the bordering uplifted graben shoulders. Delimited to the south by the Jura mountain range (mesozoic limestones) and to the west by the Vosges (Paleozoic crystalline formations and mesozoic sandstones), the Alsace region occupies the south-western part of this zone.

Numerous studies have already been carried out on the Quaternary and prehistoric periods of the Alsace Plain (e.g., Wuscher and Moine 2017). These have recently been supplemented by the excavation of the early Upper Pleistocene rockshelter at Mutzig (Koehler et al. 2016), by several rescue excavations (most notably investigations carried out as part of the Rhine-Rhône LGV and the Strasbourg Western Bypass; see, e.g., Steiner et al. 2012), and by the Ministry for Culture's PaleoEIS project (Wuscher et al. 2016, 2017 and 2018). However, the highly faulted character of the region results in a compartmentalization of the surficial formations, thus making it difficult to gain a clear overall picture. Nevertheless, a number of broad tendencies can be observed.

The subsiding zones are characterized by stacked alluvial layers. In the southern part of the region, around Mulhouse, the alluvial material is coarse, while in the north, fine and often quite organic horizons have been observed. Their faunal and vegetal contents reveal their interglacial character, as for example at Strasbourg (Geissert et al. 1976; Fig. 1) and at Bischwiller where George Roque spent over 20 years collecting skeletal remains from dredged sands (Louguet 2005). However, new core samples and numerical dating will be necessary in order to determine the exact age of these various Quaternary geological formations, as has recently been carried out in the Heidelburg area (Gabriel et al. 2013). At the surface of the Rhine Plain, particularly around Colmar (Hirth 1971) and to the north of Strasbourg (Striedter 1988), it appears possible to subdivide the Late Glacial and Holocene alluvial deposits into bands, which run parallel to the river, on the basis of the topography, soils distribution and

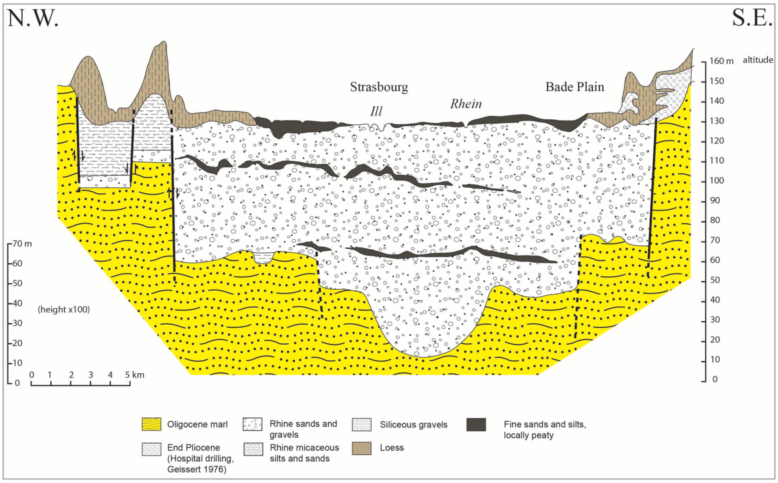


Fig. 1.
Cross-section of the Lower Rhine Plain (Ménillet after hydrogeological cross-section n°2 in Elsass and Rau 1995 and after Geissert et al. 1976).

observations conducted in quarries. In certain areas at least, this evidence points to a shrinking of the active plain during the Late Glacial to the late Holocene.

The alluvial terraces of the River Rhine and those related to tributaries originating from the Vosges are tiered along the graben shoulder bordering the Upper Rhine Plain. The nature of the connection between terrace zones and the area of the stacked alluvial bodies is often difficult to ascertain due to the height of the water table. Therefore, the phenomena that produced these formations (geomorphology, paleoclimate and neotectonics) and their respective contributions remain unclear. Geological maps indicate four tiered alluvial levels in the Vosges and on their fringes (Fv: Hypothetically Lower Pleistocene; Fw: Middle Mid-Pleistocene; Fx: Later Middle Pleistocene; Fy: Upper Pleistocene). These chronological attributions of the deposits are sometimes based on palaeontological data (e.g., Théobald 1970), but are more often based on their position and degree of alteration. However, this criterion, which depends as much on local pedogenetic conditions as on the age of the materials, is not very reliable (Puissegur 1965). The malacological content and the age of the overlying loess, when present, provide more solid arguments as, for example, in the case of the Schiltigheim terrace, situated to the west of Strasbourg, which has been attributed to the Upper Saalian (Puisségur 1965) or of Erstein, to the south of Strasbourg, which has been attributed to the Middle Weichselian (Mazenot 1963). However, with the exception of Achenheim (e.g., Buraczynski and Butrym 1984; Zöller et al. 2004), only the loess overlying the Middle Pleistocene fluvial deposits of the eastern edge of Sundgau has been dated using optically stimulated luminescence (Rentzel et al. 2009).

The highest terraces and tertiary horsts are generally covered by thick loess formations. At Achenheim the loess deposits reach a maximum thickness of 30 m, but the entire stratigraphic sequence is never accessible in a single location. Therefore, a synthetic profile of the site has been created. The basis of the profile is composed of grey Rhenish sands overlained by pink Vosgian sands. These alluvial deposits support several loess series, interspersed with paleo-soils which correspond to at least four glacial-interglacial cycles (Fig. 2) whose palaeoenvironmental and palaeoclimatic evolution has been reconstructed in detail thanks to a comprehensive analysis of the malacofauna (Rousseau 1987). Despite the numerous paleontological (Wernert 1957; Heim et al. 1982) and archaeological remains discovered, only two levels, soils 74 and 81, which are located respectively beneath the Achenheim I and Achenheim III paleosoils, have been investigated through excavation. These initial studies were followed by dating studies using thermoluminescence (TL) (e.g., Buraczynski and Butrym 1984; Zöller et al. 2004) which have provided a chronological framework, particularly for the last glacial cycle. Comparable stratigraphic sequences have also been described at Riedisheim (Franc de Ferriere 1937; Mazenot 1963), Neewiller (Ménillet 1995) and Sierentz (Rentzel et al. 2009).

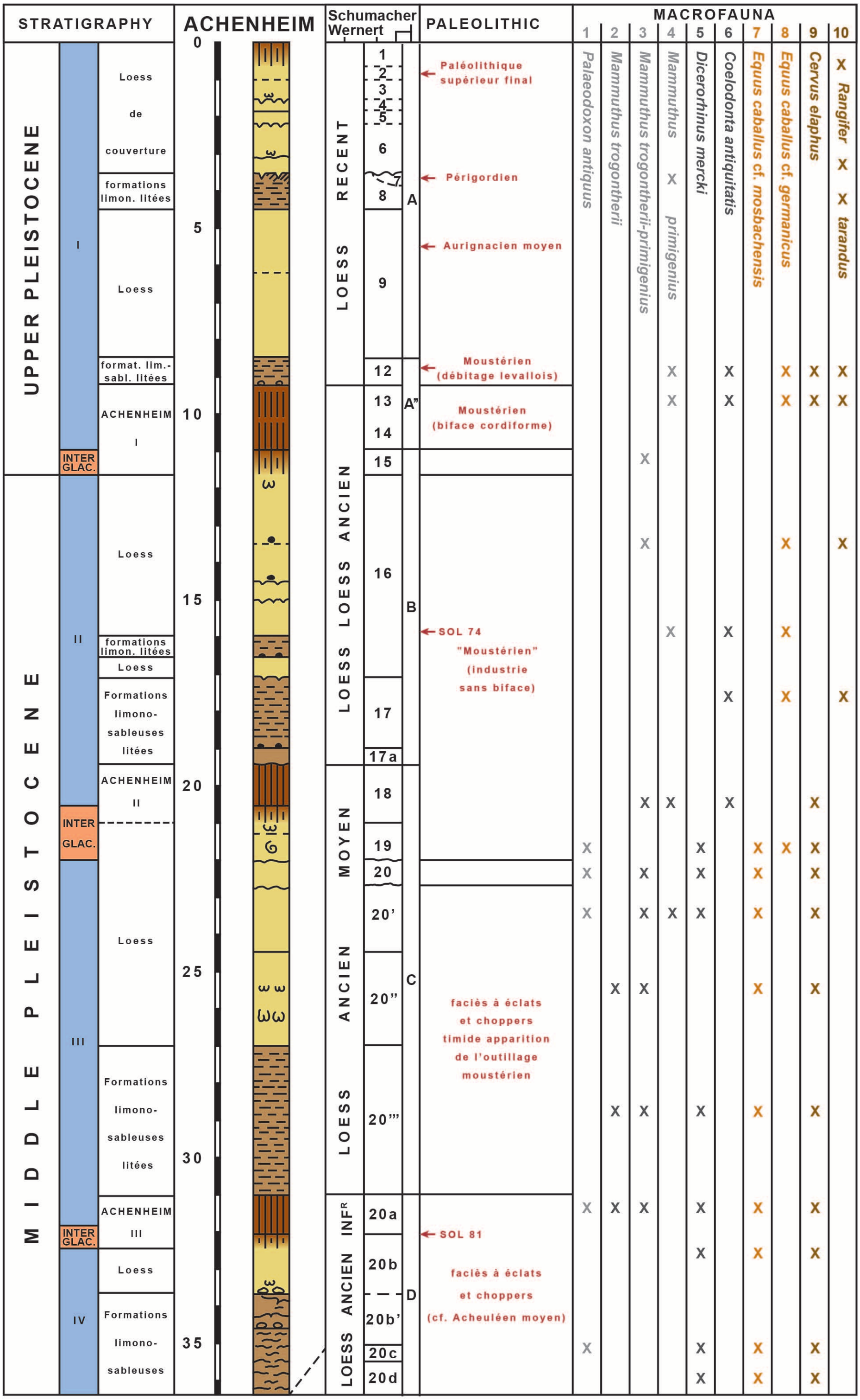
PROBLEMS AND METHODS

In Alsace, the majority of recorded Paleolithic sites are concentrated along the foothills of the Vosges, around the valley of the Bruche and in Sundgau, which raises the question of the influence of geology and geomorphological dynamics on their location and preservation (Wuscher et al. 2016; Fig. 3). The geographical distribution of the sites also raises the issue of the geological and geomorphological uniqueness of the Upper Rhine Plain within the North European Plain. How might the physical and palaeoenvironmental characteristics of the Rhine Plain have contributed to making this a frontier zone or, alternatively, an axis of communication?

Recent surveys carried out in the loess quarry faces at Schaffhouse-près-Seltz as part of the Minister for Culture's PaleoEls project (Wuscher et al. 2016, 2017), as well as recent rescue excavations at Weyersheim in the Rhine Plain, have added significantly to our existing knowledge and go some way to providing answers to these questions.

A classic approach has been adopted. First, existing data have been mapped using 1/50,000 geological survey maps. This was followed in the field by cleaning the quarry faces and the mechanical excavation of test pits undertaken as part of rescue excavations which allowed a representative log to be selected. This log was then represented realistically and described in detail, with the inclusion of numerical dating provided by radiocarbon measurements[1] and optically stimulated luminescence. For a certain number of cases it also includes analysis of the malacological, palynological and charcoal contents.

1 One of the Weyersheim dates was obtained thanks to the international program entitled "Improving Late Glacial European tree-ring chronologies for accurate climate archive dating – Consolidation and extension of the Swiss-German pine chronology back to 14,000 BP" (Laboratoire ETH Zurich, the Universities of Fribourg, Mannheim and Heidelberg, the Swiss Federal Research Institute and the German Research Centre for GeoSciences).


STRATIGRAPHY
ACHENHEIM
Schumacher Wernert
PALEOLITHIC
MACROFAUNA
UPPER PLEISTOCENE
MIDDLE PLEISTOCENE
Loess de couverture
formations limon. litées
Loess
format. lim.-sabl. litées
ACHENHEIM I
INTER GLAC.
ACHENHEIM II
ACHENHEIM III
Formations limono-sableuses litées
Formations limono-sableuses
LOESS RECENT
LOESS ANCIEN
LOESS LOESS ANCIEN
LOESS MOYEN
LOESS ANCIEN INFR
Paléolithique supérieur final
Périgordien
Aurignacien moyen
Moustérien (débitage levallois)
Moustérien (biface cordiforme)
SOL 74
"Moustérien" (industrie sans biface)
faciès à éclats et choppers timide apparition de l'outillage moustérien
SOL 81
faciès à éclats et choppers (cf. Acheuléen moyen)
Palaeodoxon antiquus
Mammuthus trogontherii
Mammuthus trogontherii-primigenius
Mammuthus primigenius
Dicerorhinus mercki
Coelodonta antiquitatis
Equus caballus cf. mosbachensis
Equus caballus cf. germanicus
Cervus elaphus
Rangifer tarandus

Thus, having been rendered accessible through quarrying by the Wienerberger Group, the stratigraphic sequence for Schaffhouse-près-Seltz, which was exposed in several quarry faces, has been captured using 37 logs (Wuscher et al. 2017b). On the eastern fringe of the Upper Rhine Plain, in the Zorn Ried at Weyersheim, the stratigraphic sequences have been revealed by sand and gravel extraction works carried out by Eurovia. The sequences have been examined through a series of 19 test pits distributed along a roughly north-south axis as part of an archaeological survey carried out in the Winter of 2015 (Chosson and Wuscher 2015). In general, the test pits are spaced at intervals of about 50 m, with each covering an area about 10 m^2 so as to reveal any potential archaeological remains. Significant inflows of water, which generally occurred once the pebble layer was reached, at a depth of 2.5 to 3 m, led to the abandonment of the test trenches. The two paleochannels present in the area were the subject of

Fig. 2. left
Stratigraphy and Quaternary formations from Achenheim/Alsace, locations of Paleolithic levels and various species of large mammal (redrawn after Lautridou et al. 1985).

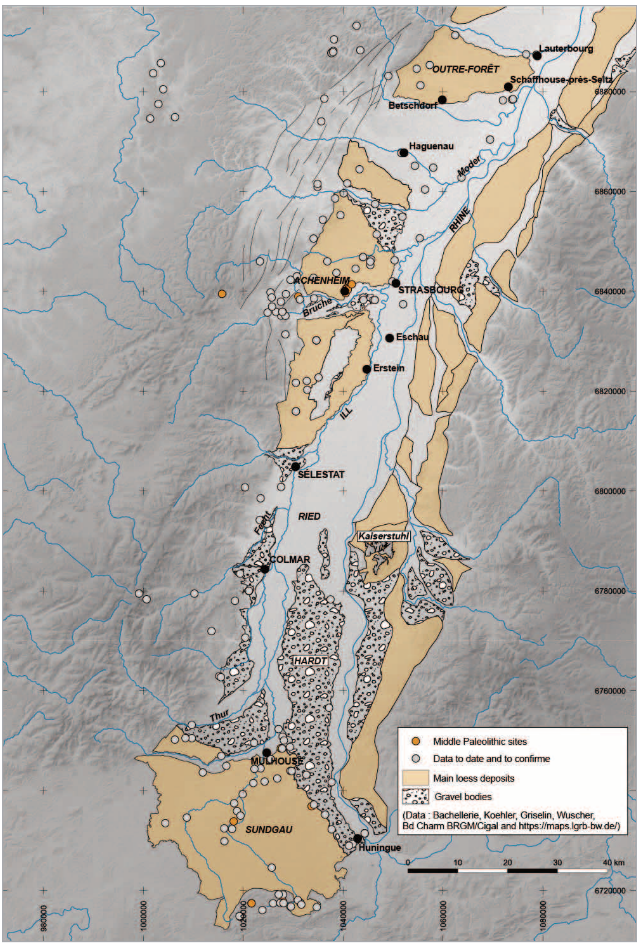


Fig. 3.
Locations of the Middle Paleolithic remains of Alsace.

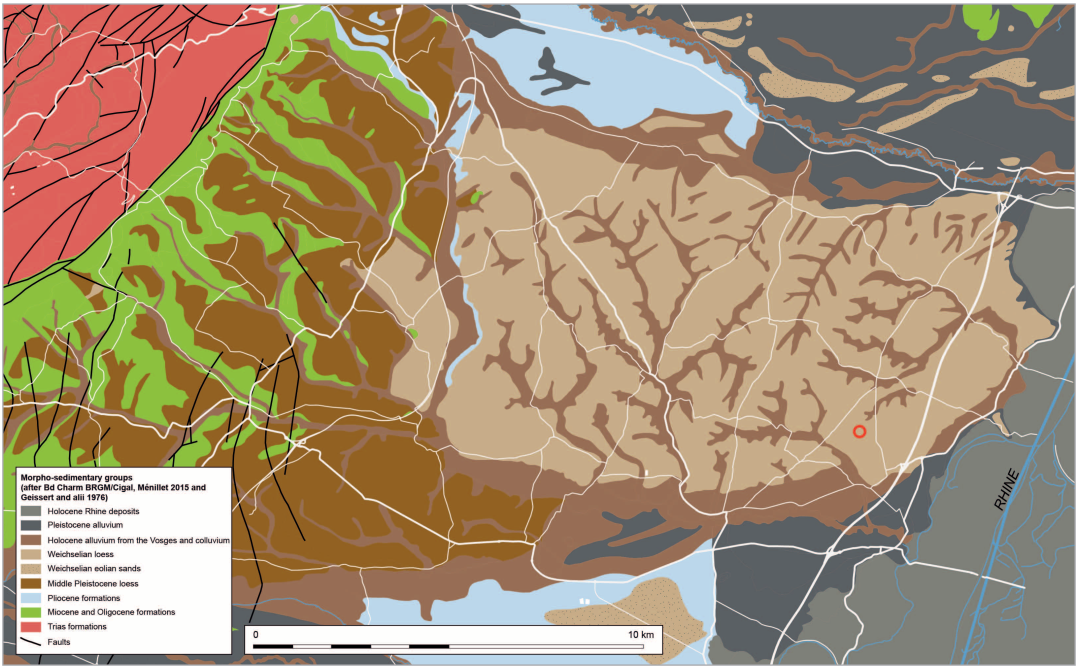
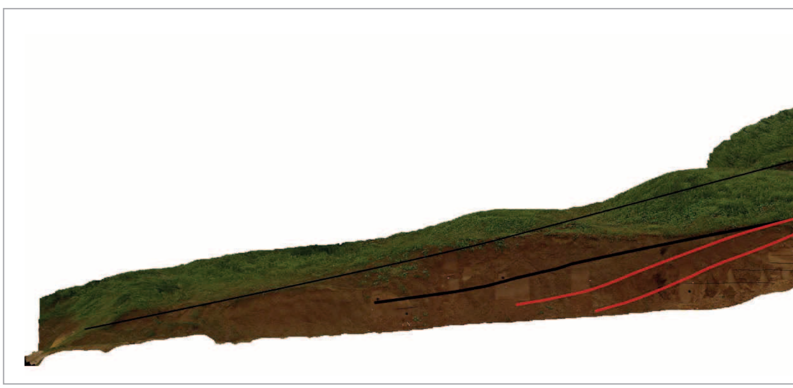


Fig. 4.
Schaffhouse-près-Seltz (red round), morpho-sedimentary groups (after DB Charm BRGM/Cigal).

continuous cross-sectioning using a mechanical digger and with the aid of a pump used during the excavation of a small rural Early Iron Age settlement in Autumn 2015 (Rault et al. 2018). Deeper horizons were identified by means of two sonic cores, measuring 50 m in depth, which were carried out by the quarry operators. Four samples of gray clayey loams, with variable organic contents, which are present between a depth of 24 and 34 m, were taken for palynological analysis; these samples were retrieved between -24.24 and -24.28 m, between -26.9 and -26.93 m, between -27.13 and 27.16 m and between 27.25 and 27.28m.



NEW DATA ON THE LAST TWO GLACIAL-INTERGLACIAL CYCLES FROM THE LOESS FORMATIONS AT SCHAFFHOUSE-PRÈS-SELTZ

The Outre-Forêt Hills, at the foot of the sandstone Vosges in northern Alsace, are delimited to the north by the Lauter Plateau, to the east by the Upper Rhine Plain and to the south by the Haguenau Plateau (Fig. 4). They rise to heights of 40 to 50 m above the Upper Rhine Plain and a little more than 30 m above the Lauter and Haguenau Plateau. They are transected by a number of small valleys which are usually asymmetrical, the south-facing slopes being generally steeper than those facing north. They are made of loess, more than 20 m thick, which overlie Oligocene formations in the west and Pliocene fluvio-lacustrian or Quaternary alluvial formations in the east (see, e.g., the Wintzenbach survey, undertaken at Schaferhubel, N°199-3-40; Geissert et al. 1976: 157; Ménillet 2015). According to the geological map, in the west, Middle Pleistocene polycyclical loesses predominate over a large area from the Vosges foothills to the Betschdorf area, while in the east loesses dating to the last glacial cycle predominate. The site of Schaffhouse-près-Seltz lies within the latter sector (Skrzypek et al. 2007).

The stratigraphic succession making up the Schaffhouse Hills is composed of at least two glacial-interglacial cycles, each comprised of a group of beige- to grey-colored loess loams and orangey-brown clay horizons. The succession displays an onion-like structure with the deposits of the latest cycle completely enveloping those of the older cycle on the north- and east-facing slopes (Fig. 5).

The most recent cycle (Fig. 5) is composed of a luvisol that developed on the surface, on top of loess material. Measuring 50 to 100 cm in thickness, from the bottom upwards it is made up of a decarbonated horizon, laminated loess and clays and a clayey horizon (Bt horizon). The loess materials from which the luvisol developed differ depending on the topography. Thus, the hilltop is composed of the following units (from top downwards, Fig. 6):

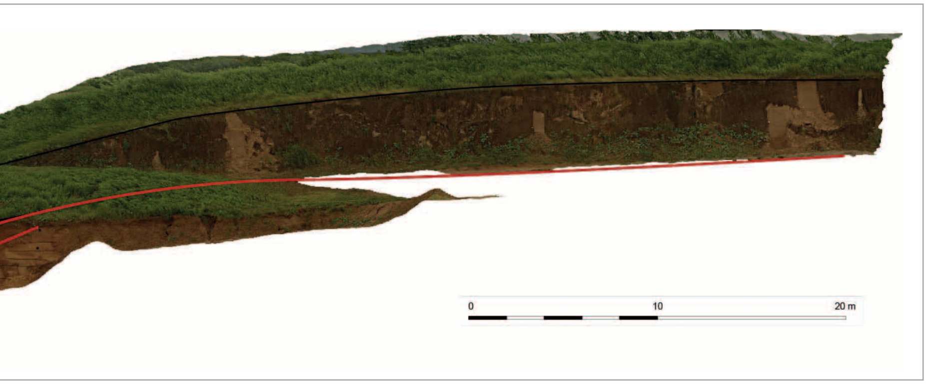


Fig. 5.
Onion-like structure of the loess successions of the Schaffhouse Hills (red lines indicate the position of the Eemian Bt horizon).

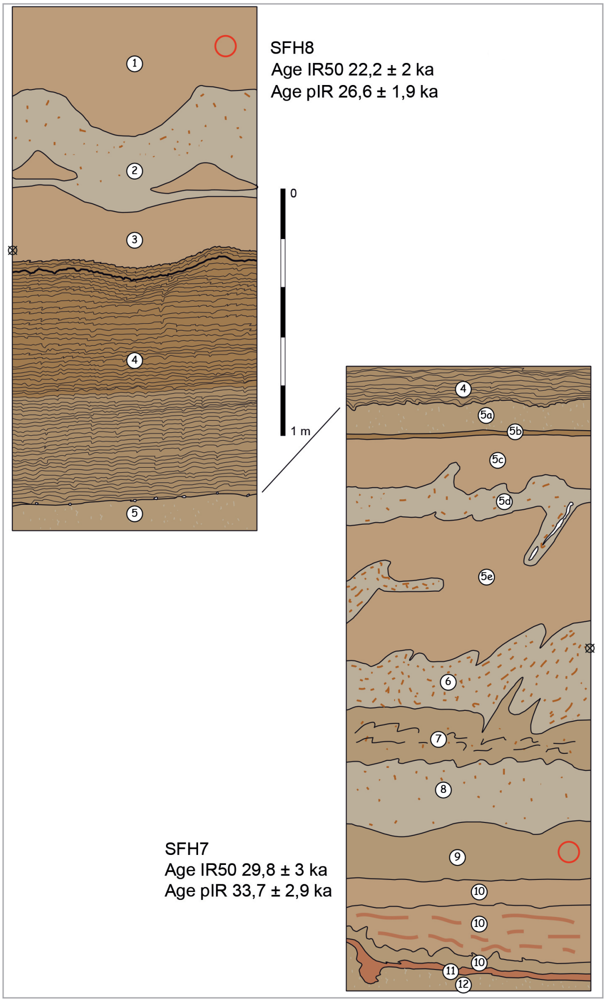


Fig. 6.
Schaffhouse, stratigraphic succession on the hilltop.

- Massive loess (Fig. 6, unit 1)
- A tundra gley (Fig. 6, unit 2)
- Bedded loess with a dark volcanic tuff at the top (Eltviller tuff, Fig. 6, unit 4)
- Massive loess (Fig. 6, unit 5)
- A gley (Fig. 6, unit 5d)
- Massive loess (Fig. 6, unit 5e)
- A gley (Fig. 6, unit 6)
- Massive loess (Fig. 6, unit 7)
- A gley (Fig. 6, unit 8)
- Massive loess (Fig. 6, unit 9)
- Soliflucted and laminated loess (Fig. 6, unit 10)
- A clay horizon fragment, all that re mains of the Bt horizon of the luvisol that developed on loesses of the pre ceding cycle (Fig. 6, unit 11)

This sequence is typical of Upper Weichselian deposits (Antoine et al. 2009) and is very complete. It is similar to that revealed at the Bossenrot quarry, located at the summit of the Achenheim compartment, and which is currently under study (Wuscher and Moine 2017).

On the east-facing slope, the most recent loess is 4 to 5 m thick and displays a different stratigraphic succession whose geometry closely follows the topography of the earliest cycle (Figs. 5 and 7). The followings units have been revealed (from top downwards):

- A gley (Fig. 7, unit 5)
- A thick loess (Fig. 7, unit 6)
- A brown, slightly bioturbated, horizon containing mollusk shells (Fig. 7, unit 7)
- A brown, decalcified and slightly bioturbated horizon (Fig. 7, unit 8)
- A grey horizon with a polyhedric to layered structure, containing charcoal (Pine; identification by Steffen Wolters, NIHK Wilhelmshaven) which is sometimes concentrated in lenses (Fig. 7, unit 9)

This succession is much more atypical and is unlike any other known sequences. The decarbonated nature of the brown and grey basal layers, the numerous charcoal inclusions and the optically stimulated luminescence dates allow the succession to be attributed to the Early Wechselian and the Lower Wechselian.

A Bt horizon of brown-orange luvisol with grey tongues developed on top of the loesses of the earliest cycle. The laminated loess and clays observed at its base are reminiscent of those of the surface soil. This paleosoil is well preserved on the slopes. On the summit of the hill, however, it only survives in the form of fragments and decimetric limestone concretions (loess dolls) within the underlying loesses.

The oldest cycle is located beneath this Bt luvisol horizon or beneath the decimetric loess dolls. It is less accessible and is, for the moment, described in less detail than the most recent cycle. It is made up of a succession of loesses and gleys, the latter being rich in mollusk shells (Fig. 7, units 12, 15, 17, 19, 21, 22, 23, 25 and 28). Its base has not yet been reached and no evolved paleosoil, linked to a pronounced interstadial or to an interglacial, has been revealed.

Finally, while the stratigraphic sequence of the Schaffhouse-près-Seltz loess quarry is thick, it is also very discontinuous and displays a particular onion-like geometry where the deposits of the latest cycle completely envelope those of the earlier cycle. The interglacial range paleosoil (Horizon Bt of the luvisol) which separates the two loess cycles is, however, only conserved on the slopes (Figs. 5 and 7). In fact, in most of the quarry the Eemian interglacial is, at most, represented by a few centimetric loess dolls. While the Saalian cycle, which is the earliest cycle, can be distinguished from the more recent cycle by the presence of a larger quantity of mollusk shells, it is in fact often difficult to differentiate the two cycles only on the basis of the facies observed.

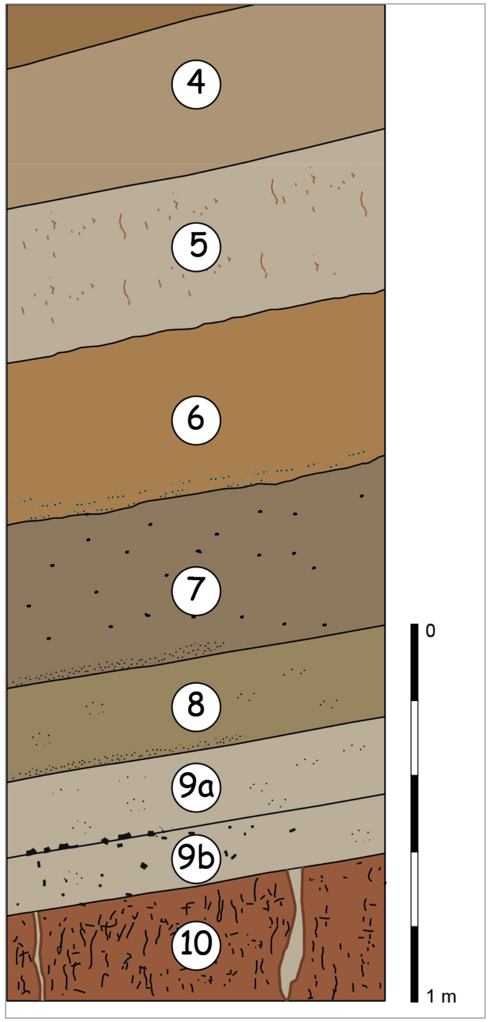


Fig. 7.
Schaffhouse, stratigraphic succession on the hillside.

NEW DATA FROM WEYERSHEIM RELATING TO THE INTERGLACIAL CONTEXT OF THE RHINE PLAIN

At Weyersheim the Rhine Plain is about 10 km wide and the summit of its fill is between 127 and 129 m NGF. The Zorn, one of the Rhine's principal Vosgian tributaries, enters its left bank where it has created an alluvial cone whose summit is at about 135 m NGF. On the right bank, the Rhine is constrained by an alluvial terrace, the summit of which reaches about 130 m NGF (Fig. 8).

On the left bank it has been possible, on the basis of mapping of surface soils and observations of sub-surface soils in quarries, to subdivide the Late Glacial and Holocene formations into several bands which run

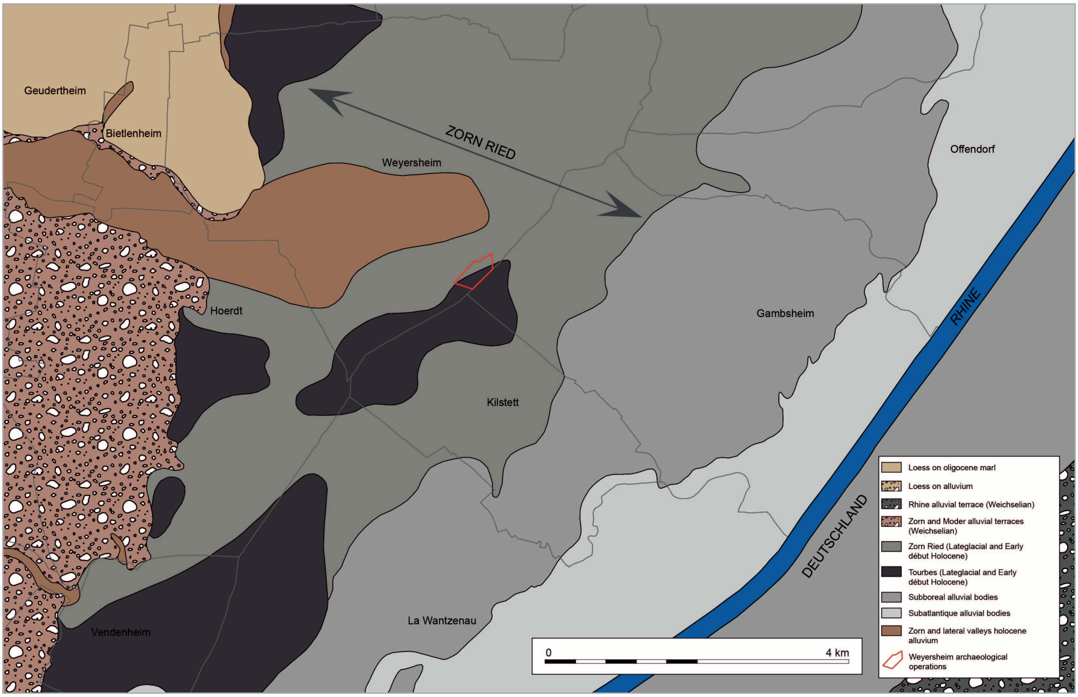


Fig. 8.
Weyersheim, morpho-sedimentary groups (after Bd Charm BRGM/Cigal and http://www.lgrb-bw.de).

parallel to the river (Striedter 1988). To the west (denoted FzT by the BRGM; Fig. 8) lies an area of *ried* (water meadow) which is characterized on the surface by very dark soils that developed on loamy clays, and by peaty deposits. To the east of Hoerdt, within this *ried* zone, several thousand *Pinus Silvestris* cones have been found on the summit of the highest gravel layer. In the 1930s, a palynological succession spanning from the Late Glacial period to the present was studied and, more recently, the remains of *Bos Primigenus* (aurochs) have been found in the peat deposits (Blanalt et al. 1972).This ried is covered by a small alluvial cone which has been deposited by the Zorn (Fig. 8). It is located slightly downslope, behind a group of alluvial bodies composed of loams which lie on top of gravels and which have yielded several fossil tree trunks (Fz1-2R); one of these bodies dates to the Bronze Age (Striedter 1988).

In this area the fill of the plain is composed of at least 50 m of Quaternary deposits (Eurovia data; Fig. 9). Lying beneath 2 to 3 m of clay, these deposits are principally made up of sands and gravels (Fig. 9). Between depths of 19 and 28 m (South core) and between 24 and 33 m (North core), a clay-loam layer has been revealed. The upper part has been sampled for palynological analysis (Fig. 9). Pollen samples n°1 to n°3 display very high sporo-pollen concentrations (Fig. 10). In contrast, sample n°4, taken from the top of the layer, shows a much lower concentration associated with poor preservation of pollen grains (more than 8% of the grains counted could not be determined), which indicates alteration of the

Fig. 9. right
Quaternary succession encountered in cores and positions of palynological samples (after the log provided by Gravières d'Alsace-Lorraine).

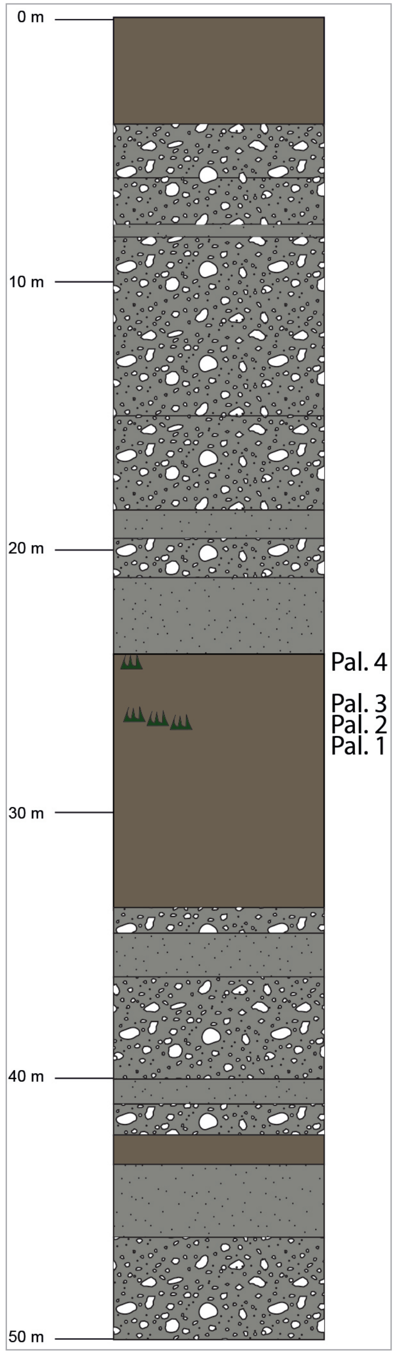
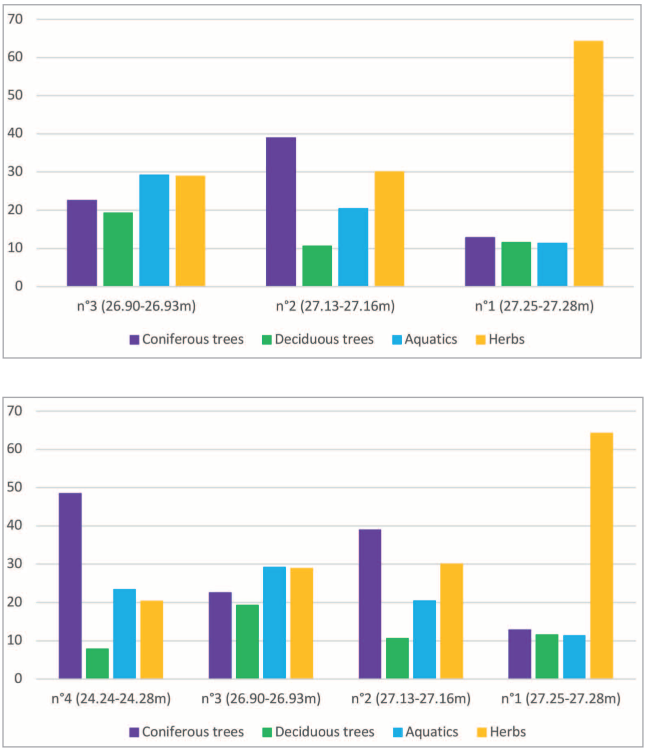


Fig. 10. below
Schematic representation of the palynological spectra (A. Gauthier).



pollen content. As a result, for this particular sample, the count was not continued until 400 grains had been obtained. For samples n°1 to n°3, the diversity of the pollen taxa present is quite high (23 to 29 taxa present; Fig. 10, Table 1). We note that there is little variation in the tree taxa (8 to 10 taxa identified) while herbaceous taxa are more numerous (15 to 19). The frequencies of *Pinus* and *Picea* vary in parallel (an increase of *Pinus* in sample n°2 and a decrease in sample n°3) while *Betula* values show a regular increase from samples n°1 to n°3. The percentages of other tree taxa do not display significant variations and remain low (<20%). As regards the herbaceous plants, the two dominant taxa are Poaceae, whose frequencies decrease from 55 to 22%, and Cyperaceae, whose frequencies increase from 11 to 29%. Any paleoenvi-

Table 1.
Results of palynological analyses of Pleistocene samples (A. Gauthier). Pollen percentages are calculated on the basic pollen sum (AP + NAP) excluding Pteridophytes spores, algae and indeterminables grains. Pteridophytes spores, algae and indeterminables grains percentages are calculated from the total sum.
The calculation of pollen concentrations followed the volumetric method of Cour (1974).

Sample	**n°4 (24,24-24,28 m)**		**n°3 (26,90-26,93 m)**		**n°2 (27,13-27,16 m)**		**n°1 (27,25-27,28 m)**	
	n° of grains	**%**	**n° of grains**	**%**	**n° of grains**	**%**	**n° of grains**	**%**
CUPRESSACEAE	6	9.38			17	2.38		
Picea	6	9.38	26	6.60	66	9.23	4	0.84
Pinus	19	29.69	63	15.99	195	27.27	57	12.00
Alnus	2	3.12	8	2.03	5	0.70	18	3.79
Betula			54	13.71	31	4.34	4	0.84
Corylus	2	3.12	5	1.27	3	0.42	4	0.84
Fagus					1	0.14		
deciduous Quercus-type			2	0.51	12	1.68	14	2.95
Salix	1	1.56	2	0.51	11	1.54	4	0.84
Ulmus			5	1.27	13	1.82	11	2.32
A.P.	**36**	**56.25**	**165**	**41.88**	**354**	**49.51**	**116**	**24.42**
AMARANTHACEAE-CHENOPODIACEAE-type					1	0.14		
APIACEAE			3	0.76	3	0.42	6	1.26
ASTEROIDEAE-type	1	1.56	4	1.02	2	0.28	1	0.21
Anthemis-type			1	0.25			3	0.63
Artemisia			8	2.03	4	0.56	2	0.42
Centaurea scabiosa-type			1	0.25				
CICHORIOIDEAE-type	3	4.69					9	1.89
BRASSICACEAE	1	1.56			1	0.14	3	0.63
CARYOPHYLLACEAE							4	0.84
CYPERACEAE	15	23.44	114	28.93	122	17.06	51	10.74
FABACEAE			1	0.25			1	0.21
Lemna					3	0.42	1	0.21
Nuphar					1	0.14		
Nymphaea					1	0.14		
Plantago					1	0.14		
POACEAE	6	9.38	81	20.56	190	26.57	263	55.37
Polygonum aviculare-type					1	0.14		

Table 1. cont.

Sample	n°4 (24,24-24,28 m)		n°3 (26,90-26,93 m)		n°2 (27,13-27,16 m)		n°1 (27,25-27,28 m)	
	n° of grains	%	n° of grains	%	n° of grains	%	n° of grains	%
Polygonum persicaria-type					1	0.14		
Rumex			2	0.51				
Potamogeton							2	0.42
RANUNCULACEAE			2	0.51			3	0.63
Thalictrum			2	0.51	4	0.56	1	0.21
ROSACEAE	1	1.56			1	0.14		
Filipendula			5	1.27	5	0.70	2	0.42
RUBIACEAE			2	0.51			6	1.26
Sparganium-Typha-type					12	1.68		
Typha latifolia			1	0.25	7	0.98		
URTICACEAE					1	0.14		
VALERIANACEAE	1	1.56	2	0.51			1	0.21
N.A.P.	**28**	**43.75**	**229**	**58.12**	**361**	**50.49**	**359**	**75.58**
MONOLETE SPORES			11	2.59	4	0.56	30	5.68
POLYPODIACEAE	1	1.41						
TRILETE SPORES							5	0.95
TRILETE SPORES ECHINATE							1	0.19
Equisetum			4	0.94				
Sphagnum			2	0.47				
Isoetes			9	2.12			8	1.52
Pediastrum			1	0.23				
Zygnema			2	0.47	3	0.42		
INDETERMINABLES	**6**	**8.45**	**5**	**1.18**			**9**	**1.70**
N° OF POLLEN TAXA	**13**		**23**		**29**		**25**	
A.P. + N.A.P.	**64**		**394**		**715**		**475**	
TOTAL SUM	**71**		**425**		**719**		**528**	
POLLEN CONCENTRATION	**8217**		**108418**		**719000**		**81481**	

ronmental interpretations of these data must be treated with caution given that only three samples are involved. The results allow us to envisage a damp, meadow-like environment where Poaceae and Cyperaceae predominate, similar to a megaphorb, with the presence of tall herbaceous plants such as Apiceae, *Thalictrum*, Valerianaceae, *Filipendula*, and Rubiaceae. The presence of aquatic plants (*Potamogeton*, *Lemna*, *Nuphar*, *Typha*) might indicate that there was a river bank close by. *Alnus*, *Salix* and *Betula* may have formed part of this vegetation as elements of riparian woodland. Conifer forest of *Pinus* and *Picea* developed regionally, probably mixed with occasional deciduous trees (*Quercus*, *Ulmus*).

With regard to the dating of this deep layer, the palynological results obtained are too few to allow any correlation with a particular period. However, we can state that while the characteristics of the three spectra do not correspond to a glacial phase (absence of steppic and xerophilic elements), neither do they correspond to a typical interglacial phase (very few thermophilic and mesophilic forest taxa). Nonetheless, no "exotic" taxa, corresponding to plants of tropical or sub-tropical environments, or to plants of warm temperate forests, such as *Carya*, *Nyssa* and *Zelkova* (whose last presence is recorded in the MIS 9), have been observed in the systematic examination of the microscopic slides from the various samples.

On the surface of the plain, open test trenches have revealed five major sedimentary formations (Chosson and Wuscher 2015). These are illustrated by test Trench 27 (Fig. 11). At the base, Body V is composed of gravels. Its upper surface is marked by pronounced ondulations which relate to the deposition of these materials (probably by braided streams) and to their subsequent reworking by channels that were partially masked during the laying down of the later deposits. These gravels originate from the Rhine. Body IV is composed of sands which have yielded frequent wood remains. The absence of intercalated gravel horizons within the group, and its wide extent, allows it to be distinguished from Body V and thus to exclude a simple lateral variation in facies. The sands are similar to Rhine deposits. One of the tree trunks exposed has provided a date of 9526 ± 185 BP (Trench 19). Body III is made up of several clayey loam layers, some of which are very organic. Secondary carbonations, of milimetric and centimetric size, have been observed locally at the summit of the body (Unit 4 in Trench 27). They attest to a drying out of the area and the development of a soil. The body therefore suggests the existence of an area of still water, which was rich in vegetation, with exposed zones. The geometry of the body indicates that its upper part may have been partially truncated prior to the laying down of Body II, which is composed of loamy clays that evolved laterally into clayey sands. It is brown in color and is characterized by the presence of ferromanganese oxides. The geometry and facies of this group indicate lateral inputs from the Zorn. The deposition of the body was followed by a long phase of exposure which is evidenced by the pronounced oxidation of the deposits. The fact that it has been cut by several structures dating to the

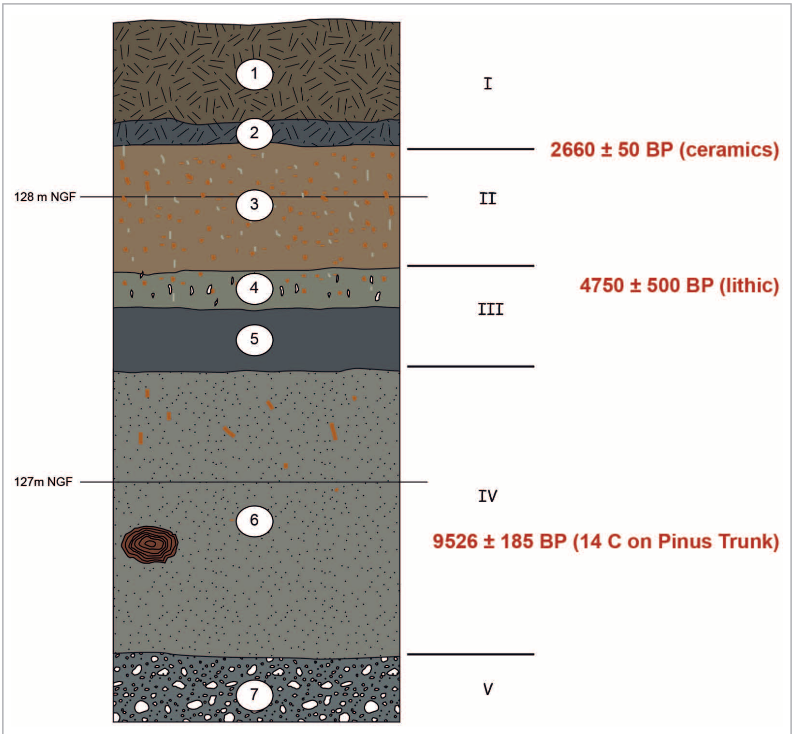


Fig. 11.
Stratigraphic succession encountered in test pit 27; 1: Brown beige loamy clays; 2: Grey-blue clays, Antique finds found in the formation; 3: Heterogenous gray-orange clays, ferromanganese oxides, structures dating to the Early Iron Age dug into the summit of the formation; 4: Gray clays, ferromanganese oxides, calacareous granules (approximately 2 mm in diameter); 5: Dark gray clays; 6: Greenish-gray fine, slightly clayey sands, occasional ferromanganese oxides, wood fragments; 6: Gravels.

Halstatt Iron Age provides a *terminus ante-quem* for its formation (Rault et al. 2018). Body I is made up of clays which indicate major episodes of flooding and sedimentation. The bluish color of its lower limits indicates significant waterlogging which has persisted up until the present. Based on finds from the base of the body, it would appear that it began to be deposited in Antiquity (Rault et al. 2018). In summary, the Rhine Plain was therefore much wider at the beginning of the Interglacial, in the Late Glacial and in Early Holocene, than in Middle and Late Holocene when the Rhine shifted eastwards and formed a coarse alluvial layer, which is rich in wood, and on which most of today's settlements were established (Striedter 1988). At the mouth of its valley, the Zorn has deposited a vast alluvial cone in the space vacated by the Rhine.

DISCUSSION

At a first glance it is clear that the considerable thicknesses of the sedimentary deposits described above constitute an obstacle for detecting and mapping archaeological sites and prove unfavorable for developing territorial approaches. They are responsible for the current distribution map of known archaeological sites, particularly the low number of sites in the central part of the Rhine Plain. This fact is highlighted by the thick stratigraphic succession observed at Weyersheim, within the alluvial deposits of the axial zone. Furthermore, the deep interstadial and interglacial clay formations identified a few kilometers to the north, and which have yielded significant quantities of bone remains and wood (Louguet 2005), are covered by several meters of water. The loess formations also reveal considerable thicknesses. Schaffhouse-près-Seltz, which is in a similar position to Achenheim, clearly demonstrates the vast scale of these deposits in Alsace, even though the formations predating the second last glaciation are still inaccessible. The later deposits are more accessible due to extraction sites for the manufacture of bricks and roof tiles. Above all, their thicknesses vary considerably, and sequences such as those of Schaffhouse-près-Seltz and Achenheim remain exceptional, even for Alsace. In the other sedimentary environments, such as the colluvial deposits in the fracture zones on the edges of the Rhine Plain, the thicknesses vary significantly and "… quaternary material can occur… practically on the surface" (Forrer 1925: 42), as is demonstrated by the site of Mutzig (Koehler et al., this volume). In the end, while the distribution of known archaeological sites closely obeys the geological structure of the Rhine Plain, this fact should not hinder the development of territorial approaches.

Due to their thickness, the loess formations can serve as a complete chronological and environmental framework for the Middle Paleolithic of Alsace. For the Weichselian, the Schaffhouse sections confirm what was already known at Achenheim, namely that the beginning of the period (approximately 100,000 years ago) was marked by the establishment of pine forests, while the end of the period (between 30,000 and 20,000 years ago) saw the deposition of significant loess deposits, with several tundra gleys at their base. This sequence is distinct from the sequences of northern France due to the lack of ice wedges. It has more in common with the Nussloch sequence, located on the plateau above the Rhine Valley to the south of Heidelberg (Antoine et al. 2009), and with eastern European deposits which formed in environments that were drier and richer in terms of biodiversity than those of northern France (Rousseau et al. 1998; Antoine et al. 2013; Moine 2014). For the Saalian, it is interesting to note the resemblances between the units forming the succession and those of the Upper Weichselian. It appears to be quite thick, but in the absence of an interglacial type paleosoil, it is not yet possible to confirm that it dates fully, or even partly, to the Saalian.

While the loess formations are thick, they are far from being continuous. First, the different phases of the Middle Paleolithic are not recorded in all of the topographical contexts. Thus, the horizons dating to the onset of the Weichselian glaciation at Schaffhouse have only been observed at the foot of the slope, while at Achenheim they are only found in a large dry valley (Sommé et al. 1986) and on the north-east facing slopes (Wuscher and Moine 2017). However, the thickest Upper Weichselian succession is found on a hilltop at Schaffhouse-près-Seltz, and this might also be the case in the area around Achenheim (Wuscher and Moine 2017). These sequences are also discontinuous in time as they are characterized by a number of hiatuses which vary in length. The brown soils of the Middle Weichselian (between approximately 50,000 and 30,000 years ago), which are well represented at Nussloch (Antoine et al. 2009) and which are ubiquitous in northern France where they take the form of one or several horizons, have not yet been clearly identified at Schaffhouse-près-Seltz. An orangey clay-rich horizon, several tens of centimeters thick, is clearly evident at the base of the Upper Wechselian loesses, but it still has not been dated. Nor has it been described in the literature dealing with Achenheim (Heim et al. 1982, 1984; Lautridou et al. 1985; Sommé et al. 1986; Fig. 3). Likewise, the Lower Weichselian deposits (between approximately 70,000 and 50,000 years ago) are virtually absent at Schaffhouse-près-Seltz and have not been clearly identified at Achenheim. The analysis of the malacological content at Schaffhouse-près-Seltz should clarify this issue. Nevertheless, it should be noted that while the Lower Wechselian is exceptionally well represented at Nussloch (Antoine et al. 2009), it is much rarer in the north of France (Antoine et al. 2016) and in western Europe generally. Construction work carried out in advance of the Strasbourg Western Bypass thus offer a unique opportunity for recording the archaeological sites and paleoenvironments of the Lower Wechselian (Schneickert 2017) and the Middle Weichselian (Carbillet 2017).

The alluvial deposits of the Rhine are much less accessible than the loess, especially in the axial zone of the Rhine rift where they are under water, and have not been the subject of recent study. The stratigraphic log and four samples that were made available to us for palynological analysis by the operator of the Weyersheim gravel pit are, therefore, an invaluable resource particularly because no stratigraphic sequence has hitherto been described in this area which has yielded a large quantity of paleontological remains (Louguet 2005). The clayey loams lying at a depth of 20 m relate to a flood plain occupied by water meadow with occasional trees reflecting an interstadial, or indeed interglacial, environment that would have been conducive to human settlement. Unfortunately, these loams are currently only accessible by coring. Laterally, these alluvial formations are discontinuous and heterogeneous (presence of channels, paleochannels and levees). The formations are also discontinuous upstream and downstream due to lateral inputs (truncation or covering over by sediments from the Zorn) and neotectonic activity (compartments that have slumped). In fact, further cores are required in order better to understand the precise paleogeographical history of the Rhine.

The Late Glacial and Holocene deposits studied at the surface allow us to construct a model for the Interglacial evolution of the plain, which in turn provides us a better understanding of the earliest deposits. The work carried out at Weyersheim confirms that there was a trend towards a shrinking of the active band from the Pleniglacial to the recent Holocene, as had previously been suggested in this area (Striedter 1988). This process, which had previously been demonstrated in the area around Colmar (Hirth 1971), may have been fairly generalized in the Rhine rift, as for example in the area to the north of Mannheim (Erkens et al. 2009) and is reminiscent of the trajectories of many large European rivers (e.g., Pastre et al. 2002). At a more or less constant flow rate, a wider plain logically leads to shallower channels. To the extent that a large part of the sediments deposited in the Rhine Plain during recent millennia are linked to the impact of agro-pastoral activities, the plain may have been wider during the preceding interglacials than in the Holocene. In general, therefore, it may have been easier to cross the plain during the Middle Paleolithic than in recent periods. Thus, from a geomorphological point of view, the River Rhine did not constitute a boundary or obstacle to human movement.

CONCLUSIONS

While many previous studies have concentrated on the Quaternary and Prehistory of the Alsace Plain, very few detailed descriptions have been conducted of the sedimentary formations and paleosoils, and there has been a general lack of absolute dates. Furthermore, several areas are poorly documented. It is therefore difficult to propose accurate reconstructions of the paleoenvironments and to draw conclusions regarding the territorial dynamics of Middle Paleolithic societies. However, the examples of Schaffhouse-près-Seltz and Weyersheim show that the numerous test pits carried out during rescue archaeology operations across the plain, in parallel with targeted research programs, such as the Minister for Culture's PaleoEIS program, are an invaluable means of filling the gaps in our knowledge.

While the results presented here are still preliminary, past studies and the examples of Weyersheim and Schaffhouse show that the Rhine Plain is a unique space, a vast plain bordered by mountains within a Cenozoic rift valley. The geological structure and form of this rift are responsible for various discontinuous Pleistocene sedimentary formations, with alluvial terraces on its edges and layered alluvial deposits at its center. This arrangement of surficial deposits clearly determines the distribution of currently known archaeological sites, some of which are located deep in the ground beneath the water table. Alluvial and loess formations attest to attractive environments which evoke the reconstructed past environments of Germany and eastern Europe (Erkens et al. 2009; Antoine et al. 2013). In particular, the post-glacial dynamics at Weyersheim, which can be taken as a model for the interglacial evolution of the plain and which greatly contribute to our understanding of the earliest deposits, indicate that there is no geomorphological reason to consider the Rhine as an obstacle to human movement.

In fact, there is still a lot of work required in order to gain a more accurate picture of the paleogeographical and environmental evolutions of the Middle Paleolithic. The results from Weyersheim and Schaffhouse-près-Seltz need to be supported by complementary analyses and confirmed by studies of other sites. Large scale groundworks involving the removal of loess formations around Achenheim, undertaken in advance of the construction of the Strasbourg Western Bypass, may thus provide valuable insights into the paleoenvironments of the Lower Weichselian (Schneickert 2017) and the Middle Weichselian (Carbillet 2017). In particular, other sedimentary contexts need to be investigated, particularly colluvial deposits and rockshelters, which have the potential to yield exceptional sites such as that of Mutzig, which dates to the beginning of the last glacial cycle (Koehler et al. this volume). This site shows that a steppe landscape, populated by mammoths, became established from the very beginning of the glacial cycle while formations on the slopes indicate an environment that was still dominated by woodland.

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