Fluvial evolution of the Moselle valley in Luxembourg during late Pleistocene and Holocene: palaeoenvironment and human occupation

L’évolution de la vallée de la Moselle luxembourgeoise durant le Pléistocène final et L’Holocène : paléoenvironnement et occupation humaine

Henri-Georges Naton, Stéphane Cordier, Laurent Brou, Freddy Damblon, Manfred Frechen, Anne Hauzeur, Foni Le Brun-Ricalens and François Valotteau
FLUVIAL EVOLUTION OF THE MOSELLE VALLEY IN LUXEMBOURG DURING LATE PLEISTOCENE AND HOLOCENE: PALAEOENVIRONMENT AND HUMAN OCCUPATION

Henri-Georges NATON¹, Stéphane CORDIER², Laurent BROU³, Freddy DAMBLON⁴, Manfred FRECHEN⁵, Anne HAUZEUR⁶, Foni LE BRUN-RICALENS³ & François VALOTTEAU³ in collaboration with Robert BAES⁷, Franziska DÖVENER⁸ & Jean KRIER⁸

ABSTRACT

Located in the Moselle valley in Luxembourg, the Wintrange basin has been the subject of systematic geoarchaeological investigations for the last fifteen years. According to observations made upstream, the study area could represent a system of lower terraces build up of two stepped alluvial formations (M2 +10m, M1 +3-5m). A recent synthesis of palaeoenvironmental studies done on the M1 formation has produced a chronological framework (radiocarbon and IRSL dating) and permits to precise the stages of morphosedimentary and environmental evolution for this part of the basin since the end of the Weichselian. This preliminary synthesis presents the sedimentary units of the lower terraces M1, the present state of knowledge on the dynamic and the chronology for the deposits, as well as an assessment for the human occupation and its impact on the landscape. The work study shows that there is an important hiatus for the Lateglacial and the beginning of the Holocene for this part of the Moselle valley.

Key-words: Geoarchaeology, IRSL and AMS datings, anthracology, soil erosion, Late Pleistocene, Weichselian, Holocene, preventive archaeology, Moselle valley, Grand-Duchy of Luxembourg.

RéSUMÉ

L’ÉVOLUTION DE LA VALLÉE DE LA MOSELLE LUXEMBOURGEOISE DURANT LE PLÉISTOCÈNE FINAL ET L’HOLOCÈNE : PALÉOENVIRONNEMENT ET OCCUPATION HUMAINE

Situé dans la vallée de la Moselle luxembourgeoise, le bassin de Wintrange fait depuis une quinzaine d’années l’objet d’études géoarchéologiques systématiques. Selon les observations en amont, le secteur d’étude présenterait un système de basses terrasses constitué par un ensemble de 2 nappes alluviales étagées (M2 +10m, M1 +3-5m). Un récent travail de synthèse des études paléoenvironnementales menées notamment sur la nappe M1 a permis d’établir les bases d’un cadre chronologique (datations radiocarbone et IRSL) et de préciser certaines étapes de l’évolution morphosédimentaire et environnementale dans cette partie du bassin depuis la fin du Weichselien. Cette synthèse préliminaire présente les unités sédimentaires de la base terrasse M1, l’état actuel des connaissances sur la dynamique et la chronologie de mise en place des dépôts ainsi qu’un bilan de l’occupation humaine et de son impact sur le milieu. Il ressort d’ores et déjà en l’état actuel des travaux qu’il existe un important hiatus pour le Tardiglaciaire et le début de l’Holocène dans cette portion de la vallée de la Moselle.

Mots-clés : Géotarchéologie, datations IRSL et AMS, anthracologie, érosion des sols, Pléistocène final, Weichsélien, Holocène, archéologie préventive, vallée de la Moselle, Grand-Duché de Luxembourg.

¹ Independent geoarchaeologist, association RooTS (Research Team in Archaeo- and Palaeo-Science), 18 rue de la Moselle, F-57100 Manom, France. Courriel : hg.naton@laposte.net
² Laboratoire Géodynamique des Milieux Naturels et de l’Environnement, Université Paris 12 - Val de Marne, 61 avenue du Général de Gaulle, F-94010 Créteil Cedex, France. Courriel : s-cordier@club-internet.fr
³ Service d’archéologie préhistorique, Musée National d’Histoire et d’Art du Grand-Duché de Luxembourg, 241 route de Luxembourg, L-8077 Bertrange, Luxembourg. Courriel : Laurent.Brou@mnha.etat.lu
⁴ Institut royal des Sciences naturelles de Belgique, Micropaléontologie et paléobotanique, 29 rue Vautier B-1000 Bruxelles, Belgique. Courriel : freddy.damblon@naturalsciences.be
⁵ Leibniz Institute for Applied Geosciences (GGA), S3: Geochronology and Isotope Hydrology, Stilleweg 2, D-30631 Hannover, Germany. Courriel : Manfred.Frechen@gga-hannover.de
⁶ Institut National de Recherches Archéologiques Préventives, 148, avenue André Maginot, F-37100 Tours, France. Courriel : anne.hauzeur@inrap.fr
⁷ Pedologist, association RooTS (Research Team in Archaeo- and Palaeo-Science), 197 rue Belliard, bte 3, B-1040 Bruxelles, Belgique
⁸ Service d’archéologie romaine, Musée National d’Histoire et d’Art du Grand-Duché de Luxembourg, 241 route de Luxembourg, L-8077 Bertrange, Luxembourg
1 - INTRODUCTION

For the last fifteen years, preventive archaeological research has been carried out in the Luxembourgian part of the Wintrange basin. This small alluvial basin, located in the Moselle valley, straddles the border between Germany and Luxembourg (fig. 1). This research is coordinated by the Department of prehistoric archaeology at the National Museum of History and Art of the Grand Duchy of Luxembourg (Musée National d’Histoire et d’Art du Grand-Duché de Luxembourg, MNHAL), and is based on a multidisciplinary approach (archaeology, geology, sedimentology, geomorphology, dating, palaeobotany, malacology, etc). A recent geoarchaeological synthesis, together with new IRSL datings, enables us to put forward a preliminary reconstruction of the palaeoenvironmental evolution of this part of the Moselle valley since the Late Pleistocene. The successive stages of human occupation (attested by numerous remains) can be placed within this new chronological framework. These results can be used to discuss the relationship between human occupations and their fluvial environment in southeast Luxembourg, especially since the Holocene.

2 - STUDY AREA, METHODS AND AIMS

Downstream from the Vosges Massif, the Moselle valley is characterized by the presence of several alluvial basins (Cordier, 2004; Cordier et al., 2006) developed either in the marly depressions of the Paris Basin or along the entrenched meanders in the Rhenish Massif (fig. 1). The studied area is located in the Wintrange basin, which is approximately 10 km long and 4 km wide. This basin, which corresponds to a syncline depression, developed in Keuper and Liassic marls and clays (Baeckeroot, 1942), is limited by two alluvial gaps. Upstream from this basin, the Moselle River flows through the Sierck Gap (“Siercker Sattel”) formed within the Buntsandstein (sandstones) and Devonian quartzite. Downstream from the Wintrange basin, the river flows through a narrow valley formed within the Muschelkalk (limestones) of the Middle Moselle anticline (“Mittelmosel Sattel”, de Ridder, 1957), before reaching the alluvial basin of Wasserbillig (Ferrant, 1933a, b), 30 km downstream from Wintrange (fig. 1).

Middle and lower terraces are well-preserved in the Wintrange basin. Their bases are regularly stepped, with a mean height difference of about 10 m between two successive bedrock steps. This difference in height is about 5 m for the youngest terraces (M2 and M1), their bases being located at +10 m (M2) and +3-5 m (M1) above the base of the modern floodplain (Cordier, 2004, fig. 2).

While the upper terraces are well preserved on the right bank of the Moselle, located in Germany, terrace M1 and the alluvial floodplain M0 are well-developed on the left bank, in Luxembourg territory. In this latter area, fluvial sediments were intensively extracted in quarries over the past decades. Since 1993, the Musée National d’Histoire et d’Art du Luxembourg has carried out systematic archaeological excavations, especially around the village of Remerschen (the studied sites are identified by the abbreviation “Rem” and a Roman number ranging from I to VI; fig. 3). These investigations revealed evidence for human occupation from the Palaeolithic to the Middle Ages.

In addition, geoarchaeological analyses correlative to this preventive archaeology work were used to study the sedimentary formations. These studies, which were initially mainly sedimentological, have recently been completed by a chronological approach, with the carrying out of numerical datings, using both radiocarbon and luminescence methods. Anthracological and palynological analyses carried out in the Rem I-Schengerweis site in connection with Neolithic Linear Pottery and Iron Age (Hunsrück-Eifel culture) occupations also shed new light on the evolution of palaeoenvironments. Taken together, these studies have therefore led to a better understanding of sedimentary processes during the last glacial-interglacial cycle: fluvial processes of the Moselle River, slope processes s.l. (since the deposits were regularly covered with slope deposits or even wind-blown deposits), and anthropogenic processes.

These studies therefore lead us to propose an initial reconstruction of palaeoenvironments in the Wintrange...
Fig. 2: The stepped alluvial terrace system and the absolute datings for the Meurthe valley (150 km upstream from Wintrange).

Fig. 2 : Etagement des terrasses alluviales et datations absolues pour la vallée de la Meurthe (150 km en amont de Wintrange).

Fig. 3: Preventive archaeological research and archaeological founds in the Wintrange Basin.

Fig. 3 : Recherches archéologiques préventives et découvertes dans le bassin de Wintrange.
basin and their evolution since the second part of the Weichselian. They can also be used to refine the chronostratigraphy of the alluvial terraces of the Moselle River, and lastly to reconstruct the various phases of human occupation in this part of the valley.

3 - SEDIMENTARY FORMATIONS

The inventory of sites Rem I to Rem VI led to detailed observations carried out on the lower terrace M1. This is in fact made up of a continuous succession of sedimentary beds. 7 major sedimentary units were identified (fig. 4 & 5):

Unit A - At the base there is a coarse-grained alluvial deposit with an average thickness of 6 m. It lies directly over Keuper marl, found in the Rem V and Rem VI gravel pits during coring, at about 141 m altitude (General Levelling of Luxembourg).

This coarse-grained unit is made up of gravels and pebbles (some as large as decimetre-scale blocks) incorporated within a sandy matrix. In places it contains lenses of well-sorted sands, 10 to 20 cm thick on average, and up to several metres in length. Large boulders of Taunus quartzite (up to 0.5 m and up to several metres in length. Large boulders of Taunus quartzite (up to 0.5 m) were found within this coarse-grained unit (Fechner & Langohr, 1994a, b). These quartzites of Devonian age outcrop in the Sierck Gap, upstream from the Wintrange basin.

Unit B - A unit made up of sandy sediments with a few small pebbles. The thickness of this unit generally ranges between 1 and 3 metres. Curved inclined bedding features can be observed in this unit.

Unit C - This deposit of varying thickness (between 50 cm and 2 m) is made up of a series of centimetre-scale beds of sands and silts. The latter are of varying thickness, tending to become thicker with time.

Unit D - On top of the alluvial silts and sands lies a silty unit (fig. 6), which is particularly well-preserved at the foot of the slope that marks the boundary of the alluvial basin to the west: it can be as much as 50 cm thick (for example at Rem V). In other areas (Rem IV), it only survives in the form of residual pockets, or is absent. This unit is characterized by the presence of calcite nodules at its base, while decalcification is observed at its top. It revealed a cold terrestrial malacofauna (Papillia muscorum, Succinea oblonga and Trichia hispida). These sediments underwent major disturbance due to subsequent periglacial processes.

Unit E - Marly slope deposits soliflucted from the left bank slope of the Moselle River (Keuper marls). These slope deposits of Unit E are less than 1 m thick and may be directly in contact with the alluvial formation (unit C), where the loess has not been preserved (e.g. in exposure Rem IV). Units D and E are characterized by various cryoturbation features such as involutions, plications or ice-wedge casts. With stripping, large polygons were observed in one area of Rem IV (fig. 7a).

The ice wedges (fig. 7b & c) show an infill of well-sorted red sands. These well-sorted deposits of red sands are only found in the wedges, which suggests a phase of post-sedimentary erosion.

Unit F - The overlying unit is made up of a series of sandy sediments one metre thick showing numerous alterations of pedogenic origin (tongues, oxidation, iron manganese oxides, deferrisation, root marks, etc). The neolithic or protohistoric archaeological structures were cut into this unit and with stripping are found at the interface between units F and G.

Unit G - The upper unit, preserved below the present soil (PS), consists of slope deposits (colluvia). Two subunits could be distinguished, especially in the southern part of the studied area: a dark lower layer (G1) and a paler upper layer (G2), for a total mean thickness of about 1 m. The Roman archaeological structures were cut into the dark slope deposits (G1) and with stripping are found at the interface between units G1 and G2.

4 - THE CHRONOLOGICAL FRAMEWORK

Numerical datings were made on sediments in the lower alluvial and upper formation. For the alluvial formation, three IRSL samples were taken in sands from units B and C on the gravel pit Rem VI (fig. 4). Their pre-treatment included sieving (analysed grain size: 100-150, 100-200 or 150-250 µm), chemical treatment (removal of carbonates and organic particles) and heavy-liquid separation to isolate the potassium-richfeldspar grains. The samples were then analysed using both the Multiple Aliquot Additive Dose and the Simple Aliquot Regenerative protocols (Wallinga, 2002; Murray & Wintle, 2003). The age estimates range between 21.3 ± 1.5 ka and 17 ± 1.4 ka (tab. 1). However, further luminescence analyses on unit A, these datings give the minimum age of the lower alluvial formation which was deposited during or before the Upper Pleniglacial (OIS 2, M1 terrace); secondly to confirm the above results: these may actually be slightly underestimated due to the possibility of a fading effect on feldspar grains (Wallinga, 2002).

In another gravel pit (Rem IV, fig. 4), AMS dating of a Juniperus piece of charcoal sampled at the limit between the bottom of the slope deposits (unit E) and the top of the succession of thin sandy and silty layers (unit C), gave an age of 30,770 ± 300 BP (Beta-182248, tab. 2). The size of the charcoal (5 mm) and the fact that it is very little rounded leads us to believe that it has moved on a short distance. However, its position right at the limit between unit C and unit E, which shows numerous disturbances, forces us to consider possible reworking (which could no be detected in the field, as the charcoal was discovered during the removal of a block of sediment). Given the current results of IRSL datings obtained in unit C at Rem VI, the hypothesis of a reworking of this charcoal appears to be strengthened.

Absolute dating was not possible for units D and E. However, they show marks linked to periglacial processes, which indicates that they date right from the Upper Pleniglacial, or even from the Late Glacial.
Fig. 4: Sedimentary logs of the main sections.

Fig. 4: Logs sédimentaires des principaux secteurs.
On the site of RemI-Schengerwis, a series of AMS dates (Damblon & Hauzeur, in press) was obtained for remains found in early Neolithic structures cut into unit F (tab. 2). The dates for the occupation of the early Neolithic village are in the range 6320 ± 50 and 6110 ± 60 BP; i.e. between 5230 and 5060 calBC (calibrated at 2σ by Calibration Program Version Oxcal 4.0 on the Intcal 2004 curve, Reimer et al., 2004; Bronk Ramsey, 1995; Bronk Ramsey, 2001). A date obtained for Corylus branches gave 7055 ± 45 BP, i.e. between 6010 and 5800 cal BC at 2σ. This age is comparable to that of scattered Mesolithic artefacts found in pits at the site (cf. infra).

The analysis of two Quercus sp. charcoal fragments of windfall origin located in the lower part of unit F in the Rem IV exposure gave subboreal ages (Beta-157202: 3770 ± 50 and Beta-157203: 4030 ± 50 BP, tab. 2). These dates are fairly close if the old wood phenomenon for this species of tree is taken into consideration. They give a terminus ante quem for unit F, at the top of which in the site close to Rem II there are cremation pits dating from the late Bronze Age (cf. infra). At Rem I, supposedly analogous sedimentary formations (unit F) were cut across by neolithic structures, (fig. 4), thus revealing the existence of at least two stages of deposition for unit F prior to its pedological alteration. However, we do not have the means to undertake correlations between the different areas (Rem I, Rem II and Rem IV).

Younger archaeological structures at Rem I-Schengerwis also provided some radiocarbon dates. For instance, dating of bone from a silo burial gave an age of 2220 ± 40 BP, while two fragments of Fagus charcoal gave ages of 2155 ± 45 and 2145 ± 40 BP (tab. 2). Slope deposits (unit G) have covered all these archaeological remains. Some areas enabled us to distinguish between two stages: a stage prior to the Roman period (G1), since the Roman structures were cut into this sub-unit, and a stage subsequent to the Roman period (G2), since the sediments of this sub-unit cover the Roman structures.

5 - HUMAN OCCUPATION FROM LATE UPPER PALAEOLITHIC TIME TO THE MIDDLE AGE

Numerous archaeological remains were found in a limited area (fig. 3). They cover a period ranging from the Late Upper Palaeolithic to the Middle Ages.

Palaeolithic and Mesolithic remains were found during archaeological excavations at the bottom of the Raederberg hill (Enner dem Raederberg, fig. 3), in 1999. They correspond to a lithic industry made of high-quality flint. The raw material was not obtained from the Moselle sediments (since such flints are absent in the Moselle catchment), but originated from remote areas (Cretaceous limestones from the Paris basin or the lower Meuse area, Brou, 2001). These artefacts were attributed to the Ahrensburgian or Epi-Ahrensburgian tradition (ca 10 ka BP, Brou, 2001; Fagnard, in press), on the basis of their lithological and technological characteristics. Mesolithic
artefacts and a Federmesser point have also been found in the same area. However, all these artefacts had been reworked, since they were found either in the slope-deposits of unit G (Spier & Le Brun-Ricalens, 1994; Gaffié & Baes, 2001) or in excavated structures from the early Neolithic dug into in the sediments of unit F (Hauzeur, 2006).

The main archaeological evidence from this latter period was studied between 1992 and 1994 in Rem I-Schengerwis (Hauzeur et al., 1994a, b, c). It consists of the most important Linear-Pottery Culture village (early Neolithic) found in Luxembourg. Excavations revealed 21 houses in varying states of preservation, as well as pottery and carbonized plant remains. The archaeological structures are found in the sediments of unit F, sometimes covered by the slope deposits of unit G, or often directly beneath the actual surface. Stylistic analyses of ceramics point to a lower-Linear-Pottery Culture age, which is in good agreement with 13 AMS dates from plant remains (tab. 2). The duration of human occupation of this site may be estimated to be about 170 years (Hauzeur, 2003, 2006; Damblon & Hauzeur, in press).

Anthropological analyses were made for the Linear-Pottery Culture and Iron Age human settlements in the Rem I-Schengerwis gravel pit (Buydens et al., 2000; Damblon et al., 2006; Damblon & Hauzeur, in press). Results have provided a better knowledge of the forest landscape, and especially of its use by humans (fig. 8). During the Linear-Pottery Culture period, the main three species used for building were oak, ash and hazel, while Malacea, maple and elm had a domestic use. The presence of Sorbus, Betula, or Acer campesist also demonstrates the expansion of border and hedge species. Despite the present location of the Rem I gravel pit close to the Moselle, anthropological data surprisingly do not show the presence either of elder or lime. Studies of charcoal show that oak, hazel and Malacea were present everywhere, whereas the other species had a more variable distribution (Damblon & Hauzeur, in press).

Copper and Bronze Age remains consisted only of small isolated objects (such as axes), dredged from the bed of the Moselle (Valotteau et al., 2005). However in 1995, excavations in the Rem II-Klosbaam gravel pit revealed a cremation necropolis of Late Bronze Age whose pits are cut into the sediments of unit F and are covered by the slope deposits of unit G (Le Brun-Ricalens & de Ruijter, 1994; Le Brun-Ricalens et al., 1995). Until now no evidence of dwellings has been found in the...
surrounding area, possibly due to anthropogenic erosion or to several decades of intensive quarrying.

Iron Age remains have been found in the Rem I-Schengerwis exposure (de Ruijter & Le Brun-Ricalens, 1994; Unsen, 2005). They correspond to Hunsrück-Eifel culture (Younger Hallstatt-Older Tène). Plans of dwellings, storehouses and about 150 grain silos, associated with several burials (cremations in urns and inhumation in storage pit), were recognized. The presence of remains of storehouses and silos provides, for the first time, evidence of substantial agricultural activity in the Wintrange basin. As already recognized in north western Europe, such activity can be the cause of significant soil erosion. This soil erosion might have generated the deposition, during the Iron Age and/or Roman period, of dark slope deposits (G1). Anthracological studies on Iron Age settlements in the Rem I-Schengerwis gravel pit show a high diversity of taxa in the anthracological assemblages and a marked presence of Fagus or Carpinus revealing a different structure of the landscape compared to that of the early Neolithic (Damblon & Hauzeur, in press).

Roman occupation is attested by numerous finds, in particular a section of road, a villa and the remains of an important funeral monument built in the middle of the second century A.D. Ornamentation of this monument confirms the importance of wine growing, which started at the end of the 1st century AD in this part of the Moselle valley and took place not only on the Moselle floodplain, but also on the slopes of the Wintrange basin (Thill, 1970; Krier, 1986, 1992). Roman buildings have also been found (Schoellen & Gazagnol, 1998). Ceramic evidence clearly demonstrates human occupation in the Wintrange basin from the middle of the first century AD to the end of the fourth century (Dövener, 2004). Most of the Roman structures are dug into the dark slope deposits G1 and are covered by pale slope deposits G2. Such intensive human occupation and activity during the Roman occupation must be associated with the importance of the Moselle valley as an important trade route of communication (Le Brun-Ricalens, 1994). As already noted for the Iron Age, a probable consequence of this intensive occupation was the acceleration of soil erosion. This may be correlated with the pale layer of slope deposits (G2), as well as by the increasing sedimentation in the Moselle river bed at Trier, about 40 km downstream from Wintrange (Zolitschka & Löhr, 1999). After the Roman period, human presence in the Wintrange basin seems to have diminished, since the only find has been an early Medieval cemetery.

The wide range of periods represented amongst the various archaeological discoveries, however, underlines the fact that the Wintrange basin was occupied from at least the end of the Palaeolithic, this occupation being more or less continuous from the early Neolithic to the present. Human occupation during the Iron Age and the Roman period may be the reason for the poor preservation of archaeological remains from earlier periods. Soil erosion and the deposition of the slope deposits of unit G no doubt correspond to these two major periods of agricultural activity.

6 - SYNTHESIS: PALAEOENVIRONMENTS AND HUMAN SETTLEMENTS IN THE WINTRANGE BASIN SINCE THE LAST GLACIATION

Combining sedimentological, chronological, archaeological and anthracological results has enabled us to propose the following reconstruction of landscape evolution and human occupation in the Wintrange basin during the Late Pleistocene and Holocene (fig. 9). The sequence begins with the deposition of the coarse-grained sediments of unit A. Due to the gentle longitudinal slope of the Moselle River (about 0.5 m/km) and to the lack of a main tributary in the Wintrange basin, the presence of Sierck quartzite blocks is likely to be the result of ice-rafting (even if the possibility of a severe flood is not to be excluded). The sedimentological characteristics of this first unit (large grain size of deposits,
presence of possible ice-rafted blocks) implies that this coarse-grained unit was laid down in a periglacial context, no doubt by a braided river. According to datings, part of the observed sequence is likely to belong to the Upper Pleniglacial. Since we were unable to date the base of the alluvial infill (unit A), we cannot conclude that this is a single sequence.

The sedimentary features of unit B, characterized by the presence of curved inclined bedding, suggest that these sediments must also be associated with a braided fluvial style. The succession of sandy and silty beds in unit C seems to be similar to a facies described in several European valleys (Van Huissenden et al., 2000). These layers may be interpreted as natural levee sediments, deposited during minor floods (Arche, 1983). Units B and C are formations that are progressively made up of fining-upwards sediments (small gravel, sands and then increasingly thick beds of silt), which can be interpreted as a progressive decrease of the fluvial energy of the river. On the basis of the reconstitution proposed by Stéphane Cordier (Cordier, 2004; Cordier et al., 2006), units A, B and C appear to correspond to terrace M1.

This is in agreement with observations of terrace M2, allocated to OIS 4 and 3 (Cordier et al., 2005, fig. 2), and of the present floodplain M0, which correlates to the Late Glacial and Holocene period, as evidenced by radiocarbon dating upstream from the studied area, in the French Moselle valley (Carcaud, 1992), and by palynological results downstream at Trier (Zolitschka & Löhr, 1999).

This chronological framework is also in agreement with field observations made downstream from Wintrange, in the Wasserbillig alluvial basin. In this latter area, sediments from below the youngest terrace ...

---


Fig. 9: Chronological evolution of the Wintrange Basin.

Fig. 9 : Chronologie de l'évolution du bassin de Wintrange.
(assumed to be M1, considering of its relative height of +3-5 m) show well-developed cryoturbation features such as ice-wedge casts and involutions (Cordier, 2004; Coûteaux, 1970). In contrast, similar features are absent on the current floodplain (M0). Furthermore, numerous remains of cold fauna (including Mammutthus primigenius) were found in this youngest terrace (M1) near Wasserbillig (Ferrant, 1933b; Heuertz, 1969).

This chronology could also explain the little difference in height observed between the youngest alluvial terraces, since alluvial floodplains M1 and M0 formed during a single glacial-interglacial cycle (OIS 2-1), in contrast to the upper terraces which formed one per cycle. This phenomenon is interpreted as resulting from a stronger erosional period at the Pleniglacial-Late Glacial transition (Cordier et al., 2006).

Despite this imprecision, the IRSL results would be in agreement with the chronostratigraphic framework for the Moselle alluvial terraces (especially with the age estimate for the alluvial terrace M2, allocated to MIS 4 and 3, fig. 2). This sequence shows characteristics (decreasing grain size towards the top of the formation, contrast between coarse deposits and finer ones) resulting from a gradual slowing of water flow similar to those in alluvial formations correlating to the alluvial terrace M1 described in the Moselle valley both upstream and downstream from the Wintrange basin (Cordier et al., 2006). The alluvial terrace M1 of the studied area however consists of a thick sedimentary formation including non-alluvial deposits above the fluvial units, which is unusual in the rest of the Moselle valley (Cordier, 2004).

The overlying silty unit (D), which reflects a gradual drying of landscape, was deposited just after unit C. Similar aeolian deposition has actually been described in several European valleys between 28 and 13 ky BP (Antoine et al. 2003; Frechen et al. 2003; Mol et al. 2000). Another consequence of this change could be the aeolian deposits correlating to unit D, with their cold malaco fauna remains (Papillia muscorum, Succinea oblonga and Trichia hispida). All the features in this unit point to deposition in a terrestrial context; the silts show the characteristics of loess-type aeolian sediments (fig. 6).

The solifluction deposits in unit E can be interpreted as slope deposits in a periglacial context (annual thaw, Van Vliet Lanoë, 2005). The cryoturbation features recognized in units D and E, however, point to the persistence of periglacial conditions in the basin. The red sands found in the wedges may attest to either the existence of a resumption of alluvial activity contemporary with the melting of ice wedges, or to the trapping in periglacial conditions of deposits from the sheet M1 or from an earlier sheet outcropping further up the slope. Cryoturbation features like plications and involutions can also be attributed to periglacial processes (Van Vliet-Lanoë, 2005). We currently have no evidence dated from the Late Glacial in this area of the Moselle valley, which leads us to put forward the hypothesis of the existence of a major phase of erosion in the area which obliterated deposits prior to unit F.

Although the conditions under which unit F was build up remain uncertain, the hypothesis of deposition during flooding by the Moselle remains the most plausible one, due to the well-sorted nature of the sands (attesting to sorting during transport) and to the lack of sandy formations on the slopes overlooking the valley towards the west (these slopes are formed in Keuper marls).

The pedogenic evolution of this formation may be attests the gradual establishment of more temperate conditions in the Wintrange basin during or after the deposition of unit F.

Detailed field studies thus reveal a complex evolution of the Wintrange basin, with a succession of alluvial, colluvial or aeolian sedimentary processes, all within a climatic context marked by a shift from periglacial conditions (units A to E) to a temperate environment (units F and G).

These new interglacial conditions allowed the development of human settlements and activities, as seen in the numerous Neolithic to Medieval remains found in the basin. Human occupation also led to major landscape evolution, as also attested downstream at Trier (Löhr, 1998; Lukas & Löhr 2001), caused by agricultural activity: while increased deforestation from the Neolithic onwards, a modification in the diversity of forest species, farming generated major soil erosion, as evidenced by two main phases of slope deposit (unit G) in the Iron Age and/or Roman period.

7 - CONCLUSION

Research carried out for several years in the Wintrange basin has made it possible to get a better understanding of its development since the end of the Weichselian, in parallel with the successive stages of human occupation of the basin. A decrease of fluvial dynamic can be observed, with a resulting gradual shift to increasingly terrestrial processes marked by aeolian and slope deposits. In recent periods of human occupation (since the Neolithic), human impact on sedimentary processes has become increasingly visible. However, these preliminary results need to be supported especially with regard to dating, which implies the need to increase the corpus of IRSL and AMS dates, in order to specify the stages of the formation of sedimentary deposits as well as gaps in erosion or sedimentation. It would be especially interesting to obtain chronological data from the alluvial plain M0, in order to confirm that it forms part of the Late- Glacial/Holocene. No deposit or channel of Late-Glacial age has in fact been characterized in this part of the Moselle valley, unlike the observations made upstream (Carcaud, 1992) and downstream (Zolitschka & Löhr, 1999). This lack in the study of M0 in the Wintrange basin can partly be explained by the many unrecorded destructions caused by the extraction of sediments from gravel pits between 1930 and 1993, near the actual course of the Moselle. However, future gravel extractions in a new area several kilometres
downstream from Remerschen hold out the possibility of obtaining new results.

ACKNOWLEDGEMENTS

The authors gratefully thank Dr David Bridgland (University of Durham), Patrick de Mornay, and Denise Leesch, who kindly revised the manuscript and polished the English. The authors would like to thank Alphonse and Jean-Pierre Hein (managers of the Hein company S.A.), Marc Wiltzius and Fernando Soares (in charge of administrative and technical departments of the Hein company S.A.) for enabling the access to the gravel pits of the Wintrange Basin for 15 years. Robert Maquil and Robert Colbach (Geological Survey of Luxembourg) are also acknowledged for constructive advice. We would also like to thank Serge Orcietti and the anonymous reviewer for their very constructive comments which enabled us to improve our manuscript.

REFERENCES


BRONK RAMSEY C., 2001 - Development of the radiocarbon calibration program OxCal. Radiocarbon, 43 (2A), 355-363.


VAN HUISSTEDEN J., VANDENBERGHE J., VAN DER HAMMEN T., & LLAAN W., 2000 - Fluvial and aeolian interaction under permafrost conditions: Weichselian Late Pleniglacial, Twente, eastern Netherlands. Catena, 40, 511-541.

