ACTA PALAEONTOLOGICA ROMANIAE V. 6 (2008), P. 349-358

MIDDLE WEICHSELIAN PALEOENVIRONMENTS IN NORTH-WESTERN TRANSYLVANIA: SEDIMENTOLOGY, PALYNOLOGY AND MALACOFAUNA ANALYSIS

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Abstract. The aim of this paper is to analyse a Weichselian Pleniglacial cyclic sedimentation sequence located at Floresti, near Cluj-Napoca in western Transylvania, Romania. The sequence represents an interfinger of reworked löess-like sediments and paleosols. Detailed grain-size analysis, pedological analysis, pollen and malacofauna investigations allow the separation (recognition) of four main morphoclimatic cycles similar to those of stadial-interstadial type. Boreal forest-steppe to periglacial steppe oscillations developed during the Weichselian Pleniglacial in Europe. According to the U/Th ages, the period between 70 and cca. 20 ka BP was cool and variably dry, showing a progressive evolution towards a glacial maximum. The Floreşti section shows strong similarities to other Central and Eastern European pedocomplexes of similar age (the Moravian section of Dolní Věstonice and Middle Dnieper area, Ukraine).

Keywords. Paleoenvironment reconstructions, Weichselian Pleniglacial, loess-like deposits, alluvial fan, paleosols, malacofauna, palynology, Transylvania.

1. INTRODUCTION.

Cyclic sedimentation processes are included in a well-established landform development pattern in the Northern Hemisphere during the Pleistocene. Loess-paleosol sequences best illustrate this model though in certain cases the loess deposits are replaced by different slope debris with similar environmental significance (Kukla, 1975; Smalley and Leach, 1978; Frechen et al., 2003). A lot of Central and Eastern European studies have focused on the genetic context of key loess-paleosol sequences (Pécsi, 1990, 1993; Smalley and Leach, 1978; Tillmanns and Brunnacker, 1987; Velichko, 1990; Bogutskiy *et al.*, 2000). However, a large part of these deposits are re-worked, the typical airborne loess facies being replaced by coarser grain slope deposits. There are divergent opinions in the literature on the characterisation of such deposits and on the nature of the slope processes involved in the re-working. Some authors assign them to the general notion of loess derivatives, which includes sand pellets and rock detritus, intermingled in the loess-paleosol sequences (Pécsi, 1993). In Bohemian and Moravian loess sequences (Frechen et al., 1999) the terminology employed is colluvial sediments or re-worked loess of predominantly colluvial origin, emphasizing the role played by slope sedimentation in the genesis of certain pedocomplexes. Balandin (1984), who concludes that the so-called loess mantles are frequently represented only by "loess-like eluvial-deluvial facies", provides an interesting insight into the dynamic behavior of loess environments in Ukraine. More detailed sedimentological studies, especially in Western European sections emphasize the role of slope wash and in general the translocation of the loess material by flowing water (Vandenberghe et al., 1998), while in other cases solifluction processes are an important genetic factor for different loess derivates (Lautridou et al., 1987).

The objective of this study is to present new data from the Transylvanian Basin, Romania, on the geomorphological, sedimentological and pedological processes associated with climatic oscillations during the Weichselian Pleniglacial in a reworked, loess-like environment. The paper analyses three paleosols and four slopes deposit units preserved in a 5 m thick cyclic sedimentation sequence. Posea (1961) formerly studied this site, concluding in general terms that the deposits have a periglacial origin. Grain-size, pollen and malacological analyses, along with U/Th dating, allowed a paleoenvironmental reconstruction. Results are compared with those originating from similar sequences in the neighboring regions, notably the Great Hungarian Plain, Bohemia, Moravia and Ukraine.

2. LOCATION AND SITE DETAILS

The site is located at Floreşti, on the left slope of the Someşul Mic River valley, westward from Cluj-Napoca in western Transylvania, Romania (Fig. 1). This area exposes two terraces cut in a scarp slope sculpted on Eocene limestone and clay formations (Fig. 2). The studied sequence is located in the late Pleistocene unconsolidated deposits overlying the upper terrace and stands

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approximately 25 m above the actual valley floor (391 m above sea-level). The sequence represents an interfinger of slope deposits (coarse fan structures and reworked loess-like sediments) and paleosols. It lies upon a discontinuous alluvial series consisting of gravels with sandy matrix. Limestone fragments generated by periglacial weathering of the scarp slope represent the clastic material in the cyclic sedimentation sequence.

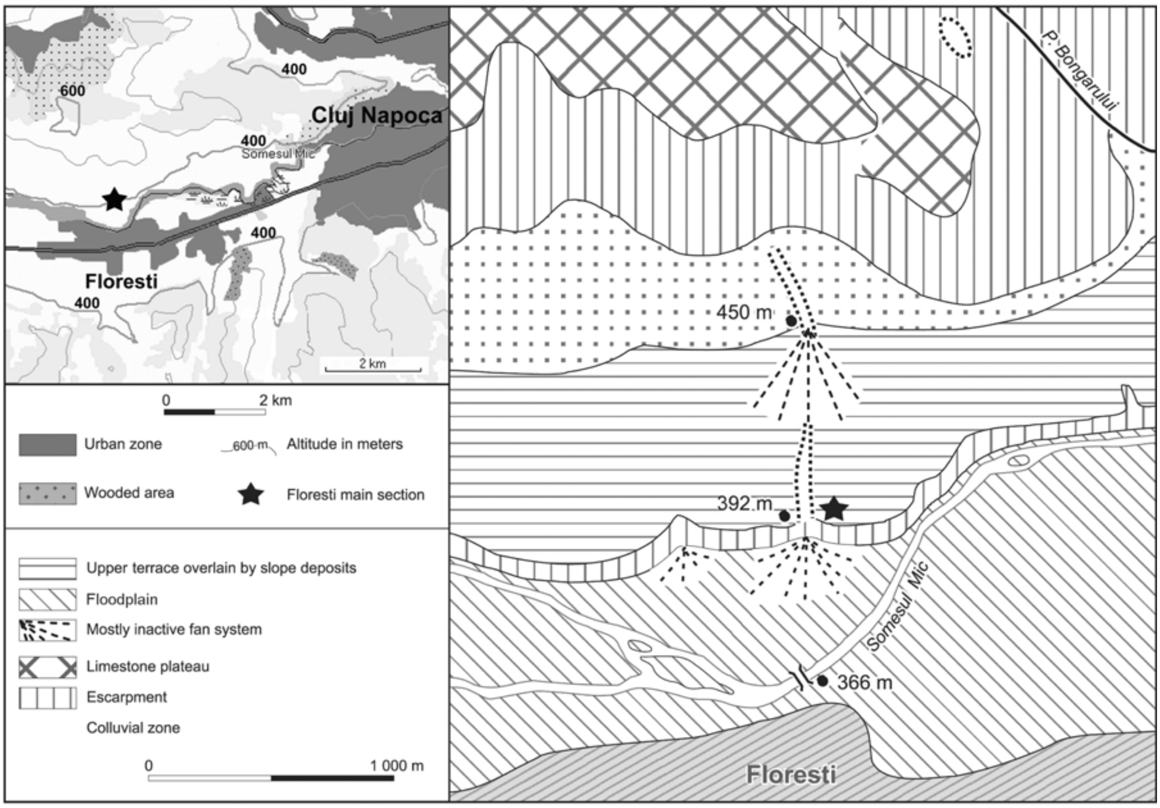

Figure 1. Location and the general geomorphologic context of the Floresti section.

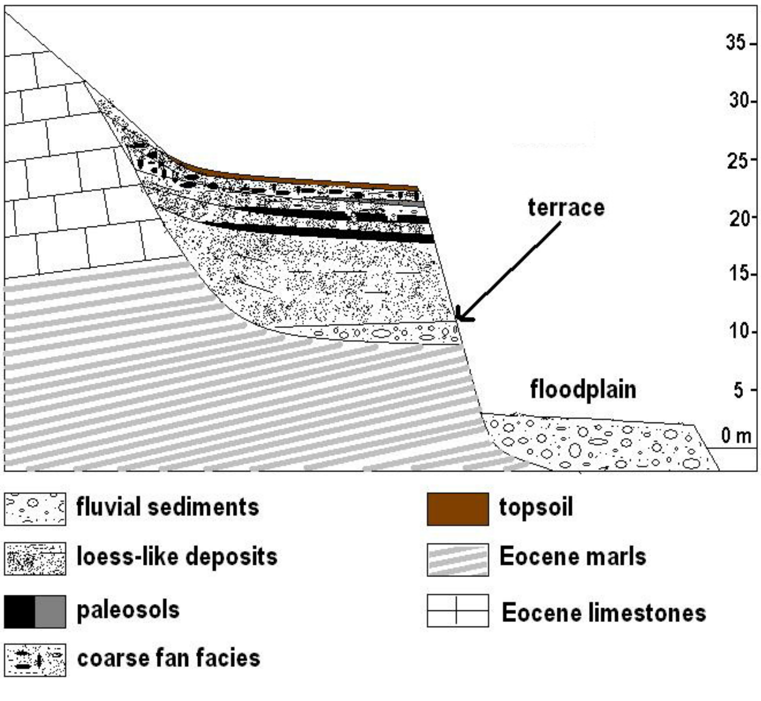

Figure 2. Morpholithostratigraphy of the Somesului Mic River valley (left slope).

3. MATERIALS AND METHODS

A combined geomorphologic, sedimentologic and paleoecologic approach has been used in order to reconstruct the depositional environment of the sequence. This approach consists on detailed analysis of morphostratigraphic structures, soil morphology, laser grain-size, pollen and malacofaunal assemblages. U/Th dating on snail shells allowed the establishment of the chronostratigraphic framework.

3.1. Grain-size data

Studies in different loess areas demonstrate that particle size variation is related to changing climate (Vandenberghe et al., 1997, 1998). Strong winds and cold climatic environments are responsible for the coarser sediments outputs. Our evidence shows that this assertion is also true in the case of slope dynamics. Higher energy morphodynamic systems such as gullies and the associated fan deposition were particularly active during colder intervals when slopes became destabilized due to a depletion of the vegetation cover. In more benign climatic conditions slope erosion was reduced and consequently soils were formed.

Grain-size sampling was conducted at 25 cm intervals or whenever a change in facies was obvious. The grain-size distribution of the fraction under 2000 µm was obtained using a laser particle sizer following the methodology used by Vandenberghe et al. (1997, 1998) and Konert and Vandenberghe (1997). The *U* ratio, which is the ratio between the sediment fractions of 44-16 µm and 16-5 µm (Vandenberghe et al., 1985), was used to avoid the influence of pedogenic clay formation, thus emphasising the energetic behaviour of the geomorphic system. The 5-µm diameter in laser grain-size analysis is the equivalent to the 2 µm value in classic sieve and pipette analysis (Konert and Vandenberghe, 1997).

3.2. Pollen analysis

Pollen samples had been taken at 25 centimetres intervals but only five levels yielded enough pollen for a statistically valid diagram. The samples were pre-treated with HCl 10% in order to remove the high content of carbonates and were then sieved over a 200 µ mesh screen for removing the coarser sediments. The remaining material had been washed in demineralised water and centrifuged several times (1 minute, 2000 r.p.m). A classic treatment with KOH 10%, acetolysis and heavy liquid separation (sodium polytungstate solution) was conducted. A minimum of 300 pollen grains were counted; one sample had only 238 grains. Pollen abundances represent percentages of the total pollen sum. Abundances <1 % are represented by a black dot in the pollen diagram.

3.3. Malacofauna assemblages

Bulk sediment samples close to 7 kg each had been taken from all loess-like and paleosol layers. Samples were washed and sieved through a 0.7 mm mesh and the unbroken gastropod shells were retained and identified under a binocular. The ecology of species and assemblages relationships is assigned according to Ložek (1964, 2001) and Krolopp et al. (1996).

3.4. Dating

U/Th dating on snail shells from three levels in the sequence (Fig. 3) was carried out at the GEOTOP facilities of the University of Quebec at Montreal. Prior to dating, shells were thoroughly cleaned by mechanical abrasion using a diamond head fixed on a Deremel^{TD} tool. Then a subsample of ~1 g was weighed and transferred to Teflon beakers in which weighed amounts of a mixed spike ^{233}U - ^{236}U - ^{229}Th had been placed and evaporated. This sample and spike were covered with water, then HNO_3 was added slowly until all of the shell material was dissolved. Further processing was done using a procedure based on that of Edwards et al. (1987). The uranium and thorium were separated from the bulk of the material with $Fe(OH)_3$ and from more similar elements by adsorption on a Dowex AG1-X8 ion exchange column using standard techniques. Uranium and thorium were loaded onto an out-gassed, zone-re fined rhenium filament coated with graphite. The concentration and isotopic composition of U and Th were measured by TIMS using a VG Sector mass spectrometer equipped with a 10 cm electrostatic analyzer and a pulse-counting Daly detector. Mass fractionation was corrected for by normalizing to the known ^{236}U/^{233}U ratio (1.0540) in the double spike. The overall analytical reproducibility was estimated from replicate measurement of a coral from Timor Island that dates from the last interglacial stage (oxygen isotope substage 5-e) and of a uraninite standard. Precision is routinely better than U 0.5%.

4. RESULTS

4.1. Stratigraphy and sedimentology

The entire sequence is approximately 20 m in depth according to Posea (1961), but at present only the uppermost 5 m are available for study. The section can be assigned to four major sedimentation cycles (Fig. 3). The three lowermost units are characterised by paleosols, and are referred to as pedocomplexes (PK); the uppermost, composed of a coarse debris mantle overlain unconformably by the present day soil cover is hereby described as a sedimentary complex (SK) (Pendea, 2005).

4.1.1. The basal pedocomplex (PKA) consists of sandy silt loam, with a total silt fraction (5.5-63 µm) more than 40%, interrupted by laminar coarse detritus (angular and subangular limestone clasts).

The most important feature of the PKA is a well-developed dark-brown paleosol (10 YR 2/2) with typical chernozem profile (Ah-Ah/C-Cca) slightly truncated at the top (Fig. 3). The parent material of the paleosol presents an intriguing coarsening-up trend suggested by a decrease of the <16 µm grain-size fraction (Fig. 5). Normally it is expected that at paleosol levels, corresponding with more benign climatic conditions, the finer <16 µm fraction should be dominant. The coarse grain-size of the PKA paleosol does not reflect the corresponding interstadial reduced slope morphodynamic and finer eolian deposition, but that of the previous cold period when the parent material of the soil had been deposited. The finer sediments deposited during the interstadial are removed and re-deposited in the next cold phase, therefore, they are reflected to some degree in the grain-size of the loess-like sediments immediately overlying the paleosol (Fig. 5).

4.1.2. Pedocomplex B (PKB) starts with an increase of the fine (<16 µm) grain-size fraction (Fig. 5) through deposition of silty-sandy loams as discussed above after which it continues the coarsening up trend started in PKA. The most conspicuous feature of this pedocomplex is the presence of coarse angular gravel facies, intercalated within a silty-sand matrix, similar to the sandy silt loams of the first cycle. In a nearby exposure (200 m west of the main sequence), PKB is composed almost entirely of angular gravels covering the PKA paleosol. The *U* ratio values, comparatively higher than those of PKA (Fig. 3), suggest higher energy eolian process prior and during the reworking by slope processes. At the same time the variable, but decreasing <16 µm fraction (coarsening-up trend), points to an increased energy of the slope processes, which culminates in the coarse angular fan gravels underlying the PKB paleosol.

The polymodal grain-size distribution of the loess-like material reflects the combination of different transport and sedimentation processes characteristic for these deposits (Sun et al., 2002), in this case reflecting the overlap of aeolian processes (traction, saltation or suspension) with the hydraulic transport during redeposition (laminar or turbulent flow). This distribution pattern is practically similar to that reported for fluvial environments (Kasse et al., 1995; Sun et al., 2002)

The PKB complex ends with a truncated dark-grey chernozem paleosol (10YR 3/1) with variable thickness (40-70 cm). The erosional contact is sinuous with clear evidence of paleo-gully activity and related channel infill material. The parent material of this paleosol shows a coarsening-up grain-size trend (Fig. 5), clearly repeating the pattern shown in PKA unit.

4.1.3. Pedocomplex C (PKC) is represented almost entirely by fan deposits, with a coarse limestone gravel lithofacies alternating with finer silty-sands. Alternation of erosion and deposition is suggested by numerous stratigraphic unconformities. Most of the grain-size cumulative frequencies curves are largely unimodal and sediments are better sorted than in the two previous sedimentary cycles. The dominant grain-size population is sand (usually over 50%). As in the cases of PKA and PKB, after an initial increase in the fine fraction (Fig. 5), immediately above the PKB paleosol, the coarsening-up trend is maintained and seems to be a characteristic pattern of each pedocomplex.

U ratio values are variable but generally high (Fig. 3), emphasizing the increasing input of coarser eolian silts, in contrast with previous sedimentary cycles. The lowest *U* ratio value is registered in the PKC paleosol zone, reflecting a phase of finer eolian deposition that allowed pedogenesis at this level. In fact, this is the only evidence for the presence of a paleosol in this sedimentary complex, along with a distinct chromatic change from yellow-red, in the fan sediments, to a reddish-brown at the paleosol level. Most of the diagnostic horizons of this soil were eroded; therefore its classification is unclear. Its color (10YR 4/8) suggests a brown earth (incipient luvisol), but the soil material is slightly reworked and is hereby classified as a pedolith.

4.1.4. Sedimentary complex D (SKD), representing the uppermost morphoclimatic cycle of the Floreşti section, is entirely made of coarse cryoclastic debris. The gravel material (subangular-angular) is made of medium (3-7 cm diameter) to large (15- 40 cm diameter) limestone clasts. The clastic material originated from the Eocene limestone scarp through frost shattering and has been subsequently reworked by extensive fan systems. The debris layer has a discontinuous distribution over the top of the terrace. Pure debris flow material cut deep into the underlying PKC paleosol, preserving the former paleo-gully channel or even entirely eroding the paleosol. In the latter case, the erosional surface makes contact directly with the finer fan deposits of PKC. The SKD complex is topped by Holocene colluvia that formed the parent material of the topsoil (euthric cambisol).

4.2. Palynological and malacological data

Due to the generally reworked nature of sediments in the Floreşti section a detailed and meaningful biostratigraphy is difficult to establish. However, variation of pollen spectra and malacofaunal assemblages provide information on stadial-interstadial alternations during the Middle to Late Weichselian Pleniglacial.

The loess-like layers are characterized by an equivalent of Helicopsis striata-fauna (*sensu* Ložek, 2001) with *Helicopsis striata* (Müller, 1774), *Pupilla muscorum* (Linné, 1758) and *Chondrula tridens* (Müller, 1774). This gastropod assemblage is dominated by eurythermic species and resembles the “warm loess steppe” fauna described by Ložek (2001). It should be noted that the snail assemblages reflect the local conditions of the slope with a warmer and drier microclimate (xerotherme) typical for south-facing slopes. The pollen content is usually very poor in loess-like sediments, but in the case of PKC loess-like loams, where enough pollen counts were possible, non-arboreal pollen (NAP) shows absolute dominance (almost 100%), *Artemisia*, Poaceae and Chenopodiaceae being the most important contributors (Fig. 3). Few grains of *Pinus, Alnus* and *Betula* represent the arboreal pollen.

The paleosol layers of PKA and PKB are characterized by snail assemblages resembling the interstadial Chondrula tridens-fauna (Ložek, 2001), marked by the dominance of *Chondrula tridens* associated with *Pupilla muscorum, Vallonia pulchella* (Müller, 1774), *Vertigo pygmaea* (Draparnaud, 1801), *Cochlicopa lubrica* (Müller, 1774) and the xerotherme *Granaria frumentum* (Draparnaud, 1801). In the case of the PKC paleosol the snail assemblage is very poor in species and individuals and it is largely dominated by *Pupilla muscorum*. The palynological evidence suggests the presence of *Pinus*-dominated woodland during the formation of these paleosols, with very low percentages of *Alnus, Betula, Salix, Juniperus* and *Picea*. The absence of thermophilous broad-leaf tree pollen throughout the Floreşti section is a characteristic feature and contrasts with other Central and Eastern European sequences of similar age. During the Mid to Late Pleniglacial interstadials, broad-leaf tree pollen was reported from Ukraine (Rousseau et al., 2001) and Central Europe (Urban, 1984). The absence of local refugia and the configuration of the Transylvanian region as a closed basin surrounded by the Carpathian Mountains could have contributed to the absence of thermophilous trees during the short warm oscillations of this period.

4.3. Chronology and correlations

Three U-Th age measurements on gastropod shells provide a first chronology for sediments of Weicheselian Pleniglacial age from Transylvania.

Starting at the base of the sequence, snail shells in the upper part of the PKA paleosol yielded a U-Th age of 57.6 ± 4 ka BP, which would suggest the formation of this soil during the early MIS 3 (Oerel interstadial). However, we suspect a much older age for the beginning of this pedogenic phase because the U-Th measurement was taken from the upper part of the paleosol thus it reflects only the end of this pedogenic phase. Because the age estimate of 57.6 ± 4 ka BP corresponds with the end of MIS 4 and beginning of MIS 3, it implies the unlikely scenario that the PKA paleosol was largely formed during the very cold phase of MIS 4. Therefore, we suspect that the PKA paleosol was formed before 70 ka BP, during the early Weichselian MIS 5-a (Odderade interstadial). The end of the Odderade interstadial was dated between 61 ka BP (Behre and Van der Plicht, 1992) and 74 ka BP (Martinson et al., 1987). The PKA paleosol exposes a striking sedimentologic and pedostratigraphic similarity with the lower PKII chernozem from Bohemia and Moravia (Frechen et al., 1999), also dated during MIS 5-a, and potentially with the upper Pryluky soil unit (plb2) in the Dnieper area, Ukraine (Gerasimenko, 2006). The loess-like sediments immediately overlying the PKA paleosol were most likely deposited during the preceding MIS 4 cold phase, also known as Schalkholz stadial (Caspers and Freund, 2001).

Two U-Th ages are available for snail shells from the PKB paleosol, the upper part yielding a date of 45.2 ± 3 ka BP and the lower part 50.5 ± 2 ka BP. This interval corresponds fairly well with the Middle Pleniglacial interstadial complex (Oerel-Glinde-Moershoofd cold-temperate complex) as defined by Caspers and Freund (2001). The life-span of PKB paleosol over several climate oscillations of the Middle Pleniglacial could be possible because the 55-40 ka BP time-window is often defined by short-lived, minor climatic oscillations (Caspers and Freund, 2001). These climatic oscillations are often difficult to separate stratigraphically or based on their pollen assemblages. The PKB paleosol is most likely an equivalent of the upper PKII chernozem from Bohemia and Moravia (Frechen et al. 1999) and the lowermost paleosol at Kopasz Hill (Tokay) from Hungary (Sumegi and Hertelendi, 1998) both dated between 40-55 ka BP.

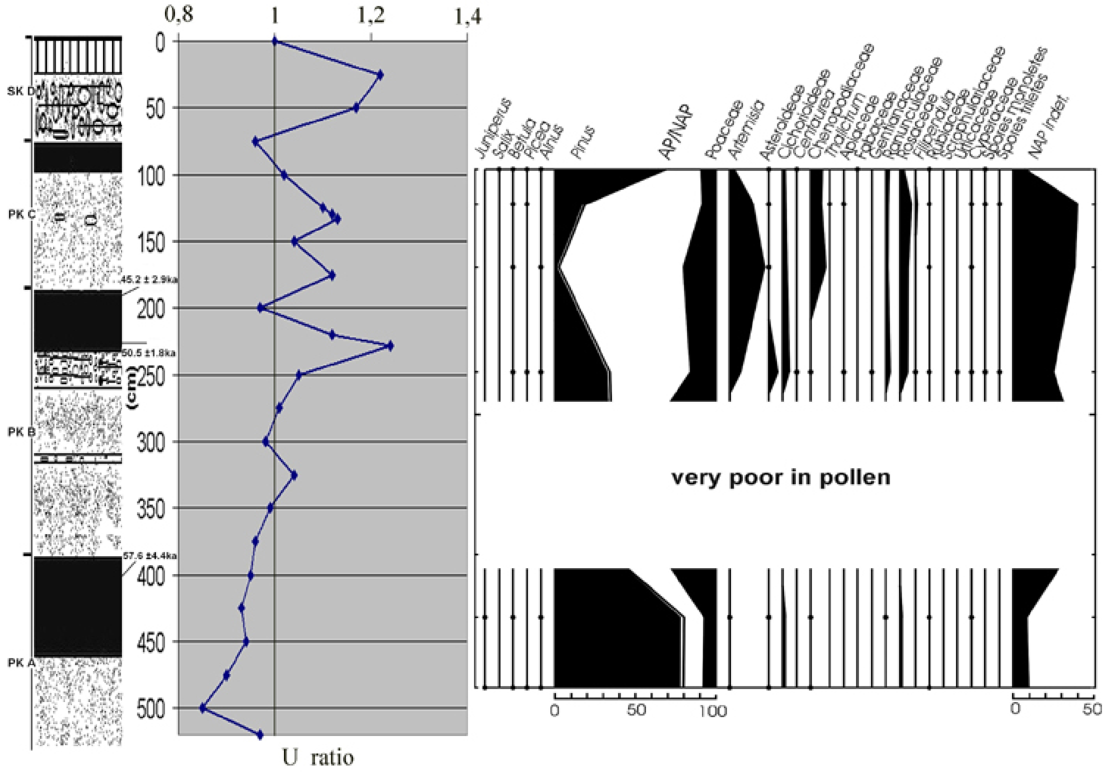

Figure 3. Grain-sizes of the silt-sized fraction (*U* ratio) and pollen evidence from the Weichselian sediments of the Floreşti sequence. PKA, PKB, PKC and SKD are the stratigraphic units described in section no. 4.1. See Fig.2 for the legend of the sedimentary units.

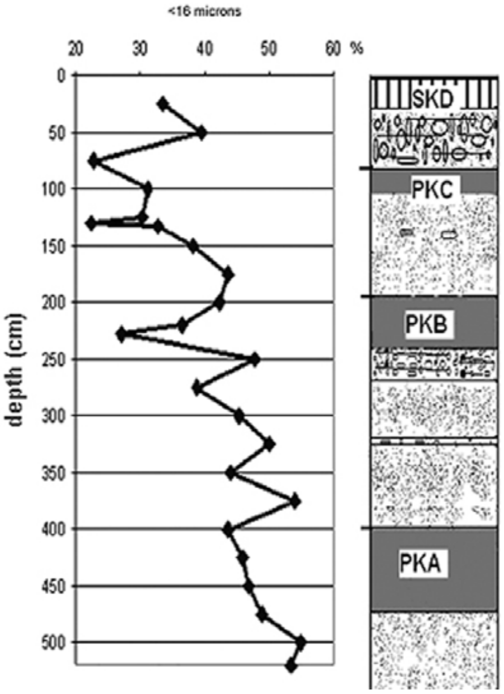

Figure 5. The energy of the slope morphodynamic as a function of grain-size distribution of the fine (<16 µm) grain-size population. The lowest percentages represent phases with high-energy slope processes. The stratigraphic units are identical with those in Fig. 3.

The loess-like sediments between the PKB and PKC paleosols were deposited roughly between 45 and probably 20 ka BP. This pedogenic phase implies milder climatic conditions around 25-20 ka BP, which is in close agreement with other studies in the Carpathian Basin. Rudner and Sumegi (2001) found that between 23-20 ka BP the climate of the Carpathian Basin became milder and wetter, with boreal forests spreading throughout the region. A warming period (interstadial) was identified around 22 ka BP, in the speleothem palaeoclimate reconstruction from a cave in the neighboring Western Carpathians (Onac and Lauritzen, 1996). The periglacial nature of the cryoclastic debris unit (SKD) and the fact that it overlies the PKC paleosol, would suggest that the SK D deposits (excluding the topsoil) were deposited during the MIS 2 phase associated with the Late Weichselian glacial advance.

5. DISCUTION - Paleoenvironmental and morphoclimatic interpretation

Facies changes and grain-size variations, associated with buried paleosols can be interpreted as episodic changes in the energy of the depositional environment. Periodic decreases in the sedimentation rate induced by climatic changes leading to a more closed vegetation cover allowed the formation of the paleosols A, B and C. The return to more arid conditions marked a rejuvenation of erosional processes and consequently slope materials of various origins were deposited, burying the paleosols of the previous cycle. The relationship between sediments and climatic conditions in the case of the Floresti profile does not always follow the simple model suggested by Vandenberghe et al. (1997, 1998) for the typical loess environment, where low deposition rates and finer sediments correspond to more benign climatic conditions and vice-versa. The morphogenetic equation at the Floresti site is complicated by the cryoclastic debris production, which is not necessarily enhanced by severe cold conditions, but by large temperature variations both diurnal and seasonal. Therefore, an alternation of continental with more oceanic climatic condition is suspected to have controlled the cyclic sedimentation pattern described above. The pollen diagram, which shows an alternation of more forested phases with phases when grasses dominated the landscape, further sustains this hypothesis. The composition of the forest vegetation does not point to warmer temperatures because thermophilous trees are absent, tree pollen spectra being dominated almost completely by *Pinus.*

Temperature variations during the Middle and Late Pleniglacial were minor. Both pollen and terrestrial snail data show that the community variation throughout the Floresti section does not point to significant changes in temperature regime. For instance, the composition of the forest vegetation, corresponding with paleosol levels, does not point to warmer temperatures because thermophilous trees are absent.

In addition, the snail fauna of the loess-like sediments is not significantly different in its temperature requirements from that of the paleosols. The presence of *Granaria frumentum* gastropod, at paleosols PKA and PKB levels, is the only indication of slightly warmer conditions during these pedogenic phases. The reworking of sediments might be partly responsible for this increased taxonomic homogeneity between loess-like sediments and paleosols.

Despite its inherent particularities, the paleoenvironmental model inferred above follows closely the general framework documented for Central Europe. For instance, the grain-size distribution of the extra-local silt-sized fraction (quartz, feldspar) largely reflects the strength of the dust-bearing winds and thus, is comparable with the loess-paleosol pattern typical for Central Europe during the Weichselian Pleniglacial. The *U* ratio curve (Fig. 3) best illustrates this pattern showing that the decrease in the energy of the depositional environment (decrease in the *U* ratio values) generally corresponds with paleosols and interstadial conditions, while peak *U* ratio values (dominance of the medium-coarse silt fraction or 44-16 μm) are attained during the deposition of loess-like sediments or coarse alluvial fan gravels, typical here during stadial periods.

Taken as a whole, the 5 m thick sequence presents a general sedimentary coarsening-up trend (Fig. 5) that could suggest an evolution towards a glacial maximum. The same pattern is suggested by the *U* ratio curve (Fig. 3), which shows a general evolution from lower-energy loess environments, around and prior to 70-60 ka BP, to higher energy (coarser) windblown dust incorporated into extensive coarse fan systems. The latter geomorphic systems dominated the slopes, probably around 20 ka BP. In detail, the grain-size analysis together with the pedological, pollen and malacofaunal investigation allows the recognition of four main morphoclimatic cycles similar to those of stadial-interstadial nature. Boreal forest-steppe to periglacial steppe environmental oscillations are shown to have occurred during the Weichselian Pleniglacial (Fig. 3). There is a distinct difference between the PKA and PKB sedimentary cycles, on one hand, and the upper two cycles (PKC and SKD), on the other hand, in terms of the energy and nature of the sedimentation and the geomorphological processes involved.

The silt loams associated with the PKA and PKB cycles were primarily deposited through eolian processes and were slightly reworked during and after their deposition by intermittent overland flow or sheet-wash, as suggested by the thin laminar structures, which interrupt the general massive structure of the deposit. The snail fauna present in these deposits indicate the so-called “warm loess steppe” landscape (Ložek, 2001). Before 60 ka BP, interstadial conditions (probably Odderade interstadial) permitted the establishment of a boreal pine forest-steppe that inhibited further development of slope processes and allowed the formation of the PKA paleosol. The chernozem nature of the paleosol, the snail assemblage dominated by steppe and forest-steppe species (with the notable occurrence of the xerotherme *Granaria frumentum* suggests that the climate was fairly dry during this interstadial and the temperatures were slightly higher than in the following "warm loess steppe" phase.

During the PKB cycle, the climate became more continental, with more effective freeze and thaw cycles, which created extensive limestone cryoclastic debris at the base of the limestone scarp. Such debris were subsequently reworked by high-energy fan systems and deposited on top of the loessic silt loams of the PKB unit (Fig. 3). The vegetation, dominated by grasses and forbs, was probably discontinuous, as suggested by the presence of Asteroideae, usually indicative of soil disturbance. At the end of the PKB cycle, around 45 ka BP, the eolian silt input became finer as indicated by lower *U* ratio values (Fig. 3) and the energy of the slope processes decreased, as seen by an increase in the <16 μm fraction (Fig. 5). Consequently, paleosol PKB was formed. Interstadial gastropod fauna (Chondrula tridens-fauna) with *Granaria frumentum* indicate a slight temperature improvement.

After 45 ka BP the climate become colder and coarser loess-like sediments were deposited (sandy-silt loams). These sediments reflect to some degree their initial eolian origin, thus are indicative of strengthened dust-bearing winds. The loess-like sediments are interrupted by coarser fan structures composed of sub-angular limestone gravels. The pollen data implies extreme arid conditions during this period because the NAP (herb pollen) represents almost 100%. The arboreal vegetation including the drought-resistant *Pinus spp.* was virtually wiped out of the region.

The return to interstadial conditions at the end of PKC is marked by a decrease in the energy of the eolian deposition, with fine silt (16-5 μm) becoming the dominant grain-size within the silt-sized range (*U* ratio values under 1, Fig. 3). The inferred interstadial conditions are also sustained by the presence of a boreal brown-earth soil and a sharp increase in arboreal pollen (Fig. 3). Cool and possibly wetter climatic conditions prevailed during this period because the xerotherme *Granaria frumentum* is missing from the snail fauna, which is dominated by *Pupilla muscorum*.

The development of an extensive cryoclastic debris mantle of the SKD burying the PKC paleosol could be associated with the extreme climatic conditions most probably present during the Last Glacial Maximum (MIS 2). Cool summers, with temperatures falling frequently below 0˚C at night, would favor frequent freeze-thaw cycles responsible for the formation of this debris mantle. A deep incision of the Little Somes river channel is suspected, because the deposition of slope material ended quite abruptly.

6. CONCLUSION

Weichselian Pleniglacial palaeoenvironmental reconstructions from terrestrial environments in lowland Transylvania are virtually non-existent. In this regard, the Floreşti section brings first palaeoenvironmental data from this region and offers new insight into the complexity of sedimentation processes in a region situated just beyond the southeastern margin of the thick Pleistocene loess deposits of Central Europe.

A detailed grain-size analysis on the upper 5 meters of the Floresti section together with pedological, pollen and malacofaunal investigation allows the recognition of four main morphoclimatic cycles similar to those of stadial-interstadial nature. In the first two morphoclimatic cycles (PKA and PKB) loess-like deposits were deposited mainly through low energy slope wash processes. The subsequent morphoclimatic cycles (PKC and SKD), especially after 45 ka BP, witnessed the development of alluvial fan channels associated with enhanced production of cryoclastic debris from upslope.

Boreal forests to periglacial steppe environmental oscillations have developed during the four morphoclimatic cycles. According to U/Th ages on snail shell assemblages, the period between 60-45 ka BP was cool and variably dry, with only one true interstadial recorded at 58 ka BP and correlated with the Oerel Interstadial.

The lower two buried chernozems from Floresti show strong similarities to other Central European pedocomplexes: the Bohemian sections of Kutná Hora and Dolni Veštonice (Frechen et al., 1999) and Basaharc Double pedocomplex from Hungary (Pécsi and Hahn, 1987), although in the latter case the age estimates of 40-45 ka BP might be too young to permit a correlation beyond doubt.

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