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CONDITIONS AND COURSE OF SEDIMENTATION OF THE MIDDLE AND UPPER PLEISTOCENE LOESSES IN THE HALIČ PROFILE (NW UKRAINE)

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Abstract

Large exposure near the brick-field in Halič represents one of the most complete loess sequences in the Ukrainian Carpathian Foreland, which illustrates a progress of events covering a considerable part of the Middle Pleistocene and the whole Upper Pleistocene. The most important of these are: the Luck soil corresponding to the soil from the Zbójno Interglacial in Polish profiles and Dömnitz Interglacial (^{18}O stage 9) in West European profiles, bottom part of the Upper Pleistocene (Dnieper = Odranian = Saalian I) loesses, which are extremely thick and stratigraphically divided into units of lower rank, and well developed soil complexes – Korshov and Horokhov. Investigations of the Korshov soil are a basis to discuss at least two stages/phases of pedogenesis development during the last but one interglacial (Lublinian = Treenian; ^{18}O stage 7). The Horokhov paleosol is connected with the Eemian Interglacial. The Dubno and Rovno soils occur within the poorly developed Vistulian loesses; the Rovno soil is a cultural layer.

Key words: loesses, Upper Pleistocene, paleogeograpahy, Ukrainian Carpathian Foreland

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INTRODUCTION

East Carpathian Foreland, except for a small western part, was situated in the extraglacial zone of continental ice sheets during the whole Pleistocene. Such a situation during glacial periods was favourable for the formation of loess covers, which are the main Pleistocene deposits in this area. The loesses occurring on the terraces of the Dniester river and its tributaries are especially worthy of notice. However, the Ukrainian loesses in the Carpathian Foreland are very poorly recognized, both in respect of their stratigraphy and lithology.

This paper contains the preliminary results of geological investigations of the Upper and Middle Pleistocene deposits, which build a high terrace of the Dniester river in Halič (Figs 1 and 2). These deposits reach the thickness of over 50 m, *i.e.* the maximum, a very rarely occurring thickness of the Quaternary deposits in the East Carpathian Foreland (Gerenčuk 1972). Two main complexes can be distinguished in the studied profile: the upper loess complex consisting of several stratigraphic units of the first rank described in this paper, and the lower complex which we started to study in 1999, complicated in structure and containing mainly alluvial deposits. An interglacial pedocomplex forms a boundary between them.

The loessy part of the profile is also important because of the occurrence of an archaeological site from the Upper Palaeolithic – significant and perspective in the East Carpathian Foreland – *i.e.* the Halič I site (Sytnik *et al.* 1999). Thus, the profile in Halič is very important both for stratigraphy and paleogeography in a regional and also supraregional scale. The distinctive character of these deposits in comparison with other loess patches in uplands of Central Europe, their facial features and stratigraphic differentiation in the western part of this area, were presented in the case study of the Przemyśl loesses by Łanczont (1995, 1997).

GEOLOGICAL AND GEOMORPHOLOGICAL CHARACTERISTICS OF THE HALIČ REGION

In the physico-geographical regionalization of Europe presented by Kondracki (1968) the Halič region is located in a transition zone between the Volhynia–Podolia Upland and the East Carpathian Foreland. According to the Ukrainian regional divisions, this region belongs to the middle part of the Carpathian Foreland (Peredkarpatia Prigorganska), within a unit of lower rank, defined formerly in the Ukrainian literature as Zadnistrovia, in the Polish papers as Naddniestrze, and according to the newest geomorphological division as Halič–Ugrynov Plateau (Kravčuk 1998).

As to tectonics the Halič region is located in a peripheric zone of a tectonically mobile Podolian plateau, and it adjoins

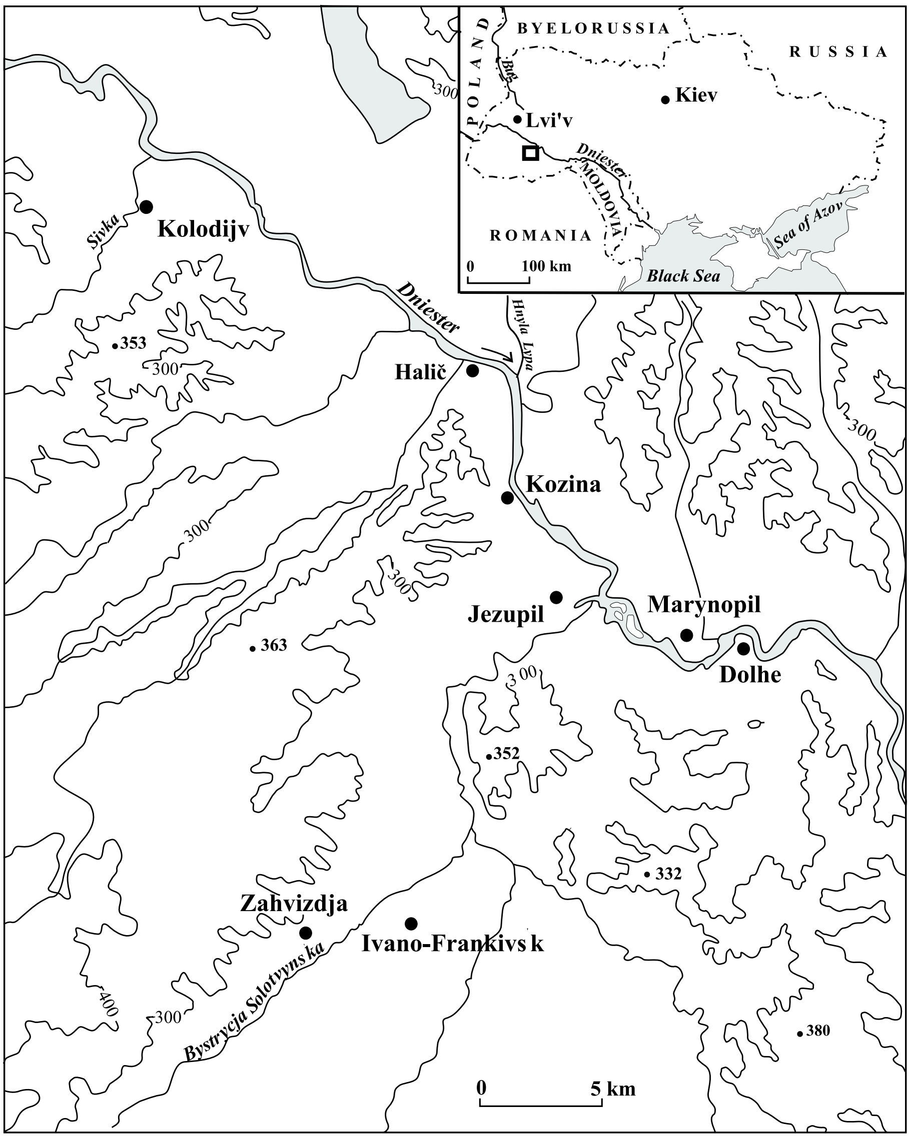


Fig. 1. Situation of the Halič profile and other neighbouring loess profiles in the Ukrainian Carpathian Foreland.

a weakly dislocated outer part of the Carpathian Foredeep (Gerenčuk 1972). This boundary is poorly visible in relief (Kravčuk 1999). Various carbonate rocks of the Upper Cretaceous (Turonian, Coniacian, Santonian) and marine sediments of the Neogene (Badenian, Sarmatian) occur under a continuous cover of the Quaternary deposits. The Cretaceous complex contains chalk, limestones and marls, the Neogene is represented by limestones of chemical origin, gypsum, anhydrites and clays (Gerenčuk 1973). The Pliocene fluvial deposits of the East Carpathian Foreland are almost entirely denuded (Gofštejn 1995).

The main landscape morphotype of the East Carpathian Foreland is a denudation-accumulation plain inclined towards the Dniester river valley and with a similar relief as in the neighbouring Volhynia–Podolia Upland. It is dissected by erosion; flat, vast plateau-ridges are separated by equally vast valleys of the Dniester river tributaries. Watersheds (interfluve areas) are covered with fluvial gravels and subaerial loess. These are old fluvial surfaces/routes, which reach the height of 300–250 m a.s.l. in the Halič region (Gofštejn 1995). Only few valleys of the rivers flowing to the Dniester river run along the lines of transverse faults occurring in the basement of the Carpathian Foredeep (Gofštejn 1995). Local widenings of the basin type with accumulation-plain relief occur in the valleys (Kravčuk 1999).

The largest areas in the Carpathian Foreland are occupied by high river terraces of steplike arrangement – there are five to seven such terraces (Polanskiy 1929, Teisseyre 1933, Gerenčuk 1972, Kravčuk 1999, and others). In the Dniester river valley near Halič the highest terraces are recognized as equivalents of the planation surfaces called Krasna (Gofštejn 1962, 1979, 1995) and Lojova (Teisseyre 1934), which are correlated with the Upper Pliocene and Eopleistocene, respectively. The largest remnants of the Krasna surface, reaching the relative height of 120–160 m, are preserved on the right bank of the Dniester river, southwards of Ivano-Frankivs'k. The Lojova surface of the relative height about 100 m is well developed *e.g.* southwards of Halič (Fig. 2), occupying large areas of the watershed between the Lukva nad Bystrycja Solotvyns'ka rivers (Teisseyre 1933, Gofštejn

Fig. 2. Hypsometry and geomorphological sketch of the Halič site. Holocene terraces: 1 – valley-bottom, lower (1–2 m and 2.5–3 m); 2 – valley-bottom, higher (5–6 m) with ox-bow lakes; Pleistocene terraces of relative height: 3 – 12–25 m, 4 – 50–55 m, 5 – 75–85 m, 6 – parts of the Lojova surface at a height of 300–315 m a.s.l.; 7 – denudation remnants; 8 – denudation valleys and erosion dissections; 9 – higher erosion scarps; 10 – scarps of erosion undercuts of younger terraces; 11 – landslides; 12 – alluvial fans; 13 – river channels; 14 – site of loess deposits.

1995). According to Kravčuk (1999) the successive terraces – fifth (50–70 m), fourth (up to 45 m), third (15–25 m) and second (5–8 m) – loosely correlate with the Eopleistocene (fifth terrace), Mesopleistocene (fourth terrace) and Neopleistocene (third and second terraces); the first terrace (2.5–5 m) was formed in the Holocene.

The Halič region is situated in the borderland of two provinces of temperate climate: oceanic-transitional and continental-steppe (Pontian), with mean annual temperature of 7.0°C (from -5.0° in January to 18°C in July). Annual precipitation averages at 800 mm, and 40–45% of precipitation falls during the summer, *i.e.* from June to August (Wróbel, Mrugała in press).

THE STATE OF RESEARCH OF THE PLEISTOCENE TERRACES IN THE HALIČ REGION

Recently published Ukrainian papers describe rather monotonous deposits (known mainly from drillings) building the covers of terraces. They consist of gravelly-sandy-silty alluvial series and uniform beds of yellow and yellow-brown loess-like loams of eolian and deluvial origin, liable to vertical fissuring (Kravčuk 1999). The stratigraphy of the subaerial covers of the Halič Podolia is more complex, which was revealed by Polanskiy (1929), who distinguished older calcareous loess with molluscan remains and decalcified loess topped with fossil chernozem (both correlated with the Middle Polish Glaciations = Dnieperian+Moscovian), occurring on the fifth and higher terraces, and typical Vistulian younger loess, covering alluvia on the lower terraces (except the lowest one).

Studies of the Halič part of the East Carpathian Foreland carried on by Bogutskiy and Łanczont let us get an insight into the sedimentary cover structure of the several Pleistocene terraces of different heights over the river water level, including the terraces of the Dniester river – in Jezupil' and Kozina (22–25 m), in Marynopil' (about 45 m), and in Halič (75–80 m), the terraces of the Sivka river in Kolodijv (about 27 m), and the terraces of the Bystrycja Solotvyns'ka river in Zahvizdja (80 m) as presented in Fig. 1. A typical sequence of the main sedimentary units is usually visible in these covers. Alluvial series occurring on the successively higher rock socles represent a complete cycle of fluvial accumulation – from a channel facies to a flood one – often with a paleosol or peat of a high stratigraphic rank at the top of alluvia; peats are laterally replaced by gyttjas and paleosols in some exposures. These alluvia are overlain by loesses with paleosols of different rank, and the higher the terrace the more interglacial paleosols it contains. Various periglacial structures deforming these paleosols are very important for paleogeography of this area. The profile in Zahvizdja is worthy of special notice for various reasons. It contains eight paleosols; these soils were formed in the Meso- and mainly in the Eopleistocene and are not found in other profiles (Bogutskiy *et al.* 1999). Apart from Zahvizdja, the Halič exposure is the second profile in which several interglacial soils were found in the studied area.

Our preliminary results reveal some weak points of the classification system of the terraces in the East Carpathian

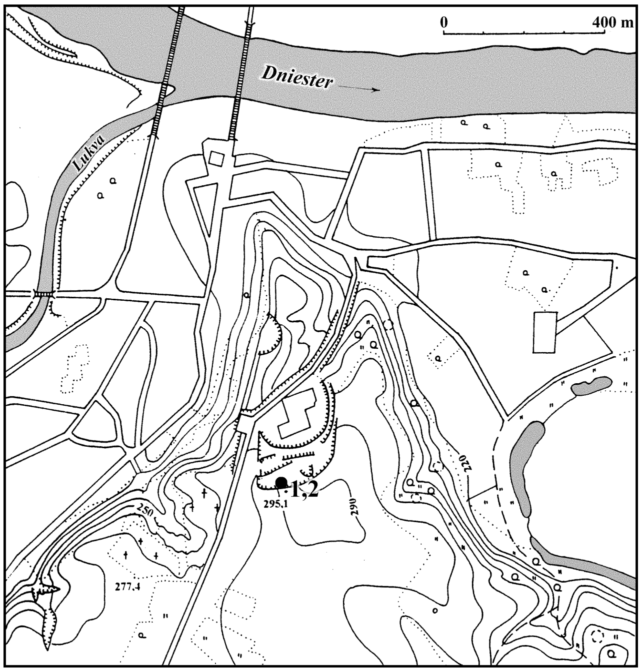


Fig. 3. Situation sketch of the loess exposure in Halič.

Foreland (Kravčuk 1999). This system, based mainly on the criteria of height and morphology, is clear but deceptive due to very variable thickness of loesses closely covering the terraces. Moreover, age estimation of terraces is too rough. Our ultimate aim is to work up a uniform and coherent classification system (based on the stratigraphic criterion) of river terraces in the Halič Carpathian Foreland. Temporarily we call the terraces using the names of sites in which they were investigated for the first time (*e.g.* Jezupil', Kolodijv, Marinopil', *etc.*)

LOCATION OF THE HALIČ PROFILE

The research site is located on the Halič Hill (Figs. 2, 3). It is a vast nose of the Dniester river high terrace (285–290 m a.s.l.), undercut by the Dniester and the Lukva rivers; it would be probably the fifth terrace in the Ukrainian classification. The next surface with alluvial (gravelly) cover rises about 10–15 m higher up; it is probably the sixth terrace (the Lojova surface) which occupies a watershed zone between the Lukva and the Bystrycja Solotvyns'ka rivers.

The studied profile occurs in the area of very diversified relief (Fig. 2). High edges (70–80 m) of the Halič terrace slope steeply (12–17°) to the valley bottom. They are dissected by many ravines and small valleys, which separate noses protruding towards both rivers. Strong landslide processes develop on these high and steep slopes.

The Holocene terrace is over 1 km wide. Numerous oxbow lakes preserved to a greater or lesser extent occur on the flat surface of this terrace rising 5 m above the water level in river channel (213 m a.s.l.).

METHOD OF RESEARCH

Loesses were investigated at two exposures (Halič 1 and Halič 2). Deposits reaching the depth of 4.90 m were studied in the Halič 1 exposure (archaeological site Halič I), and those occurring below – in the Halič 2 exposure. The lithological features of the Halič loess profile were presented on the basis of grain size analyses (Seul *et al.* 1998). Carbonate content was analysed following the volumetric method of Scheibler. Iron oxides were determined by means of a colorimetric method. Humus content was estimated using the method of Tiurin. Heavy minerals were separated in a heavy liquid (bromoform) from the fraction 0.1–0.06 mm, and quantitatively determined using a polarization microscope. TL dates were obtained by V. Shelkoplyas in the Kijev laboratory of the Ukrainian Academy of Sciences. One TL date (for the sample from the depth of 22.0 m – see Fig. 4) was obtained in the Lublin laboratory by J. Kusiak. The results of the analyses and lithologic-stratigraphic interpretation of the deposits are presented in Fig. 4. Main stratigraphic units of loesses and interglacial paleosols separating them (column I in Fig. 4) were defined according to the scheme published by Bogutskiy (1987). They were correlated with the corresponding units distinguished in the stratigraphic scheme of Polish loesses (Maruszczak 1996; column II in Fig. 4).

DESCRIPTION OF THE PROFILE

Loesses of the Halič terrace at a relative height of 77–80 m are exposed in a large brick-field open pit located in the near-edge part of the Halič Hill (Fig. 3). The Pleistocene deposits of this terrace overly a socle built of Cretaceous rocks rising about 245 m a.s.l. and about 25–30 m over the valley bottom. The top of the Halič 1 profile reaches 290 m a.s.l. In this profile the younger loesses were examined, *i.e.* those from the last glacial period (= Valdai = Vistulian = Weichselian). In the Halič 2 site the Horokhov (= Eemian) soil was investigated, and also loesses occurring below it, which represent the Moscovian (= Wartanian = Saalian II) and Dnieperian (= Odranian = Saalian I) Glacials, and which are separated by the Korshov pedocomplex. The gley horizon is visible at the bottom part of the Dnieperian loesses. Under the whole series the Luck paleosol occurs on loamy deposits and sandy-gravelly alluvia. This paleosol is correlated with soil from the Zbójno (= Dömnitz) Interglacial in the Polish profiles (Lindner 1991), and it indicates the Mesopleistocene age of the alluvia in the Halič terrace. The detailed description of the profile is given in Table 1.

We defined the paleosol of a higher rank occurring at the bottom of loesses in the Halič 2 site as the Luck soil. It developed on the loess-like loamy deposits exposed to the depth of 2 m at this stage of investigations. Field works initiated in November 1999 near the brick-field in Halič revealed that these deposits are up to 8.5 m thick and stratigraphically differentiated into 2–3 units of second rank (stadials?). They are underlain by alluvia of flood and channel facies of similar thickness; the studies of these deposits have been commenced.

CHARACTERISTICS OF LOESSES AND THEIR SEDIMENTATION CONDITIONS, AND PALEOSOLS IN THE HALIČ PROFILE

Stratigraphy of the loess profile in Halič was defined mainly on the basis of paleopedologic criterion – type and succession of paleosols (Fig. 4). Referring to the lithostratigraphic scheme of loesses in NW Ukraine (Bogutskiy 1987), we distinguished the following four stratigraphic units of loesses: the upper and bottom bed of the Upper Pleistocene loesses, and the upper and bottom bed of the Middle Pleistocene loesses (Fig. 4, column I). These four units represent three complete glacial-interglacial cycles (Fig. 4, column II). However, chronostratigraphy of the Halič loess is difficult to determine because the TL dates from the Kiev laboratory, though they form a consistent series, underestimate the age of the Dnieperian loess units in the light of the Pleistocene chronostratigraphy.

The Luck soil

Denudation (washing) has destroyed the accumulation horizon of the Luck soil. In the eluvial horizon the content of clay fraction is over 15%, and Fe_2O_3 only slightly exceeds 1%. In the B horizon the clay fraction occurs in a similar amount, but the content of iron compounds increases to over 4%. The complex development of this soil is evidenced by the net of contraction fissures forming a well visible system of small polygons in the B horizon surface and running downwards. These fissures were probably connected with drying out during intensive changes of ground moisture.

The Dnieperian/Odranian loess

The Dnieperian/Odranian glacial cycle is represented in the Halič profile by the bottom bed of the Middle Pleistocene loesses, which is very thick (over 14 m) and structurally differentiated, which is important for paleogeographical considerations. Three main stratigraphic units distinguished within this loess can be correlated with LSn, LSd and LSs in the stratigraphic scheme of Polish loesses (Fig. 4, column II). The grain size of this loess is typical (Mz ranges from 5.7 to 6.2 ϕ), so it corresponds to the proper loesses (Mz = 5–6 ϕ; for explanation of abbreviations, see Fig. 4). On the basis of the mean values calculated for particular stratigraphic units of the Dnieperian/Odranian loess we can note that this deposit is weakly sorted (σ_1 = 1.6–1.7), with grain size distributions positively skewed (Sk_1 = 0.3–0.5), meso- and leptokurtic (K_G = 1.13–1.67). The granulometric indices, especially Sk_1 and K_G, are considerably differentiated in vertical profile (Seul *et al.* in press).

The lowest carbonate layers of the Dnieperian/Odranian loess, overlying the truncated Luck soil, are above 2 m thick and represent the early phase of that glacial. Sedimentation of this loess was probably connected with mesoenvironment of low terrace. There was a vast, probably drying out, natural water reservoir in the vicinity. Sediments of the banded clay type were deposited in quiet places of this water body. Height differences between a basin-shaped valley bottom and neighbouring slopes of a higher terrace were rather small at that time. Loess accumulation occurred in cold climate and in a waterlogged area; it represents a subaqueous, boggy facies. We notice pulsatory changes and inverse proportions of humus (0.13–0.19%) and carbonates (8.5–2.5%) in the vertical profile of these layers; content of iron compounds is distinctly lower (2.2–2.6%) than in the underlying Luck soil.

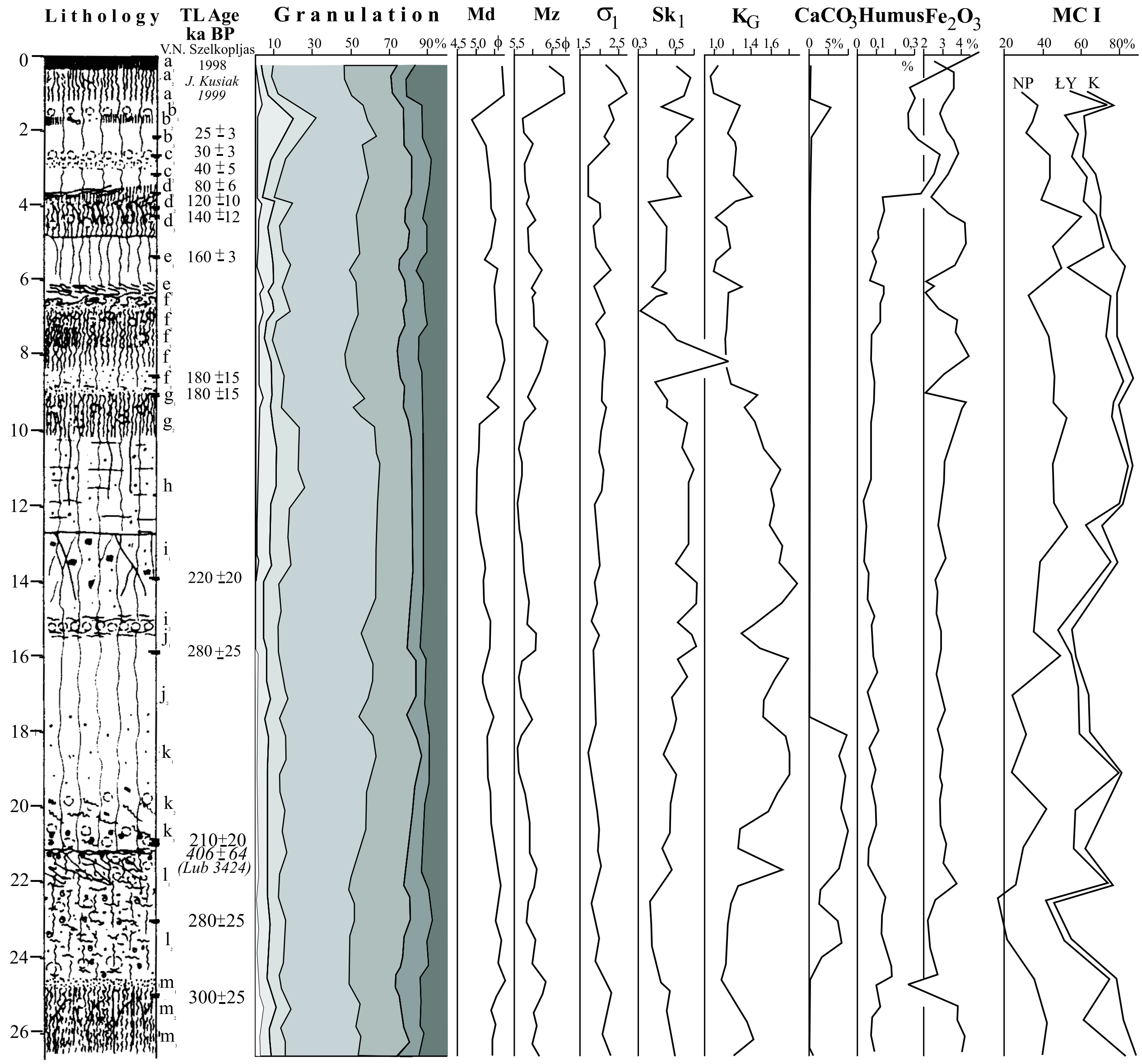
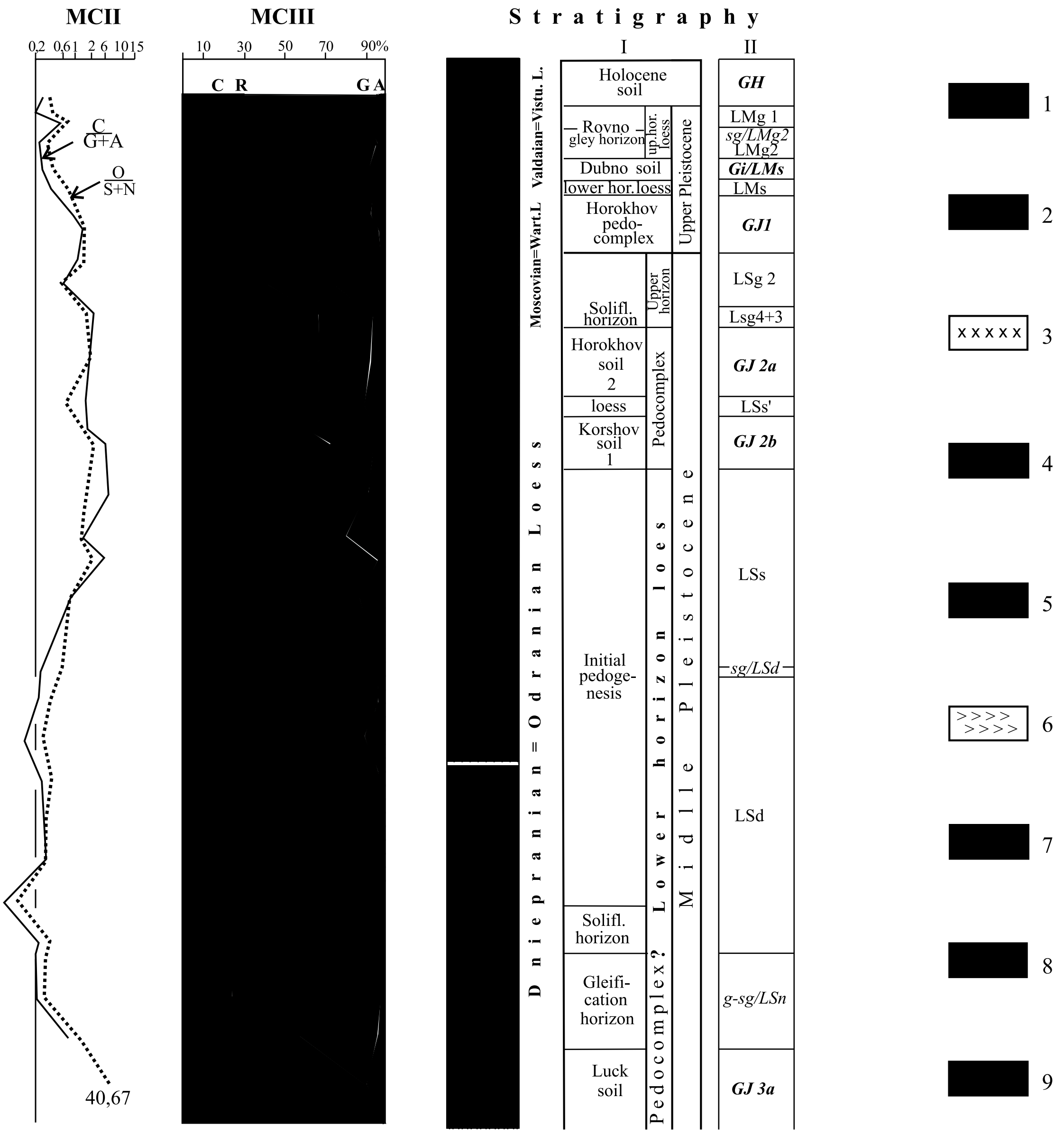


Fig. 4. Loess profile in Halič. Granulation – grain size distribution; Md – median grain size; Mz – mean grain diameter; σ_1 – standard deviation; Sk_1 – skewness index; K_G – kurtosis index; Humus – humus content; $CaCO_3$ – carbonate content; Fe_2O_3 – iron oxides content. Diagram of mineral composition of heavy fraction: MCI – Np – opaque minerals content, Ły – micas, K – concretions; MCII – composition indices of transparent minerals; MCIII – composition of transparent minerals. Letter symbols of transparent minerals: C – zircon; R – rutile; T – tourmaline; G – garnet; A – amphiboles. O – resistant minerals; S – medium resistant minerals; N – non-resistant minerals. Main stratigraphic units of loess according to Bogutskiy (1987) and Maruszczak (1991) are shown in columns I and II, respectively. Letter symbols of loess stratigraphic units after H. Maruszczak (1991): L – loess; M – younger; S – older, g – upper, s – middle, d – lower, n – lowest. Letter symbols of soil units after H. Maruszczak (1991): G – soil with well developed genetic horizons; H – Holocene soil; J – interglacial soil; i – interstadial soils; sg – soil sediments; (g) – symptoms of the development of pedogenesis. Signatures: 1 – interglacial soils and pedocomplex; 2 – non-weathered carbonate loesses, some of them with horizons of large carbonate concretions; 3 – interstadial, initial soils, pedosediments; 4 – well developed interstadial soils; 5 – carbonate-free weathered and slope washed loesses; 6 – solifluction horizons; 7 – resistant heavy minerals; 8 – medium resistant heavy minerals; 9 – non-resistant heavy minerals.

These features indicate that the accumulation processes were accompanied by pedogenesis, which only partially obliterated traces of lithogenesis, so it was rather weak, and only occasionally more intensive. Such weathering processes had rather weak effect on internal features of the deposit, so the aggregate index is relatively low (Seul *et al.* in press). These layers can be considered as a weakly developed soil sediment of gley type (*over-Luck horizon*).

Set of the layers l_2-m_3, containing the forest Luck soil and the overlying gleyed horizon, has the macroscopic features of a bipartite pedocomplex. The whole sequence is topped with a solifluction horizon, which points to the climatic cooling and increase of humidity.

The loess series higher up is over 12 m thick and built of two main units, and it represents the middle and upper pleniglacial of the Dnieperian/Odranian Glacial. The morphologi-



cal situation of the investigated exposure indicates that such a considerable thickness was a primary feature of this loess, and washing is undoubtedly reflected in its structure as a factor participating periodically in loess formation. The accumulation of eolian and eolian-deluvial facies of loess was connected with cold and rather dry climate, with continental influence. Internal aggregate structure of this loess reflects rather intensive weathering-pedogenetic processes synchronous with sedimentation (Seul *et al.* in press). Traces of grass root system are numerous within this loess; they occur as small pipes (visible in microstructure) filled with carbonized plant detritus. Abundant humus and/or manganese (?) spots were probably also connected with vegetation. Therefore, it was most probably the environment of subarctic steppe tundra with rather abundant grass, which was successively covered by mineral material.

Most of the lower Odranian/Dnieperian loess (layers j_1–k_3) is carbonate (7.5–9.5%). Primary and secondary carbonates are found here; the latter ones as pseudomycelia and mainly as large concretions occurring in three layers. The layers containing concretions occur 1–1.5 m below the layers in which the traces of steppe-tundra vegetation are most visible, and mark the extent of carbonate leaching in continental conditions. They can be defined as the horizons of carbonate illuviation, probably of interphase rank. On the basis of such large concretions it seems to correspond to the "older loess" identified by Polanskiy (1929) in the Podolian loesses.

The upper part of the discussed loess complex (layers h–i_2) is separated from the bottom part by a soil sediment with gleying signs (layer j_1), probably of interstadial rank. This loess is leached; only secondary carbonates occur, mainly as pseudomycelia. Almost horizontal lamination is here more distinct and reveals secondary deformations, such as layer deflections, plications and small folds indicating that a fresh silt was translocated down a very gentle slope with influence of solifluction and washing by rainwater/meltwater. It can be supposed that this phase of loess accumulation occurred when climatic conditions gradually deteriorated. The break or reduction of sedimentation is recorded in this loess at the depth of 12.7 m as a fossil surface with a system of dessication fissures coloured by iron oxides.

The lithologic features of the Dnieperian/Odranian loesses in Halič reflect a complex evolution of the loess cover in this glacial cycle, including the alternating phases of increased or decreased activity of eolian, deluvial and weathering/pedogenetic processes, phases of carbonate leaching and so on. This loess series seems important for discussion of the stratigraphy and paleogeography of this period not only on a regional scale.

The Korshov pedocomplex

The Korshov pedocomplex (layers f_1–g_2) overlying the Odranian/Dnieperian loess is macroscopically bipartite. Two equally well developed polygenic soils (of the older and the younger phase) were connected with forest environment. Both soils are distinctly gleyed from the top. In both soils we could distinguish only the Eet and Bt horizons. Accumulation horizons (probably thin, which is specific for such a soil type) were not preserved; each of these soils is truncated by erosion-denudation surface. The younger soil developed at

Table 1

Description of the Halič profile

Unit	Depth (m)	Description
a_{1-3}	0-1.2	Recent soil, anthropogenically transformed a_1 – 0-0.4 m – humus horizon (A), strongly transformed, silty-clayey, dark-grey, structureless; HCl–. Distinct border. a_2 – 0.4-0.8 m – B1 subhorizon, silty-clayey, with prismatic structure, rusty-brown with white spots – probably traces of penetration of the material from E horizon, not existing at present; HCl–. Gradual transition. a_3 – 0.8-1.2 m – B2 subhorizon, loamy, dark-yellow; HCl–. Distinct border.
b_1	1.2-1.7	Yellowish silty-sandy homogeneous deposit with carbonate pseudomycelia, downwards with gley spots, ferruginous spots and streaks and iron-manganese concretions; HCl–. Bottom boundary marked by artifacts, mainly bones of great mammals.
b_2	1.7-1.9	Cultural horizon, rather homogeneous silty-sandy deposit, slightly darker than in b_1 layer, transformed by soil fauna, containing flints, bones and open fire traces; HCl+. Distinct boundary. It is the Rovno subhorizon according to the stratigraphic scheme of the Upper Pleistocene in NW Ukraine after Bogutskiy (1987).
b_3	1.9-2.5	Silty-sandy deposit, straw-yellow in the upper part, downwards with bluish tint, with iron-manganese concretions up to 3 mm in diameter, which are more numerous downwards; HCl–. Distinct boundary. TL age (2.2 m): 25±3 ka BP.
c_1	2.5-3.0	Interstadial soil of the Dubno type (after Bogutskiy 1987), loamy, red-brown with gley spots up to 5 cm in diameter, with carbonate concretions, with black iron-manganese concretions up to 3 mm in diameter; HCl+ very weakly. Cluster of charcoal at the depth of 2.7 m. Distinct sinuous boundary. TL age (2.7 m): 30±3 ka BP.
c_2	3.0-3.4	Straw-yellow silty-sandy deposit, macroporous, homogeneous, with rare iron-manganese concretions; bulk mass of deposit HCl–, but secondary carbonates occur in places. Gradual transition. TL age (3.2 m): 40±5 ka BP.
d_{1-2}	3.4-4.9/5.0	Horokhov (= Eemian) pedocomplex with a sequence of A-Eet,g-Btg horizons. d_1 – 3.4-3.9 m – weakly developed humus horizon (A), preserved *in situ* only in places, loamy, red-brown, rather homogeneous, structureless, with numerous black iron-manganese concretions up to 3 mm in diameter, and rare charcoals up to 1 cm in diameter; HCl–. Distinct boundary. TL age (3.7 m): 80±6 ka BP. Layer d_1 represents a steppe development phase of the Horokhov pedocomplex. The forest phase of this complex is represented by the layer d_2. According to the scheme by Bogutskiy (1987) the Horokhov soil separates the Upper Pleistocene loesses from the Middle Pleistocene ones. d_2 – 3.9-4.0 m – eluvial horizon (Eet) in places preserved *in situ*, powder-like material, white-grey with very numerous iron-manganese concretions up to 3 mm in diameter; HCl–. Distinct boundary. d_3 – 4.0-5.0 m – red-brown, structureless illuvial horizon with gley signs – spots and streaks along vertical fissures; HCl–, but carbonate pseudomycelia occur. In the Halič II profile the illuvial horizon is more intensively gleyed and strongly deformed by solifluction, so the fissures slant along a fossil slope. Gradual transition. TL age (4.1 m): 120±10 ka BP (Halič 1), TL age (4.3 m): 140±12 ka BP (Halič 2).
e_1	4.9/5.0-6.3	Light-brown loamy deposit, compact, rather homogeneous, with small iron-manganese concretions and some greater (3 mm) ones. Vertical fissures filled with gleyed material run downwards from the layer surface; HCl–. Distinct boundary. TL age (5.5 m): 160±13 ka BP.
e_2	6.3-6.7 ±0.2	Solifluction horizon of the complex, lobe-involution structure and differentiated thickness; HCl–. Horizon is built of two main components – loamy loess and material from the eluvial horizon (layer f_1) of underlying interglacial complex. Tongue-like structures are about 0.3 m long and up to 0.1 m thick; involution structures – up to 0.3 m wide and 0.3-0.5 m high. Distinct denudation boundary.

Table 1 (continued)

Description of the Halič profile

Unit	Depth (m)	Description
f_{1-4}	6.7-8.4	Fossil pedocomplex, containing two soils, represents two phases of the Korshov pedogenesis (according to the scheme by Bogutskiy 1987) and separates the upper bed and the lower bed of the Middle Pleistocene loesses. Soil from the younger (second) phase of the Korshov pedogenesis has a well developed profile, but humus horizon is not preserved. f_1 – 6.7-6.9 m – eluvial horizon (Eet), powder-like material, white-grey, macroporous, with very numerous black iron-manganese concretions up to 5 mm in diameter, and with charcoals up to 10 mm in diameter; HCl–. Distinct boundary. Loose, powder-like material of this horizon penetrates the illuvial horizon to the depth of 0.5 m along narrow fissures. f_2 – 6.9-7.4 m – subhorizon Bt – upper part, red-rusty, loamy, of crumb structure, with gley spots and streaks; HCl–. Gradual transition. TL age (7.1 m): 160±13 ka BP. f_3 – 7.4-7.9 m – subhorizon Bt – middle part, brown-rusty, loamy, of less visible structure, with single gley spots up to 3 cm in diameter, and less numerous iron-manganese concretions; HCl–. Gradual transition. f_4 – 7.9-8.4 m – subhorizon Bt – bottom part, light-brown, loamy, of homogeneous structure, in the bottom part – plate structure (plates up to 1 cm high) probably of cryogenic origin; HCl–. Gradual transition. Layers f_{1-4} represent the second development phase of the Korshov pedocomplex; the first phase is represented by layers g_{1-2}.
f_5	8.4-8.9	Substratum of the soil from the second phase of the Korshov pedogenesis; loamy deposit, homogeneous, weakly gleyed, with very numerous iron-manganese concretions up to 3 mm in diameter; HCl–. Distinct denudation boundary. TL age (8.7 m): 180±15 ka BP.
g_{1-2}	8.9-10.2	Soil of the older (first) phase of the Korshov pedogenesis, with preserved eluvial and illuvial horizons. g_1 – 8.9-9.1 m – horizon Eet, powder-like material, whitish, of plate structure, with very numerous iron-manganese concretions up to 5 mm in diameter, and charcoals up to 10 mm in diameter; HCl–. Distinct sinuous boundary. Loose, powder-like material of this horizon weakly penetrates the illuvial horizon. g_2 – 9.1-10.2 m – horizon Bt, loamy, rather homogeneous, with weakly visible structure, reddish-brown in the upper part and light-brown in the bottom, with gley spots up to 7 cm in diameter; the spots are bordered by orange iron coatings. Fissures with gley streaks run downwards from the top of this horizon. Dark iron-manganese concretions up to 3 mm in diameter are most numerous in the upper part of the horizon, and carbonate concretions up to 3 cm – in the middle part, but bulk mass of deposit is HCl–. Gradual transition. TL age (9.2 m): 180±15 ka BP.
h	10.2-12.7	Silty-sandy and silty-clayey deposit horizontally laminated; alternately light- and dark-brown laminae 1-2 cm thick. Lamination is marked by ferruginous and manganese dark stripes; HCl–. Carbonate and iron-manganese concretions, as well as the concentric structures of the Liesegang ring type occur within the layer. Distinct boundary.
i_1	12.7-14.7	Buff silty deposit, homogeneous, weakly gleyed, with numerous dark humus and/or manganese (?) spots several cm in diameter and iron-manganese concentrations; HCl–. The layer is cut by a system of well developed vertical fissures incrusted with carbonates and iron compounds. The fissures begin on the layer surface and reach downwards the layer i_2. TL age (14.0 m): 220±20 ka BP.
i_2	14.7-15.2	Loess similar to the above, but more homogeneous, with iron-manganese concretions; HCl–. Distinct boundary.
j_1	15.2-15.4	Silty-clayey gley horizon with distinct ferruginous streaks at the top and bottom; HCl–. Distinct boundary.
j_2	15.4-17.7	Loess similar as in the layer i_2; HCl–, and below 16.50 m – HCl+ with carbonate pseudomycelia. Distinct boundary. TL age (16.0 m): 280±25 ka BP.
k_1	17.7-19.7	Buff silty-sandy deposit, homogeneous, gleyed, with very numerous carbonate pseudomycelia and two horizons (in the middle and bottom parts of the layer) with large carbonate concretions (loess dolls) up to 10 cm in diameter; HCl+. Gradual transition.
k_2	19.7-20.2	Loess similar to the above, with numerous iron-manganese concentrations and rather regular humus and/or manganese (?) spots up to 5 cm in diameter; HCl+. Gradual transition.
k_3	20.2-21.2	Loess similar to the above but more gleyed, with humus and/or manganese (?) spots, compact, with plication deformations; HCl+. Distinct boundary. TL age (21.0 m): 210±20 ka BP.

Table 1 (continued)

Description of the Halič profile

Unit	Depth (m)	Description
l_1	21.2-22.2	Silty-clayey deposit, compact, homogeneous, grey and bluish-grey with rusty ferruginous pigmentation, with gley spots (these features are more intensive downwards), and with distinct signs of solifluction deformation; HCl+. Distinct sinuous boundary marked by ferruginous streaks 5-10 cm thick. Numerous iron-manganese concretions and mollusc shells occur in the layer, and carbonate concretions 5-7 cm in diameter are found in its bottom part. TL age determined in Lublin laboratory (22.0 m): 406±64 ka BP.
l_2	22.2-24.5	Gleyed horizon (g-sg), loamy, rather homogeneous, blue-grey, and dark-brown in the bottom part, with numerous iron-manganese concretions and mollusc shells; HCl+ to the depth of 24.25 m, below HCl–. Gradual transition. TL age (22.0 m): 280±25 ka BP. Gleyed loam is horizontally replaced by banded clays with light and dark laminae (lacustrine-flood deposits), which are exposed in the southern part of the brick-field.
$m_{1\text{-}3}$	24.5-26.5	Luck paleosol m_1 – 24.5-24.8 m – eluvial horizon (Eet) – powder-like material, light-grey, of plate structure, with very numerous black iron-manganese concretions up to 5 mm in diameter; HCl–. Distinct, irregular boundary, marked by accumulation of these concretions. m_2 – 24.8-25.7 m – subhorizon B, upper part, silty-clayey, of aggregate structure, rusty-brown with very numerous gley spots, with numerous dark iron-manganese concretions 3-6 mm in diameter, with a system of fissures filled with grey gley material. These fissures form a system of polygons up to 0.5 m in diameter, which is visible in horizontal section. The depth of these fissures rarely exceeds 0.5 m, and the width – 2-3 cm. Black pigmentation of manganese compounds occurs on walls of the fissures. TL age (25.0 m): 300±25 ka BP. m_3 – 25.7-26.5 m – subhorizon B, bottom part, silty-clayey, reddish-rusty, more homogeneous; soil structure weakly visible. After Bogutskiy (1987) the layers $m_{1\text{-}3}$ represent the Luck soil, which separates the Middle Pleistocene loesses from the lower Pleistocene ones.

least partially on the layers (f_5) of fresh loess material. We found that this intrasoil loess was in certain places disturbed by solifluction and mixed with weathering residua of E horizon of the older soil in other parts of the exposure. Therefore, from the paleopedological and sedimentological point of view, the course of events during the Korshov Interglacial was very complicated; conditions were suitable for occurrence of two pedogenetic phases during which the weathering/soil-forming processes were intensified to a similar degree.

In some parts of the exposure (outside the examined outcrop) there were found very well preserved, round pseudomorphs of crotovines appearing in bottom parts of the Bt horizons. They are completely or partially filled with grey material which probably came from the eluvial horizon (the rest of filling came from the illuvial horizon).

The Moscovian/Wartanian loess

The Wartanian/Moscovian loess, not well developed, gives few data important for stratigraphy of this unit. Thickness of this loess, together with the solifluction layer at the bottom and the Horokhov soil at the top (layers d_{1-3} and e_{1-2}), ranges from 3.3 to about 5.0 m in different parts of the exposure. Incomplete profile of this loess consists of three stratigraphic horizons, which can be distinguished on the basis of lithology and facial features because interstadial soils are absent. Solifluction cover constitutes the bottom layer (e_2) of complicated structure, built of material from the Eet horizon of the younger Korshov soil and loessy silt occurring in varying ratio. It probably represents the early glacial, perhaps partially the lower pleniglacial. Middle layer is constituted by the weathered loess with the following parameters: $Mz = 6.02\ \phi$, $\sigma_1 = 1.78$, $Sk_1 = 0.33$, $K_G = 0.92$. At its top there appears a very distinct erosion-denudation surface with a system of dessication fissures running downwards; this surface can be surely correlated with an interstadial hiatus. This weathered loess probably represents the main, pleniglacial part of the glaciation. This conclusion is mainly supported by a layer sequence, and also by the TL age (160 ka BP) of this loess. The layers formed in the upper pleniglacial were completely transformed by pedogenesis during the last interglacial.

The Horokhov pedocomplex

The Horokhov pedocomplex is preserved within the exposure in Halič only in places, but where complete, it has a model form. It consists of two superimposed soils corresponding to two pedogenetic phases of different rank. Within the lower soil of forest type we distinguish the whitish eluvial horizon Eet and the well developed Bt horizon, rich in iron compounds (about 4%). The superimposed humus horizon A, in places containing about 0.3 % of humus and considerably smaller amount of iron compounds (2.4–2.6%), represents a steppe phase. The forest soil was formed in the Eemian (= Mikulino) Interglacial, and the steppe soil – during the Early Vistulian warming. The Bt horizon is cut by the pseudomorphs of fissures filled with gleyed material and deformed by solifluction. It indicates that periglacial conditions occurred during the first Early Vistulian stadial, between the forest phase and the steppe phase; it was the so-called "a" phase of the Torczyn paleocryogenic stage (Bogutskiy 1987).

The Valdaian/Vistulian loess

In the Halič profile the Valdaian/Vistulian loess (layers a_1–c_2) is thin. It contains more sand than the older units, so in the non-weathered layers the Mz index is somewhat greater (5.8 ϕ); this loess is also slightly better sorted (σ_1 = 1.6–1.8), with very positively skewed grain-size distribution (Sk_1 = 0.5–0.6). Therefore, we can suppose that in the Halič region the dynamic activity of eolian sedimentation environment was greater during the Vistulian than during the earlier glaciations. The Vistulian loess is rather rich in humus (0.2–0.3%) and iron oxides (3.2–3.6%). It contains carbonates (up to 5.6%), but only in the layers representing the upper pleniglacial, *i.e.* over the intraloess interstadial soil of the Dubno type.

Two layers with pedogenetic traces can be distinguished within this loess. The soil of the Dubno type (layer c_1), mentioned above, dated at 30 ka BP, is a rather typical tundra soil with one horizon, 0.5 m thick, with high contents of humus (0.44%) and iron compounds (3.75%). From the paleogeographical point of view the most important subject is the interphase Rovno soil (layer b_2), occurring at the depth of 1.7–1.9 m. It is a very well developed cultural layer with flint artifacts and a set of mammal bones, among them mammoth, horse and reindeer, and with traces of open fires (Sytnik *et al.* 1999). It is not unlikely that these finds are the traces of a camp of hunters from the Stone Age. For the present we refer them to the Upper Palaeolithic settlement.

THE HALIČ LOESS PROFILE IN THE LIGHT OF HEAVY MINERALS ANALYSIS

Heavy minerals analysis was carried out on the fraction 0.1–0.06 mm. The content of heavy fraction, and then the contents of opaque minerals, carbonate and iron concretions, muscovite, chlorites and group of other transparent minerals were determined quantitatively. The contents of particular transparent minerals were determined but some of them were grouped; epidotes were classified with zoisites, and rutile with the other transparent titanium minerals. The results were presented in detail in Fig. 4.

Two indices were helpful in concluding about the sedimentary process: O/(S+N), where: O – minerals resistant to weathering (zircon, disthene, monazite, rutile, staurolite), S – medium resistant (apatite, epidotes, garnets, sillimanite), N – non-resistant (amphiboles, biotite, pyroxenes), and C/(G +A), which presents the ratio of zircon grains to the sum of garnet and amphibole grains. The first index gives general information about "weathering degree" of the loess source material, selection of source material resulting from the nature and quantity of sedimentary cycles it underwent before deposition on the present site, and also about development of weathering-pedogenetic processes within the deposited loess. The C/(G+A) index is relatively more helpful for establishing the development degree of these processes because it includes contents of zircon (very resistant to chemical weathering and transport), garnet (resistant to mechanical abrasion and stable in wet environment but sensitive to chemical weathering), and amphiboles (non-resistant to physical and chemical destruction).

However, the above mentioned interpretative assumptions should be treated with great caution. When discussing sources of loess material, lithodynamic phenomena during sedimentation, and post-sedimentary weathering-pedogenetic processes, we must take into consideration also other data resulting, among other things, from granulometric and chemical features of the deposit.

Fluvio-periglacial deposits accumulated in the Dniester river valley were the main source material for the loesses in the Halič profile. These deposits came from the Carpathian flysch rocks, Tertiary deposits of the Carpathian Foreland and Cretaceous–Tertiary rocks of the Podolia. Like in the circumstances found in SE Poland (for example when studying the Przemyśl loesses, see Łanczont, Wilgat 1994), we can assume that generally all transparent heavy minerals found in the Halič loesses occur also in the flysch rocks. Typical assemblage of heavy minerals in flysch rocks contains garnet, zircon, rutile, tourmaline as main minerals, and amphiboles, pyroxenes, epidotes, biotite, chlorites and glauconite as accessory minerals. In the peri-Carpathian Tertiary rocks garnet and zircon are dominant, micas and chlorites occur in considerable quantities, and minerals non-resistant to mechanical destruction, such as amphiboles and glauconite, are marginal. In the Podolia rocks zircon and rutile prevail, and garnet occurs less frequently. Despite rather similar qualitative composition of heavy minerals assemblage, these minerals can give us some information about periodic predominance of the Podolian or Carpathian alimentation area in material supply to the alluvia occurring in the Dniester river valley, which were the main potential source of loess silt.

Qualitative-quantitative changes of the mineral material in comparison with their parent rocks resulted form weathering of these rocks, transport and repeated redeposition of the weathered material, and mixing of components coming from different sources. It should be also noticed that due to dynamic action of flowing water, the components were differentiated as to the possibility of their movement and deposition. This process caused a local enrichment in zircon, rutile and garnets (Racinowski 1995).

Periodically dried fine-grained alluvia were easily deflated and blown on neighbouring slopes. Further differentiation of heavy minerals assemblage occurred after the accumulation of loess as a result of its periodic blowing or washing down. Weathering-pedogenetic processes brought about additional transformation of the heavy minerals assemblage. Any estimation of development of these processes in the Halič profile was difficult to carry out because heavy minerals association in the source material contained mainly minerals resistant to weathering.

The content of heavy minerals in the fraction 0.1–0.06 mm is generally small (0.05–0.36% of weight). Quantities of the main components of heavy minerals assemblage in the Halič profile are typical for the loesses in Poland and West Ukraine. The content of opaque minerals is from 18 to 60%, of micas – 5–56%, and of transparent minerals – 12–54%.

The amount of transparent minerals is smaller in the interglacial paleosols of the Halič profile, especially in the oldest one, and also in the weathered loesses of deluvial facies. Concretions occur in rather small amounts; usually up to 6%, and only sometimes 20–30%. Among transparent heavy minerals, the following ones prevail: zircon (5–54%), garnets (6–82%) and rutile (5–40%). Their quantities are somewhat differentiated in particular deposit beds. Other resistant minerals (disthene, staurolite, tourmaline) occur in rather small amounts and were not taken into account because of the possibility of misconstruction. Medium resistant (epidotes) and non-resistant (biotite, amphiboles, pyroxenes) components, though occurring in small amounts, were taken into consideration as an evidence of loess alimentation from flysch deposits of the East Carpathians. Worthy of notice are similar quantities of amphiboles and pyroxenes indicating their origin from volcanic rocks, probably andesites, which were neighbouring source materials for flysch deposits. Some of the examined samples contain up to 7% of glauconite, occurring both in the Podolian rocks and in the rocks of the Carpathians and Carpathian Foreland. The increased amount of glauconite (non-resistant to mechanical and chemical destruction) may imply a short distance transport of mineral material blown on slopes (for example from the denuded valley sides).

The description of the heavy minerals composition in soils and loesses of the Halič profile is presented below.

The Luck paleosol (layers m_{1-3}) shows the strongest weathering features. It is characterized by a very low content of heavy fraction, in which the amount of concretions is relatively great and of transparent minerals – small. Zircon (>50%) and rutile (33–40%) prevail among transparent minerals. Because of the absence of biotite, garnets and amphiboles, calculation of the C/(G+A) index is impossible, and the O/(S+N) index is extremely high (>40). This assemblage is distinctly different from those occurring in the overlying beds. It can be supposed that the main alimentation source for the substratum of this paleosol was the weathered material of the local Tertiary–Cretaceous rocks of the Podolia, indicating a more intensive erosion of the north-eastern part of the middle Dniester river catchment, which was connected with a neotectonic uplift of the Podolian Platform.

In the boggy gleyed and banded flood-lacustrine deposits (layers l_{1-2}) overlying the Luck soil, mineral association is quite different. The content of heavy fraction is greater. Quantities of opaque minerals and concretions are small, when amounts of micas and transparent minerals considerably increase. Among the latter ones, garnet together with zircon and rutile prevail. Amphiboles and biotite occur in small quantities. Extreme values of the calculated indices are the following: O/(S+N) = 0.3–1.7 and C/(G+A) = 0.2–0.89. Such heavy minerals assemblage reflects a change in source material. Accumulated deposits were supplied with material coming from the redeposited and weathered rocks of the Carpathians and Carpathian Foreland. It seems that the high content of garnets results from enrichment of deposits with this component in a flowing water environment. The high content of micas points to slowly flowing water, probably of braided river.

In the lower part of the pleniglacial complex of the Odranian/Dnieperian loess (layers j_1–k_3) there was a further increase of heavy minerals content in the fraction 0.1–0.06 mm. Garnet is dominant among the transparent minerals. Quantities of medium and non-resistant minerals are rather high. The amount of micas varies. The values of the calculated indices (O/(S+N) = 0.15–0.67; C/(G+A) = 0.06–0.38) are somewhat different from those found in the underlying deposits. It seems that the source material for these loesses was blown from the drying flood-lacustrine sediments occurring in the vicinity, which were significantly enriched with components coming from the Carpathian materials deposited at the bottom of the Dniester river valley. The loess accumulation occurred in various aerodynamic conditions. Changing content of heavy fraction and variable content of micas indicate that the deposited silt material could be periodically blown to a short distance.

In the higher part of the pleniglacial complex of the Odranian/Dnieperian loess (layers h–i_2) heavy minerals assemblage is quite different from that found in the layers j_1–k_3. The weight of the heavy fraction is distinctly smaller. Zircon and rutile are the main components of the transparent minerals group, and garnets occur also in a considerable amount. The content of medium and non-resistant minerals (especially amphiboles) remains increasing. It is reflected in the values of mineral indices: O/(S+N) = 1.15–3.74, and C/(G+A) = 0.92–5.05. These results indicate that the source material was more enriched with components coming from redeposited weathered material of the Podolian rocks mixed with weathered flysch rocks of the Carpathians. It seems that floodwaters with weak flow occurred in the loess alimentation areas, so that the sediments deposited in these areas were not enriched with garnets. When drying, these deposits were blown onto the higher situated sites. Loess was accumulated under a stable wind strenght, which is evidenced by a decreased content of micas, and with participation of washing. These processes favoured transport of material from the immediate vicinity, so in this loess the glauconite content increased up to 5%.

The effect of chemical weathering on the heavy minerals assemblage is distinctly visible in both soils of the Korshov pedocomplex (layers f_1–g_2). The weight content of heavy fraction is here rather low. The amount of micas is smaller in the lower soil than in the upper one. Minerals more resistant to chemical weathering predominate among the transparent minerals group, forming the following succession: zircon>rutile>epidotes>garnets. An interruption in the pedogenetic development can be deduced from the occurrence of a thin loess stratum (f_5) separating two soils. The content of heavy fraction is somewhat higher in this loess. It is clearly a result of a sedimentation hiatus connected with blowing out of components liable to wind action from a ground surface. Succession of the main transparent minerals in this loess is as follows: zircon>garnets>rutile>epidotes. Values of the mineral indices are lower than in both soils: O/(S+N) = 0.85, and C/(G+A) = 1.00.

The upper bed of the Middle Pleistocene loesses, *i.e.* the Moscovian/Wartanian loess (layers e_{1-2}) is topped with the Horokhov soil (layers d_{1-3}). A considerably higher content of carbonate-ferruginous concretions was found in one sample of these loesses. Garnets predominate over zircon in the lower part of this bed, while in the upper part zircon prevails, though the content of garnets also increases. The content of non-resistant minerals decreases upwards reaching minimum under the paleosol. Quantities of micas are very variable within the whole soil-loess complex. Qualitative composition of the heavy minerals assemblage suggests that its source material was similar to that in the upper part of the pleniglacial complex of the Dnieperian/Odranian loess. Initially a solifluction took part in the loess accumulation; it is evidenced by the deposit structure, and also by a considerable content of glauconite (7%), which was supplied directly from the local rocks. Both dynamics and differentiation of sedimentation processes probably increased towards the top. The influence of the Eemian pedogenesis resulted in an increased maturity of the heavy minerals assemblage. The content of opaque minerals is high, especially in the Bt horizon (over 60%). Greater amounts of garnets and ferruginous concretions occur in the A horizon, which can be probably connected with wetter and colder conditions of the interglacial late phases.

The content of heavy fraction slighty increases in the Upper Pleistocene loesses (Valdaian/Vistulian loess; layers a_1–c_2), containing the interstadial Dubno soil and the interphase Rovno soil. The content of micas decreases. Among the transparent minerals garnet predominates, together with zircon and rutile. The content of minerals medium and non-resistant to weathering is similar as in the underlying Moscovian/Wartanian loess. The values of the mineral indices considerably decrease: O/(S+N) = 0.41–0.85, and C/(G+A) = 0.27–0.43. It seems that the main part of source material of this loess resulted from the denudation of the older loess deposits and that the products of this process were blown about. It can be also supposed that this loess was formed by stronger winds.

FINAL REMARKS

The Halič profile is situated in a transition zone between the Carpathian Foreland and the Volhynia–Podolia Upland, on the Pleistocene high terrace of the Dniester river; it is represented by alluvial and subaerial deposits with the total thickness of about 50 m. This profile is of great stratigraphic importance because in its loessy part three interglacial warmings are recorded (represented by the complexes of forest soils), and also three complete and stratigraphically differentiated loess units (*i.e.* with interglacial soils at the bottom and at the top) of the Valdaian, Moscovian and Dnieperian glacial cycles. Therefore, we have a well preserved record of events from the last 300 ka, with prospects of finding evidence of one more, older glacial cycle.

On the river terraces near the Halič profile a few more sites were found, where the other Pleistocene deposits, very well developed and stratigraphically differentiated, are exposed. The following ones are most important: the Marynopil' profile (unpublished data) with an extremely thick (up to 10 m) upper bed of the Middle Pleistocene loesses, *i.e.* the Moscovian/Wartanian loess, the Kolodijv profile (unpublished data) with an unique exposure of the Vistulian and Eemian deposits over 20 m thick, the Zahvizdija profile (Bogutskiy *et al.* 1999) with the Eopleistocene beds (Fig. 1). Thus, the Halič profile is an important part of the summary profile of the Pleistocene deposits about 100 m thick, which is unique in the tectonically elevated region, and representative for the Pleistocene stratigraphy and paleogeography in the above mentioned transition zone between the Carpathian Foreland and Volhynia–Podolia Upland. Owing to these features the Halič profile is also very important for the arrangement of a sequence of terraces and deposits in the Dniester river valley.

In the light of the heavy minerals analysis, a paleogeographical problem arose, concerning the origin and transport conditions of source material for the Halič loesses. Fluvio-periglacial alluvia deposited in the Dniester river valley were the main source of loessy silt. They came from the Carpathian flysch rocks, Tertiary deposits of the Carpathian Foreland and Cretaceous–Tertiary rocks of the Podolia. After having dried, these aqueous silty deposits were blown from the valley bottom onto the neighbouring slopes. Small vertical differentiation of the qualitative-quantitative composition of heavy minerals assemblage seems to indicate a primarily separate character of the silt building the particular stratigraphic horizons, which can result from a periodic predominance of either the Podolia or the Carpathians as the alimentation area for the Dniester river alluvia. These features seem to indicate an autochthonous nature of the Halič loesses.

The question should be considered whether the separate features mentioned above, could be connected *e.g.* with different directions of loess-forming winds and a long distance eolian transport. However, we suppose that these differences would be then more distinct and qualitative. This question is worth of further studies on the basis of other sites with loess deposits.

Loesses of the Polish part of the Carpathian Foreland (and Carpathian Foothills) are also of a very local nature in the topographic scale, as it was indicated by the results of the studies on their accumulation conditions in the San river valley. On the basis of mineralogic and granulometric data it was revealed that they were formed as a result of a very short distance eolian transport, and fluvio-periglacial deposits were their main source material (Łanczont 1993, 1994, 1997, Łanczont, Wilgat 1994).

In the Halič profile some layers are distinguishable by the higher contents of opaque minerals and resistant minerals from the group of transparent ones. The values of the NP index (diagram MCI in Fig. 4) and the indices of maturity of the heavy minerals assemblage (O/(S+N) and C/(G+A) – diagram MCII in Fig. 4) best reflect the changes found in the profile. Two types of peaks occur on their curves:

a) these corresponding to illuvial horizons of interglacial soils, together with the Holocene soil, indicate considerable changes of loess features under the influence of pedogenesis;

b) these corresponding to erosion-denudation surfaces indicate longer breaks in sedimentation and surface stabilization, resulting in greater intensity of weathering processes in periglacial conditions.

From the stratigraphic and paleogeographic point of view the following loess-soil units distinguished in the Halič profile are worth of notice and further detailed studies:

1. *Luck paleosol* occurring in the bottom of loess cover.

It can be correlated with the upper soil from the tripartite pedocomplex Zavadovka (in the Ukrainian scheme by Gozhik *et al.* 1995), which was dated at about 330 ka BP in the Volhynia loess profiles (Shelkoplyas *et al.* 1985). It corresponds to the interglacial soil from the Zbójno (= Dömnitz; ^{18}O stage 9) Warm Stage, which splits the Odranian and Liwiecian (= pre-Saalian) loesses in the Polish schemes. In the Halič profile this soil was dated at 300 ka BP. In Poland, corresponding soil (GJ3a) was found only in several exposures (Nieledew, Orzechowce, Zadębce, Załubińcze), and its age was estimated at 303–339 ka BP (Maruszczak 1994).

2. *Dnieperian/Odranian loess cover* is here extremely thick, whereas in other profiles of the Podolia, Volhynia and Carpathian Foreland it only sporadically exceeds 4–5 m (*e.g.* in the Prałkowce profile, where the Odranian bed is 10 m thick, see Łanczont 1994). In SE Poland the complete sequences typical for the Odranian cycle were found only in several exposures (among others in Nieledew, Odonów, Zadębce – Maruszczak 1991). In Halič this loess is stratigraphically differentiated and its structure is complex. Its lithological heterogeneity is visible both in vertical and horizontal sections. We can find here plication deformations, intraloess erosion surfaces with systems of fissures, gley and solifluction horizons, layers with large carbonate concretions and suchlike.

3. *Korshov pedocomplex.* We consider the Halič profile to be a stratotype for the Korshov pedocomplex, which contains two polygenic soils typical for the interglacial conditions. Therefore, we have here signs of temperate climate (two forest soils), with a phase of more severe climatic conditions (layer of mineral deposits separating these soils, probably accumulated within the reach of seasonal frost – that is why solifluction deformations are visible in this layer). The development of the Korshov pedocomplex is very similar to that of the last but one interglacial, which was described by Ložek (1973) as the mid-European PK IV. Such a sequence of events corresponds well to the global rhythms recorded in the oxygen isotope curve of marine sediments (Martinson *et al.* 1987) and the curve of dust content in the Antarctic ice core (Petit *et al.* 1999). It seems that the soil from the first phase of the Korshov pedogenesis corresponds to the marine substage 7.5, the soil from the second phase – to the warm substage 7.3, and the deposits in between – to substage 7.4 (climate cooling). The development of pedogenesis during the last but one glacial in the Ukraine was dated at 210–240 ka BP (Gozhik *et al.* 1995) or at 210–230 ka BP (Shelkoplyas *et al.* 1985). Unfortunately, the TL ages of the discussed pedocomplex in Halič obtained in the Kiev laboratory do not allow us to determine its chronostratigraphic situation because they seem to be underestimated and correspond to anaglacial phases of the last but one glacial.

The soil from the second phase of the Korshov pedogenesis corresponds to the Lublinian (= Inter-Saalian) interglacial soil occurring in Polish loesses, which separates loesses of the Wartanian/Saalian II and Odranian/Saalian I. This soil (GJ2 in the stratigraphic scheme of Polish loesses by Maruszczak 1994) was dated at 210–230 or 216 ka BP, and the overlying turf horizon (Gi) was correlated with the oxygen isotope substage 7.1 (194 ka BP) and with the interstadial of the early Wartanian (Maruszczak 1991, 1994). At the top of the Korshov pedocomplex such turf horizon does not occur.

Maruszczak (1993) considers the soil occurring in some profiles (Nieledew, Odonów) below the Lublinian pedocomplex (denoted by GJ2a in this situation) to be interstadial (interpleniglacial) soil. It is denoted by a complex symbol Gi?GJ2b/LSd, and correlated with the interval 260–240 ka BP.

4. *Two Vistulian paleosols – Dubno and Rovno* are preserved in the poorly developed Vistulian loesses. The Rovno interphase soil occurs within the Upper Plenivistulian loesses and contains a very well developed cultural layer with flint artifacts and rich fauna set representing the traces of a hunters' camp from the Upper Palaeolithic. According to Maruszczak (1991) the Rovno soil was correlated with the stratigraphic situation of a soil denoted by (Gi)/LMs in the scheme of Polish loesses, which was developed on the loess from the Vistulian interpleniglacial. The results of our studies do not confirm this opinion.

In conclusion we can note that the Halič loesses largely correspond with loess sequences developed in warm-dry areas of Central Europe: Lower Austria and south Moravia, inner Bohemia, Thuringia, and northern borderland of the Pannonian Basin (Fink, Kukla 1977, Ložek 1977, Mojski 1993). The Halič loesses were probably formed in somewhat moister conditions. This problem needs further studies, especially analysis of molluscs, which commonly occur in the loesses of the examined area.

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