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Stratigraphy and Paleogeography of Loess on the Przemyśl Foothills (SE Poland)

Stratygrafia i paleogeografia lessu na Pogórzu Przemyskim (Polska SE)

Abstract. On the basis of analysis of lithological features, paleosols, layer sequences and TL and ^{14}C datings three main stratigraphic units of loess in the Przemyśl section of the Carpathian Foothills have been distinguished. They represent the period of Middle Polish glaciation (= Saalian s.l. = Odranian + Wartanian) as well as North Polish glaciation (Vistulian). The presented version of the regional stratigraphy of the Przemyśl loess has been correlated with relative schemes worked out by H. Maruszczak (1991b) for southern Poland. Characteristics of the deposition environment has been worked out for some loess horizons on the basis of paleomalacological and paleobotanical data. Facial differentiation of the studied loesses has been estimated.

Key words: loess facies, loesses and paleosols, Pleistocene, Carpathian Foothills.

INTRODUCTION

In the east of the Carpathian Foothills, in Przemyśl environs, vast areas are occupied by loesses formed as silts, and silty-clayey or silty-sandy deposits. They were first mentioned on the turn of the 19th century (A.M. Łomnicki 1900, W. Szajnocha 1901). Loess distribution in the San valley was presented by M. Klimaszewski (1936), and A. Malicki (1950) characterised these formations as the "slope loesss" formed without any contribution of eolian processes. In the few publications from the 70's and the 80's they were defined as loess-like loams and referred to Plenivistulian (K. Pękala 1973, S. Gucik, A. Wójcik 1982). The present author took up research work on the loess from the Przemyśl surroundings at the end of the 80-ties. The study entitled "Main sections of loesses in Poland" (1991) and some other studies (M. Krysowska-Iwaszkiewicz, M. Łanczont 1993, 1994a,b, M. Łanczont, M. Wilgat 1994, S.W. Alexandrowicz, M. Łanczont 1995) give descriptions together with detailed results of the author's research work on loess profiles the location of which is presented in Fig. 1. The present study summarises the so-far conducted studies on lithology, stratigraphy and paleogeography of loesses from the Przemyśl region.

The stratigraphy of loesses occurring in the presented profiles has been based mainly on the paleopedological and geological criteria. Two interglacial soils of different ages together with interstadial soils that were evaluated as important from the stratigraphic point of view were found in the exposures. The soils of the higher rank can be used for the correlation of loesses with the three last glacial cycles, i.e. Vistulian (= Weichselian), Wartanian (= Saalian II), and Odranian (= Saalian I). Like in the stratigraphic scheme of Polish loesses last glaciation is represented by younger loesses (LM), and the two older cycles by upper older loesses (LSg) and middle, lower and the lowest older ones (LSs+d+n). The names and letter symbols used here for the primary and secondary units follow H.Maruszczak denotations (1991b). The chronostratigraphy of the units was specified on the basis of TL and ^{14}C datings that are precise only for the last cycle.

An attempt to reconstruct the conditions of sedimentation environment for loessial silts in various geomorphological situations has been undertaken on the basis of variability of lithological features, chemical and mineral composition as well as sedimentation structures in the studied exposures. Quite a considerable number of malacofauna remnants found in some profiles and determined by S.W. Alexandrowicz supplied some significant pieces of information on the conditions of accumulation. Pollen analysis of several samples from some sites has been conducted by Dr. K. Bałaga, and A.I. Pidek, M.Sc. (Table 3).

LOESS DISTRIBUTION

The Przemyśl loess distribution map shows mainly the areas of younger layers, i.e. the layers that were accumulated in the last glaciation cycle with the dominating silt layers from the main accumulation phase in the upper Plenivistulian. Older loesses are usually hidden underneath; they appear less frequently and their range is smaller.

Loess is unevenly distributed (Fig. 1). Some bigger patches can be found in the border area of the Carpathians; only the areas at the bottom of the valleys and at elevation are without loess. In the interior part of the Foothills there are loess islands. They can be found mainly in the San river valley that is 170 m deep and constitutes a morphological axis of the studied

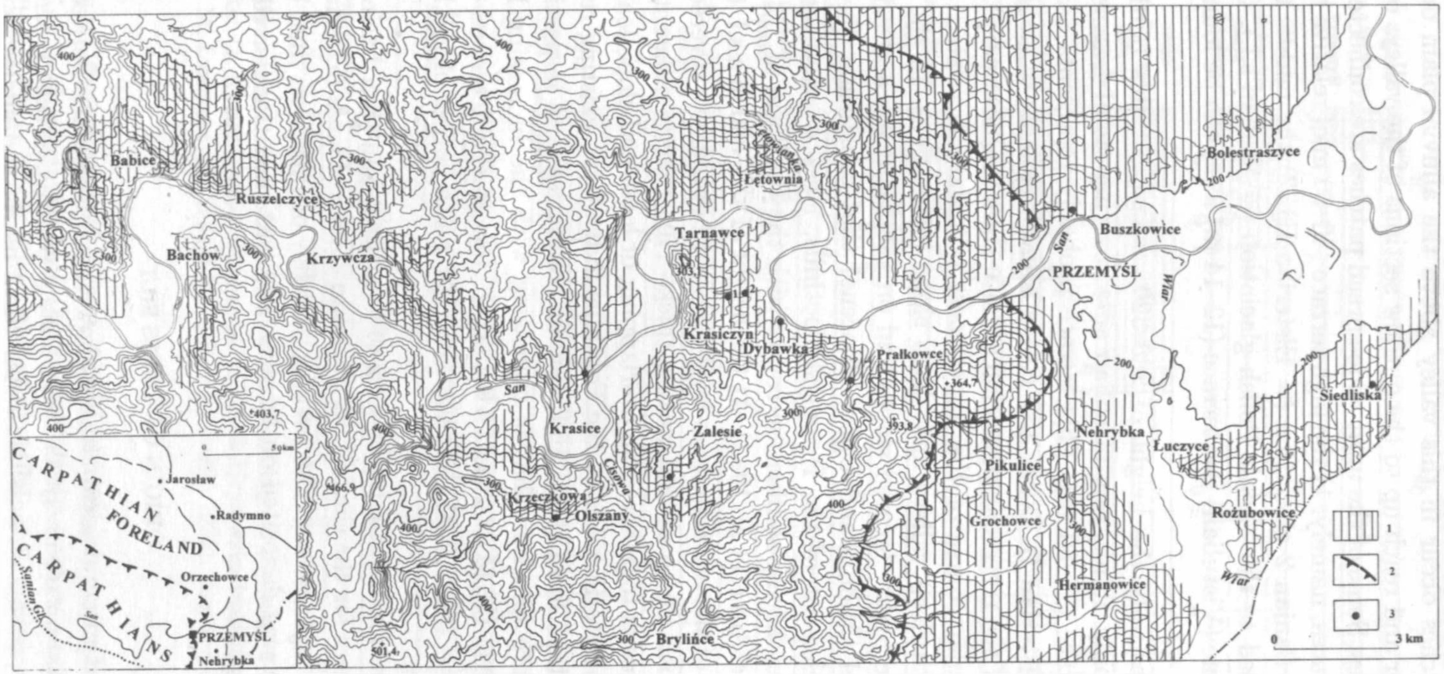


Fig. 1. Distribution of loesses in the Przemyśl environs (in the foreland of the Carpathians according to the General Geological Map of Poland 1:300 000, and in the Carpathian part of the studied area on the basis of author's own materials; 1 — extent of loesses; 2 — margin of the Carpathians; 3 — situation of the profiles

area. Loess patches occur in this valley above the alluvial plain on both sides of the river and reach up to the outflow sections of the valleys of some bigger tributaries. Some of the most wide-spread patches are connected with Pleistocene terraces, namely: 1) the high terrace (40–60 m of relative height) correlated with Sanian 2 glaciation (= Elsterian II), 2) the middle terrace (20–35 m) related to the Middle Polish glaciation (= Saalian s.l.). On the young Pleistocene (Vistulian) low terrace (12–14 m) loess can be found only at places.

Loess reaches only the height of 280–320 m a.s.l. At this border height there are only thin layers of eolian silts covering small fragments of the highest terrace (75–80 m). This terrace probably represents Sanian 1 glaciation (= Elsterian I). Loess also covers some fragments of slopes and top flattening of the river-side planation surface (Lower Quaternary). Wayward and irregular course of the upper loess boundary is related to the varied relief with deep valleys and sharp slope inclinations. In the direction towards the higher located slopes and on the flattening and ridges of the foothill level (Middle and Upper Pliocene) that constitutes the main morphological element of the Przemyśl Foothills, loess is substituted by debris-loamy, weathering-solifluction covers with the thickness of 2–4 m up to 8 m (M. Łanczont et al. 1983). At the height of 480–500 m a.s.l. the highest elevations of the intramontane level (Lower Pliocene) are covered with weathering deposit up to several meters thick. This genetic differentiation of the cover deposits together with overlapping of loess and slope loams on the higher hipsometeric levels of the Foothills indicate an existing relation between the vertical loess range and climatic conditions, and in particular, the amount of precipitation that is increasing with the increasing height above the sea level (H. Maruszczak 1991a). The so characterised upper border of the loess range is at the same time the south border of the Polish loess extent.

Loess distribution mainly in the area of the direct San river basin is an important premises for the thesis that the main source of loess material had been located at the bottom of the periglacial valley of this river; dust blown away from there was deposited on terraces and was then transferred onto the neighbouring hills.

ORIGIN OF LOESS SILT

The results of mineralogical studies show the resemblance between losses and local complexes of flysch rocks among which Cretaceous and Paleogene *Inoceramus* sandstone-shale beds, silica marls and shales are pre-

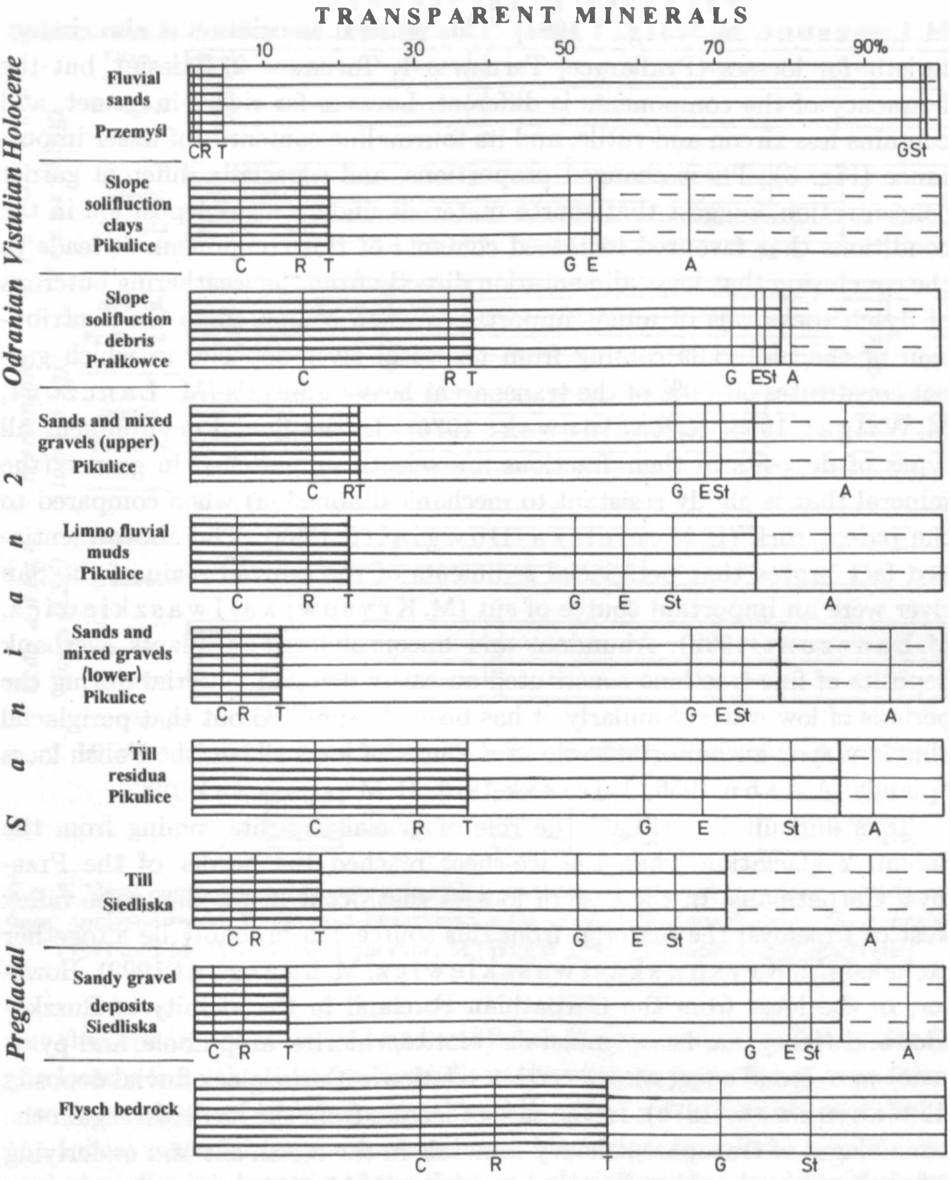


Fig. 2. Mean composition of heavy minerals assemblage in deposits of the Przemyśl environs (after G. Kociszewska-Musiał et al. 1972, M. Krysowska-Iwaszkiewicz, M. Łanczont 1992, M. Łanczont, M. Wilgat 1994, R. Racinowski 1976). Explanations as in Fig. 3

dominant. Association of zircon, rutile, tourmaline and garnet (C + R > T + Gr) is characteristic of the heavy transparent minerals of the Przemyśl Flysch (Fig. 2) (S. Geroch et al. 1979, S. Wdowiarz et al. 1974,

M. Łanczont, M. Wilgat 1994). This mineral association is also characteristic for loesses (Prałkowce, Tarnawce 1, Tarnawce 2, Zalesie), but the frequency of the components is different. Loess is far richer in garnet, and contains less zircon and rutile, and its tourmaline content is of lesser importance (Fig. 3). These changed proportions, and especially different garnet concentration, suggest that source materials underwent redeposition in the conditions that favoured increased contents of this component. It leads to the conclusion that loess alimentation directly from the weathering outcrops of flysch rocks was of minor importance when compared to the contribution of the materials coming from the local river deposits in which garnet constitutes 50–80% of the transparent heavy minerals (M. Łanczont, M. Wilgat 1995, R. Racinowski 1976). In the fluvial environment all types of deposits in their fractions are selectively enriched in garnet (the mineral that is highly resistant to mechanical abrasion) when compared to the parent rock (E. Mycielska-Dowgiałło 1992). The above mentioned fact proves that periglacial sediments of the alluvial plain of the San river were an important source of silt (M. Krysowska-Iwaszkiewicz, M. Łanczont 1992). Abundant and unconsolidated by plants overbank deposits of fine fractions constituted an easily deflated material during the periods of low water. Similarly, it has been also pointed out that periglacial alluvia played an important role as a source of loess silt on the Polish loess uplands (A. Jahn 1956, J. Jersak 1973, H. Maruszczak 1985).

It is difficult to evaluate the role of glacial deposits coming from the Sanian 2 glaciation when the ice-sheet reached the border of the Przemyśl Carpathians. In the case of loesses that occur in the San river valley west of Przemyśl the material from this source can probably be altogether excluded (M. Krysowska-Iwaszkiewicz, M. Łanczont 1992). However, in the loess from the Carpathian Foreland in the vicinity of Buszkowice and Nehrybka, heavy minerals (biotite, chlorite, amphibole, and pyroxene) were found suggesting a certain relation with the glaciofluvial deposits (R. Racinowski 1976). In the case of loesses from the Siedliska region the assemblages of transparent heavy minerals in the eolian silt and underlying till analysed in the same fractions (analyses by M. Wilgat) are significantly different both from the qualitative and quantitative points of view (Figs 2 and 3).

Relations between heavy minerals in loesses and source deposits from the closest vicinity confirm the decisive role played by low transportation of eolian dust to close distances. T. Gerlach (T. Gerlach et al. 1991) wrote also on the local origin of the loess material in the region of Brzozów in the Carpathian Dynów Foothills; basing on the mineralogical analyses he found

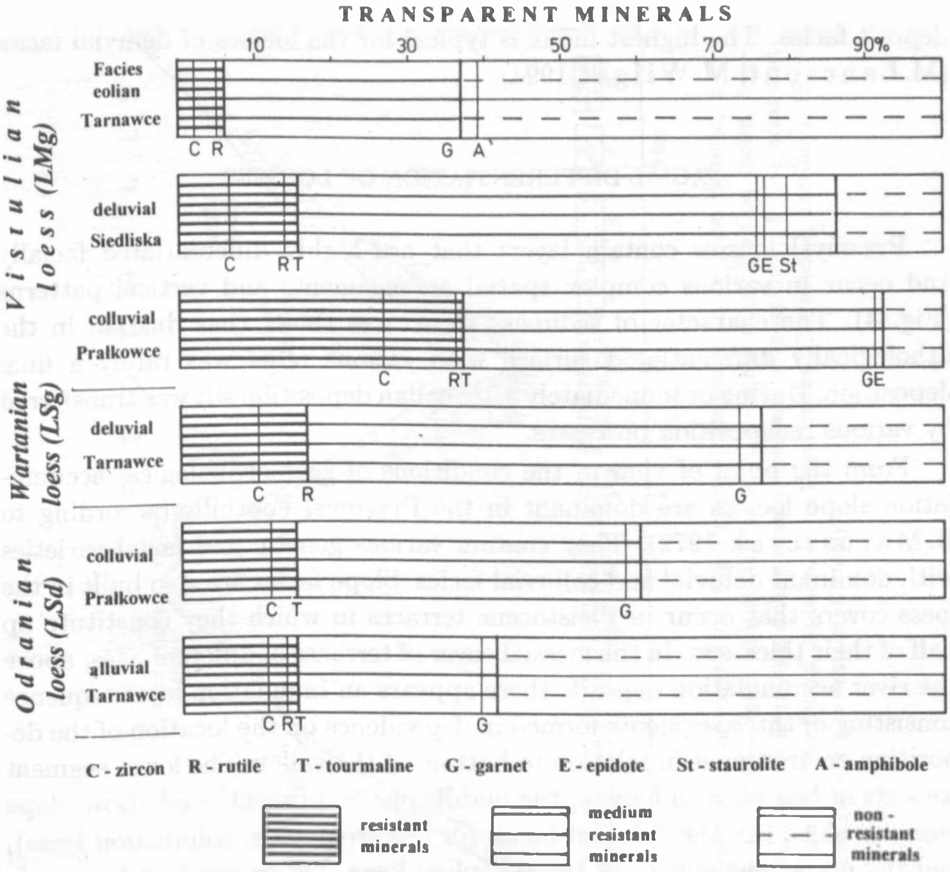


Fig. 3. Mean composition of heavy minerals assemblage in selected loess facies of different ages, analysed by M. Krysowska-Iwaszkiewicz (M. Krysowska-Iwaszkiewicz, M. Łanczont 1992) and M. Wilgat (M. Łanczont, M. Wilgat 1994 and unpublished materials)

out that the initial material was local flysch Krosno beds. Similar results for the loesses from the Rożnów Foothills in the western part of the Carpathians have been obtained by W. Zuchiewicz (S.W. Alexandrowicz et al. 1991); the initial material for the loesses from this region were local Krosno beds and glaciofluvial deposits of the Sanian 2 glaciation that occur in the close vicinity.

The index of maturity showing the relation of the very resistant minerals to the others has been estimated for the transparent heavy minerals in the loesses from the Przemyśl region. The index (O/S+N) shows the relation between the degree of the source material selection and the intensity of the various processes forming deposits. The index ranged from 0.6 to 2.0 for unweathered loesses; differentiation of its value depends on the deposit facies. The highest index is typical for the loesses of deluvial facies (M. Łanczont, M. Wilgat 1994).

FACIAL DIFFERENTIATION OF LOESSES

Przemyśl loesses contain layers that are highly differentiated facially and occur in various complex spatial arrangements and vertical patterns (Fig. 4). The character of sediment structures shows that dustfall in the lithologically differentiated surface with various relief was rarely a final deposition. During or immediately after eolian deposition silt was transferred by various redeposition processes.

From the point of view of the conditions of geomorphological accumulation slope loesses are dominant in the Przemyśl Foothills (according to H. Maruszczak 1972). They contain various genetic and facial varieties with dominant deluvial and colluvial facies. Slope facies are also built in the loess covers that occur in Pleistocene terraces in which they constitute up half of their thickness. In the loessial cover of terraces of different ages, above the river accumulation deposits there appears an innudation layer sequence consisting of three segments formed in dependence on the location of the deposition environment in relation to bottom of the valley. The lower segment consists of bog-alluvial loesses, the middle one — of mentioned above slope loess developed in the deluvial facies (or less frequently, solifluction loess), and the upper segment — of typical eolian loess (i.e. proper loess).

There are the following facies of loess deposits in the studied area (Fig. 4): alluvial-bog, deluvial, colluvial, colluvial-solifluction, and eolian.

Bog-alluvial loesses were formed in the subaqueous conditions, on the flattening of river terraces on the alluvial plain of that era. Depending on the vertical range of flood sedimentation took place either in the boggy or aqueous environment (suspension deposition). This loess facies is best represented by LMn+d layers in Buszkowice. Horizontal bedding and continuous horizontal alternating lamination is dominating in it. Visibility of individual lamine is enhanced by changes in the grain-size and colours. At times it is a fining-up sequence that indicates a quiet subaqueous deposition. Various deformational structures — in the bedded loesses involutions and load structures, and in the laminated loesses convolutions — confirm occurrence of reversed density stratification. The direct reason for convolution deformations in the laminated loesses could be ground ice thawing; pseudomorphs of the structures of segregation ground ice formed as a result of slow freezing of water saturated ground can be found in various layers (M. Łanczont

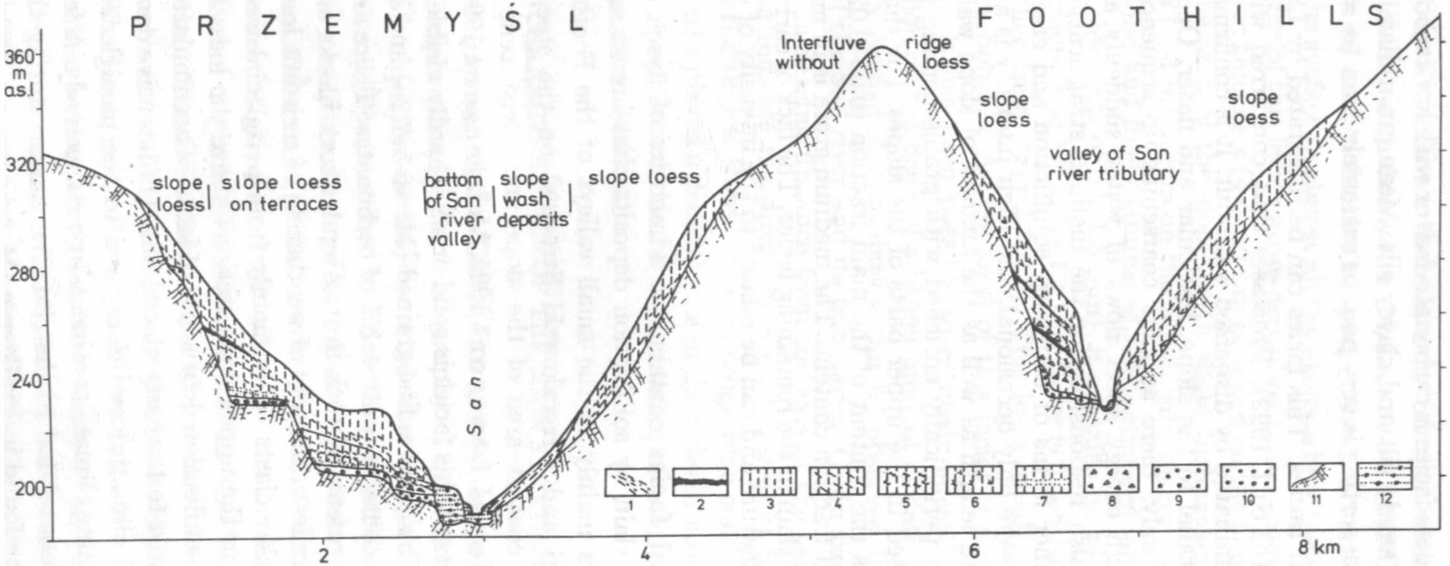


Fig. 4. Summary cross-section showing facial differentiation of loesses on the Przemyśl Foothills; 1 — loess deluvia, 2 — intraloess paleosols of interglacial rank, 3 — eolian loess, 4 — loess of deluvial facies, 5 — loess of solifluction facies, 6 — loess of colluvial facies, 7 — loess of alluvial-boggy facies, 8 — intraloess debris covers; bedrock of loess cover: 9 — glacial and glaciofluvial deposits of the Sanian 2 glaciation, 10 — Pleistocene fluvial deposits, 11 — flysch rocks (Cretaceous, Tertiary); 12 — Holocene alluvia in the bottom of valley

1994b). Alluvial-bog loess facies is carbonate-free or with low carbonate contents, and consists of sandy silt and clayey silt. Mean grain diameter (Mz) ranges from 5.7 to 7.1ø; sorting is very poor or extremely poor (σ_1=3.0–4.7).

Loess of deluvial facies. This facies can be illustrated by LSg profile in Tarnawce (M. Łanczont 1993). Processes that concurred with eolian accumulation were dominated by dispersed wash-out. It is confirmed by the lamination that is parallel to the slope, lenticular and flaser. Occasionally and at a small scale only, there appears coarsening-up sequence related to the episodes of high energy sheet flows of water suddenly appearing on slopes. They are also responsible for the inclined stratification of the delta type. Among other forms of transport solifluction and creeping can be enumerated. They were only occasional, and their intensity is a function of slope inclination and length as well as the amount of slope waters. The eolian component was periodically enriched with grains coming form the weathered rocks exposed in the upper parts of the slopes. For that reason in loesses of this facies the content of the main fraction (0.05–0.02 mm) is similar to the fine sand fraction content. The medium grain is in most cases thicker (Mz=4.8–5.2ø) than in the remaining facies. The lack of carbonates is probably a secondary feature and can be related to the intensity of wash-out processes.

Loess of colluvial facies contains an admixture of flysch rock debris and is often underlain by solifluction deposits that are loamy debris in character. It occurs mainly in the small valleys of the Foothills (the valleys of Prałkowiecki and Krzeczkowski Streams) on the steepest slopes as well as in the contact area of the slope and Pleistocene terraces (S.W. Alexandrowicz, M. Łanczont 1995, M. Łanczont 1994a). The structure of the deposits of this facies is solid or with hardly visible, discontinuous, thin lamine. This loess is fine-grained (Mz=6.5–7.2ø) and is poorly sorted (σ_1=2.8–3.9); it contains up to 4–8% of carbonates. There are single, randomly scattered fragments of rock in it. Angular rock blocks are 0.3 to 0.4 m big; their shape reflects the way of weathering of resistant local sandstones and marls. Thicker clasts came mainly from periglacial weathering debris cover occurring in the upper slope sections above the loess accumulation range. Layers of solifluction debris and of loess — accumulated in the glacial cycle — are related to the early glacial phase of intensive denudation in the cold and humid climatic conditions, and to the pleniglacial eolian processes during increasing climate continentality, respectively. A few generations of colluvial covers related to the climatic changes during the three last glacial cycles can be found in Prałkowce (M. Łanczont 1991, 1994a).

However, in Krzeczkowa there is only one generation from the Vistulian cycle (S.W. Alexandrowicz, M. Łanczont 1995).

Loess of eolian facies, i.e. proper loess, occurs in the youngest layers close to the surface in almost all the places where loess occurs. The thickness of the layers of this facies varies according to the geomorphological situation. The biggest thickness (4–8 m) can be found on the plain of the middle terrace and in the area of the slopes with slight inclination (up to 3°); a smaller thickness (2–3 m) occurs on the slopes with bigger inclination (5–10°). This loess is solid and finely laminated (discontinuous lamine, softly undulating with the thickness of 0.5–1.5 mm); it contains up to 40 or even 50% of the main fraction. The Mz index for this facies is 5.4–6.1ø; sorting is better than in the other facies (σ_1=2.2–2.4). This loess usually contains from 8–12 to 14% of carbonates. As the loess of this facies is easily accessible and well preserved, it has been possible to estimate spatial variation in grain-size distribution on the basis of a bigger amount of data (M. Łanczont 1995). Usually a change in granulation can be observed in the cross-sections of valleys of the San river and its tributaries. Grain size changes very quickly with the increasing distance from the axis of the valley and with altitude, which can indicate the direction of dust transport from the bottom of the valley to the slopes. However, local orographic conditions that modified air stream paths played a decisive role in the differentiation of the loess granular features. Special conditions for disturbance of transport dynamics occurred in the meander sections.

CHARACTERISTICS OF THE MAIN STRATIGRAPHIC UNITS

Older loesses of the Odranian glacial cycle. The Prałkowce profile is of key importance for the stratigraphy of these deposits (Fig. 5). Only in this profile older loesses are separated from the loesses of the next cycle by the forest soil representing Lublinian interglacial (= Saalian I/Saalian II). The lower loess boundary is determined by the debris solifluction cover from the earliest Odranian (M. Łanczont 1994a). It fills the bottom of a deep buried valley of the San river tributary cut in the glaciofluvial deposits of the Sanian 2 glaciation probably during the Mazovian interglacial (= Holsteinian). The Odranian loesses in Prałkowce together with intraloess debris covers are up to 10 m thick and can be divided into three stratigraphic units of the lower rank. However, in the Tarnawce 1 profile (Fig. 6) under the Odranian loesses there are river sands of the high terrace with some admixture of fine, weathered pebbles of Scandinavian rocks. In the top part these alluvia are changed by the interstadial pedogenesis. The Odranian

Table 1. Indices of grain-size distribution and selected features of loesses in the Przemyśl environs

	Strati-graphic units of loesses	Profiles	Indices of granular composition				Content in %%		
			Mz(ø)	σ_1	Sk_1	K_G	$CaCO_3$	Humus	Fe_2O_3
		Zalesie	5.41	2.65	0.39	1.71	9.08	0.11	1.89
		Tarnawce 1	6.08	2.42	0.39	1.44	9.37	0.21	2.61
V		Prałkowce	7.23	3.66	0.46	1.11	8.92	0.28	3.88
	LMg	Tarnawce 2	6.12	2.63	0.55	1.84	10.78	0.21	2.22
		Dybawka	5.38	2.33	0.44	1.78	12.22	0.20	1.27
I		Krasice	6.11	2.46	0.56	1.79	9.34	0.16	2.44
		Buszkowice	5.73	2.18	0.49	2.03	9.70	0.19	2.20
		Winna Góra	6.33	2.24	0.47	1.74	9.98	0.12	2.75
S		Siedliska	6.05	2.90	0.52	1.24	0.00	0.18	2.18
		Zalesie	5.25	2.62	0.40	1.58	9.46	0.17	1.57
		Tarnawce 1	6.26	2.71	0.38	1.32	0.00	0.14	3.22
T		Prałkowce	6.90	3.55	0.61	1.50	3.22	0.27	3.21
	LMs	Tarnawce 2	6.72	3.46	0.53	1.51	3.14	0.29	3.05
		Dybawka	5.46	2.37	0.46	1.76	12.20	0.17	2.50
U		Krzeczkowa	6.87	2.83	0.65	1.51	4.20	0.17	2.43
		Krasice	6.58	3.20	0.56	1.53	10.12	0.71	1.94
		Buszkowce	5.73	3.19	0.45	1.27	0.00	0.28	2.29
L		Zalesie	5.16	3.74	0.57	1.35	0.00	0.17	2.13
		Tarnawce 1	6.48	2.96	0.43	1.17	0.00	0.26	3.27
		Prałkowce	8.08	3.55	0.27	0.91	2.84	0.36	4.29
I	LMd	Tarnawce 2	6.31	4.23	0.55	1.24	0.00	0.37	1.83
		Dybawka	5.91	2.81	0.53	1.77	11.80	0.23	2.79
		Krzeczkowa	6.49	2.55	0.70	1.65	8.40	0.14	1.72
A		Krasice	5.18	3.20	0.49	1.79	4.29	0.18	2.80
		Buszkowice	5.59	3.23	0.54	1.94	0.00	0.21	2.34
		Tarnawce 1	6.11	3.19	0.45	1.46	0.00	0.30	2.60
N		Tarnawce 2	7.11	4.70	0.59	1.21	0.00	0.35	2.82
	LMn	Dybawka	6.78	4.20	0.53	1.18	0.00	0.21	2.64
		Krasice	6.15	4.30	0.63	1.37	0.00	0.20	2.80
		Buszkowice	5.74	3.06	0.49	1.32	0.00	0.20	3.14
WARTA		Tarnawce 1	4.78	2.44	0.38	1.48	0.00	0.07	1.90
-NIAN	LSg	Prałkowce	6.14	2.54	0.59	1.64	0.0-8.0	0.08	2.71
		Buszkowice	6.24	3.55	0.52	1.50	0.0-9.5	0.30	2.66
	LSs	Tarnawce 1	5.36	2.92	0.42	1.65	0.30	0.05	2.38
ODRA-		Prałkowce	6.24	3.74	0.20	1.20	7.67	0.17	2.94
NIAN	LSd	Tarnawce	6.63	4.20	0.49	1.12	0.75	0.07	2.57
		Prałkowce	7.32	3.91	0.46	0.00	0.0-5.8	0.24	2.27
	LSn	Prałkowce	6.93	4.42	0.66	1.47	0.00	0.15	4.79

glacial cycle in Tarnawce 1 is represented by loess-like loams 3.5 m thick, with erosion hiatuses in middle and upper layers that divide this complex into secondary units.

Older loesses have been divided into the lowest loess (LSn), lower loess (LSd) and middle loesses (LSs).

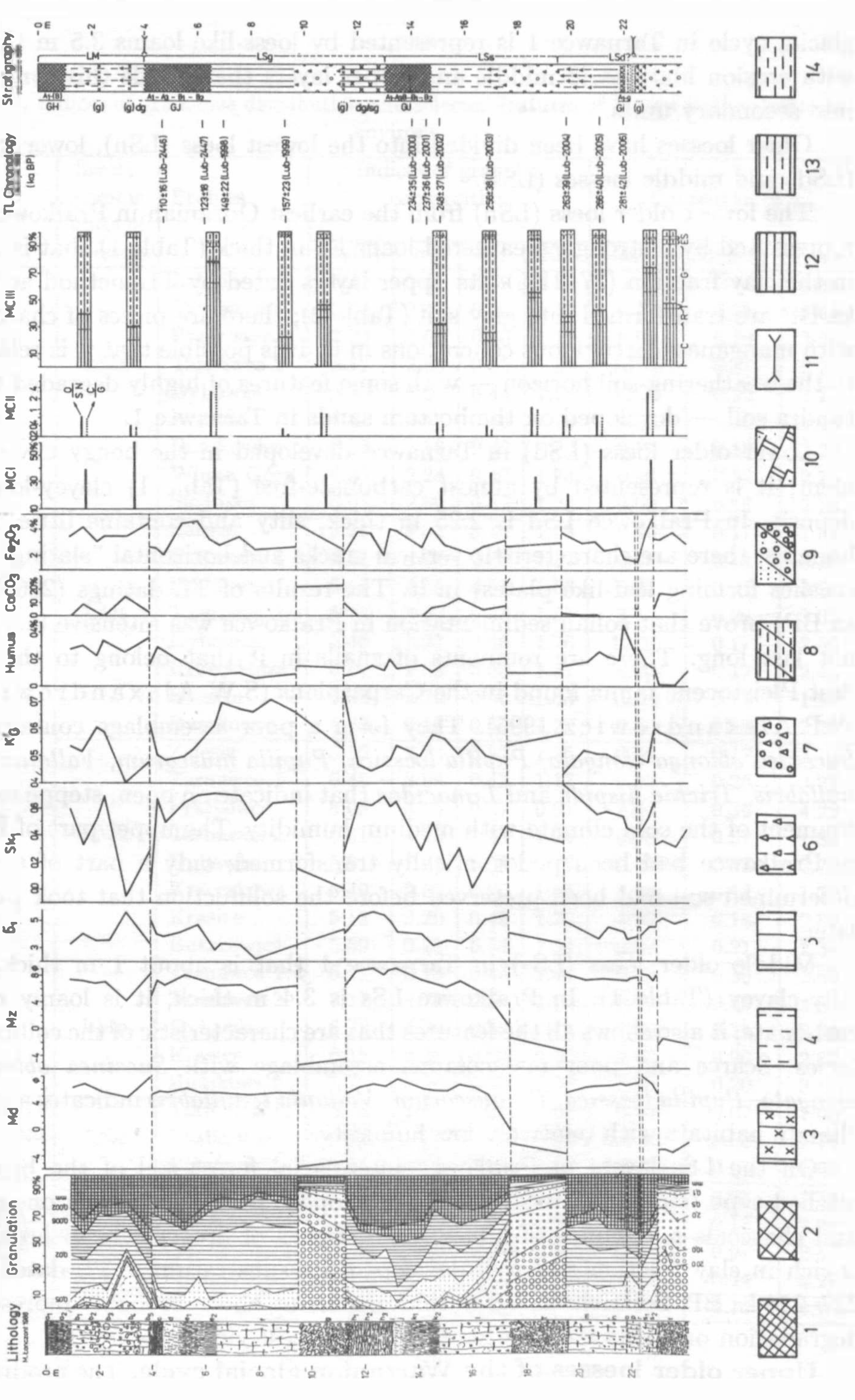
The lowest older loess (LSn) from the earliest Odranian in Prałkowce is represented by a strongly weathered loam 1.2 m thick (Table 1) that is rich in the clay fraction (27–31%). Its upper layers dated by TL method at 281 ka BP are transformed into gley soil (Table 2); there are pieces of charcoal with manganese-ferruginous concretions in it. It is possible that it is related to the weathering-soil horizon — with some features of highly degraded turf tundra soil — developed on the bottom sands in Tarnawce 1.

Lower older loess (LSd) in Tarnawce developed in the boggy environment; it is represented by almost carbonate-free (Table 1) clayey-loamy deposit. In Prałkowce LSd is 2.25 m thick, silty and contains little carbonates; there are characteristic vertical cracks and horizontal "slating" (it crushes forming leaf-like plates) in it. The results of TL datings (226–263 ka BP) prove that eolian sedimentation in Prałkowce was intensive but did not last long. There are remnants of snails in it that belong to the oldest Pleistocene fauna found in the Carpathians (S.W. Alexandrowicz, W.P. Alexandrowicz 1995). They form a poor assemblage containing *Succinea oblonga elongata, Pupilla loessica, Pupilla muscorum, Vallonia tenuilabris, Trichia hispida* and *Limacidae* that indicate an open, steppe environment of the cold climate with medium humidity. The upper part of LSd in Prałkowce had been pedogentically transformed; only a part of a undetermined soil had been preserved before the solifluction that took place later.

Middle older loess (LSs) in Tarnawce 1 that is about 1 m thick, is silty-clayey (Table 1). In Prałkowce LSs is 3.4 m thick, it is loamy and carbonate; it also shows all the features that are characteristic of the colluvial facies. Scarce and poor malacofauna assemblage with *Succinea oblonga elongata, Pupilla loessica, P. muscorum, Vallonia tenuilabris* indicates a cold climate habitats with relatively low humidity.

On the LSs layers in Prałkowce interglacial forest soil of the brown leached type (similar to lessivé soil?) developed. In the A horizon one can find charcoals and lumps of kilned loam (traces of fires?). The B horizon is rich in clay fraction and well developed; its substratum is TL dated at 237–234 ka BP. Soil deluvia 1.5 m thick occurring above probably represent degradation products transported from the closest vicinity.

Upper older loesses of the Wartanian glacial cycle. The products



Stratigraphy
TL Chronology (ka BP)
MCIII
MCII
MCI
Fe2O3
CaCO3
Humus
KG
Sk1
δ1
Mz
Md
Granulation
Lithology

of interglacial soil denudation in Prałkowce should be related to the earliest Wartanian period. They confirm intensive development of slope processes in the open landscape. Deluvia partially changed by the soil-forming processes (which is proved by obliterated bedding) are characterised by a high content of clay fraction and iron oxides (Table 2).

The upper older loess (LSg) appears in Tarnawce 1 (9.8 m), in Prałkowce (3 m), and in Buszkowice (3 m; see Fig. 7). Differentiation in the grain-size distribution of this loess in various deposition environments is illustrated by a diagram of relationship between graphic parameters of grain-size distribution (Mz and σ_1) (Fig. 8). It shows that the finest and the poorest sorted medium grain can be found in LSg in Buszkowice where accumulation took place in the former bottom of the San river valley. It allows for drawing a conclusion that the transport period was short and with weak dynamics. In the LSg layers of the slope facies in Tarnawce and Prałkowce grains are coarser and better sorted. There are some differences between these profiles connected with their facial development. The same age loess, also of the slope facies, occurring in Orzechowce in the Przemyśl Carpathian Foreland (H. Maruszczak 1985b), has grain of similar size but visibly better sorted (σ_1=1.5–2.5) which indicates a more stable conditions of transport.

Horizons of gleying or soil sediments occurring in the LSg layers allow to distinguish secondary stratigraphic units (see H. Maruszczak 1991b)

Fig. 5. Profile of loesses in Pralkowce. Heavy minerals analysed by M. Krysowska-Iwaszkiewicz (vide M. Krysowska-Iwaszkiewicz, M. Łanczont 1992); Granulation — grain-size distribution, Mz — mean grain diameter, σ_1 — standard deviation, Sk_1 — skewness index, K_G — kurtosis index, H — humus content, $CaCO_3$ — carbonate content, Fe_2O_3 — free iron oxides content. Diagrams of mineral composition of heavy fraction: MCI — opaque minerals content, MCII — composition indices of transparent minerals, MCIII — composition of transparent minerals assemblage. Letter symbols of transparent minerals: C — zircon, R — rutile, G — garnet, T — tourmaline, A — amphiboles, O — resistant minerals, S — medium resistant minerals, N — non-resistant minerals. Letter symbols of stratigraphic units of loesses: L — loess, M — younger, S — older, g — upper, s — middle, d — lower, n — lowest. Letter symbols of soil units: G — soils with well developed genetic horizons, H — Holocene soils, J — interglacial soils, i — interstadial soils, sg — soil sediments, dg — soil deluvia, (g) — symptoms of the development of pedogenesis. Graphic signatures: 1 — Holocene and interglacial soils, 2 — interstadial soils, 3 — soil sediments and poorly developed interstadial soils, 4 — non-weathered, carbonate loesses, 5 — weathered, carbonate-free loesses, 6 — loess-like colluvial deposits, 7 — debris covers, 8 — Pleistocene alluvial deposits: a) clays, b) muds, c) sandy muds, 9 — Pleistocene fluvial deposits: a) sands, b) sands with gravels, c) gravels, 10 — flysch bedrock, 11 — hiatuses (gaps) among stratigraphic units of section, 12 — resistant heavy minerals, 13 — medium resistant heavy minerals, 14 — non-resistant heavy minerals

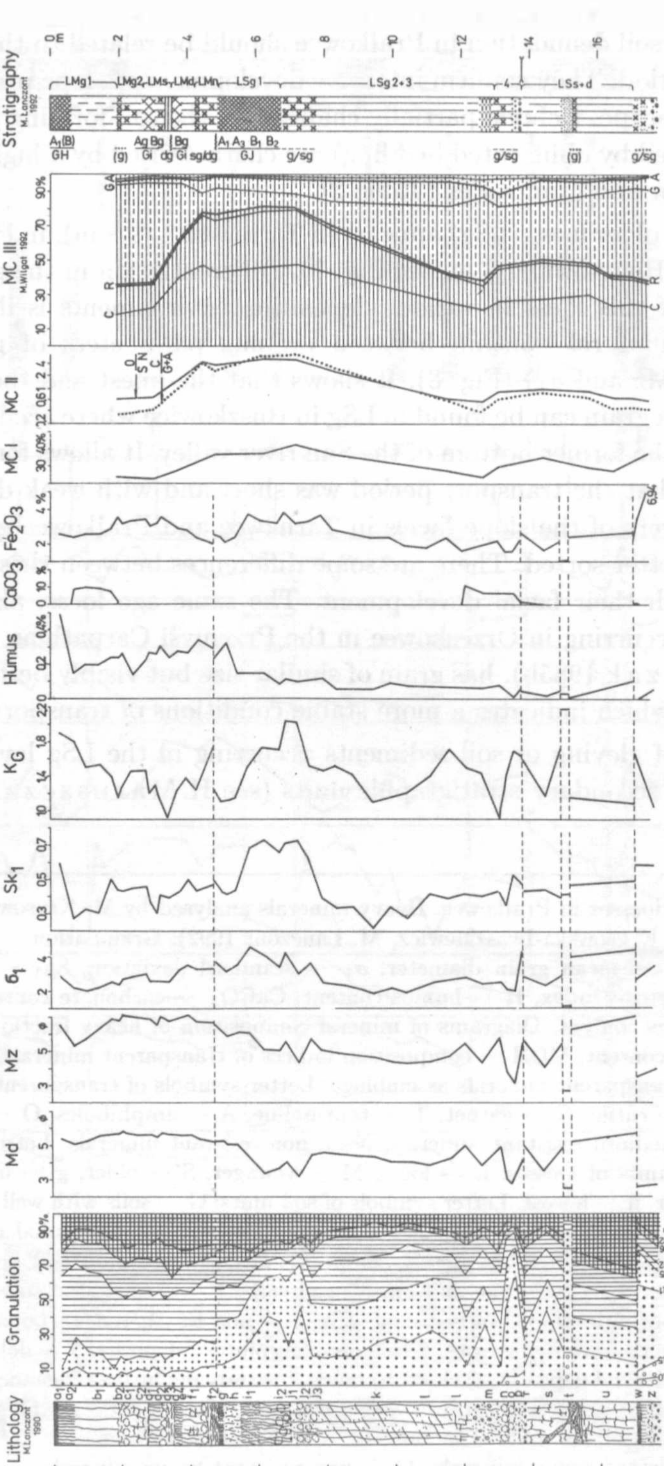


Fig. 6. Profile of loesses in Tarnawce 1; explanations as in Fig. 5. Heavy minerals analysed by M. Wilgat (vide M. Łanczont, M. Wilgat 1994)

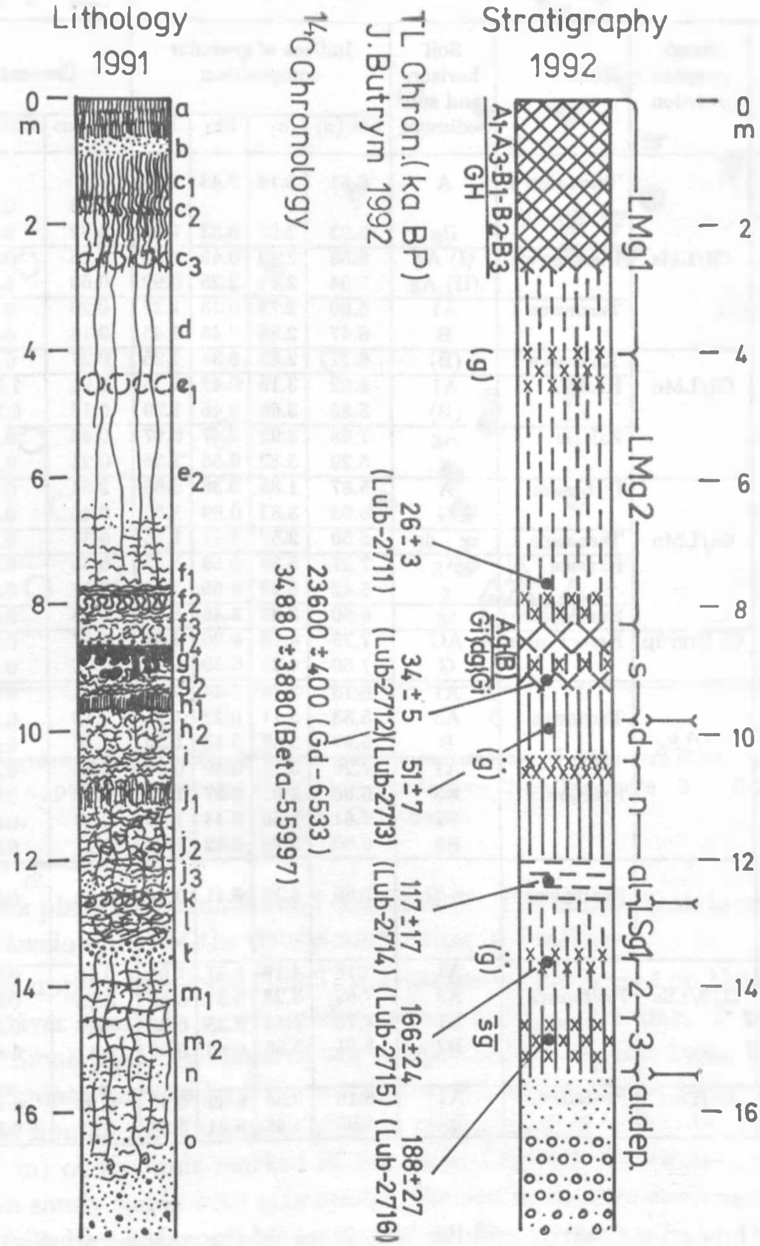


Fig. 7. Summary profile of loesses in Buszkowice; explanations as in Fig. 5

Table 2. Indices of grain-size distribution and selected features of intraloessy interglacial and interstadial paleosols in the Przemyśl environs

	Strati-graphic position	Site	Soil horizon and soil sediment	Indices of granular composition				Content in %%		
				Mz (ø)	σ_1	Sk_1	K_G	Humus	$CaCO_3$	Fe_2O_3
VISTULIAN	Gi/LMs	Tarnawce 2	A	6.61	3.16	0.43	1.15	2.31-0.08	0.0	2.47
			Bg	5.93	2.97	0.33	1.24	0.32	0.0	2.75
		Buszkowice	(I) Ag	6.58	2.49	0.49	1.04	0.86	0.0	2.93
			(II) Ag	7.04	2.42	0.25	0.92	0.60	0.0	1.97
		Tarnawce 1	A1	6.60	2.75	0.43	1.27	0.26	0.0	3.07
			B	6.47	2.86	0.45	1.45	0.14	0.0	3.22
	Gi/LMd	Tarnawce 1	(B)	6.17	2.59	0.34	1.25	0.27	0.0	3.10
		Krasice	A1	6.62	3.19	0.47	1.33	0.91	2.97	2.82
			(B)	5.83	3.66	0.46	1.29	0.14	0.13	2.54
		Zalesie	Ag	7.58	3.92	0.47	0.97	0.48	0.0	2.36
			g	5.29	3.82	0.55	1.36	0.21	0.0	2.11
	Gi/LMn	Dybawka	A	5.87	1.85	0.36	0.88	2.84	0.0	3.18
			G	6.93	3.83	0.69	1.63	0.40	0.0	3.33
		Tarnawce 1	sg - dg	6.50	2.57	0.41	1.16	0.31	0.0	3.47
		Krasice	Ag	7.27	5.86	0.69	1.45	0.35	0.0	1.85
			g	5.42	5.23	0.66	2.28	0.16	0.0	3.25
		Buszkowice	sg	6.50	3.43	0.48	1.13	0.33	0.0	2.97
	Gi Brørüp	Krzeczkowa	AG	7.73	4.13	0.20	0.89	1.17	0.0	2.29
			G	7.60	4.83	0.39	1.17	0.94	0.0	2.25
EEM INGL.	GJ/LSg	Tarnawce 1	A1	6.13	3.40	0.44	1.11	0.28	0.0	2.43
			A3	5.83	3.11	0.42	1.11	0.33	0.0	2.11
			B	5.97	3.88	0.63	1.53	0.15	0.0	3.5
		Pralkowce	A1	7.26	3.15	0.40	0.94	0.38	0.0	3.97
			A3	6.66	2.61	0.57	1.05	0.30	0.0	2.30
			B1	6.61	2.60	0.44	1.45	0.17	0.0	2.36
			B2	6.69	3.78	0.52	1.57	0.11	0.0	3.48
The earliest WARTANIAN		Pralkowce	sg-dg	7.56	4.18	0.41	0.94	0.13	0.0	3.39
LUBLIN INGL.	GJ2/LSs	Prałkowce	A1	8.18	4.19	0.51	1.00	0.16	0.0	3.65
			A3	7.62	3.28	0.34	0.88	0.15	0.0	3.36
			B1	7.73	3.43	0.35	0.88	0.16	0.0	3.57
			B2	8.21	5.98	0.63	0.92	0.11	0.0	3.43-3.75
ODRANIAN	Gi/LSn	Prałkowce	A1	8.16	3.86	0.42	0.96	0.28	0.0	1.50
			g	7.95	4.45	0.51	0.94	0.17	0.0	3.82

such as: the earliest, early, middle, late. None of the profiles studied by the present author contains all the units enumerated above at the same time. The earliest upper older loess (LSg4) distinguished in the profile in Tarnawce is sandy carbonate loam, 0.75 m thick. In the top it shows signs of the initial pedogenesis and pseudomorphs of cryogenic structures. Accumulation of

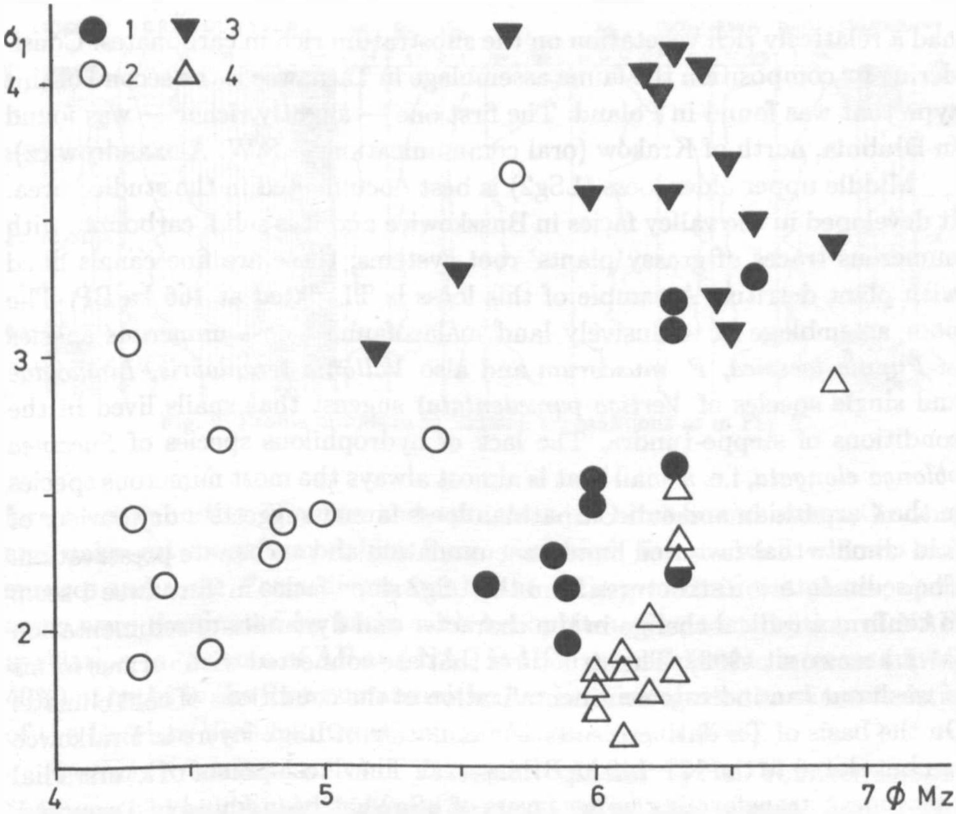


Fig. 8. Diagram of relationship between graphic parameters of grain-size distribution (Mz, σ_1) for the upper yonger loesses (LSg); 1 — Prałkowce, 2 — Tarnawce , 3 — Buszkowice, 4 — Orzechowce

LSg4 took place in the humid and cold climate. The above thesis is confirmed by the development of the debris solifluction in Prałkowce.

Early upper older loess (LSg3) in Buszkowice developed on the substratum of river sands in a wet environment of the higher part of the flood terrace. Small pieces of charcoal are redeposited within this loess. Its upper layers TL dated at 188 ka BP are transformed into soil sediment containing 0.44% of humus. In Tarnawce LSg3 is represented probably by lower layers (0.7 m) of the unit marked in Fig. 6 as LSg2+3. These are carbonate loess-like sandy muds with gley spots. The sedimentation environment was characterized by unfavourable ecological conditions confirmed by a poor assemblage of tundra-steppe fauna with an absolute dominance of *Arianta arbustorum* associated with *Columella columella* and with some species of *Pupilla loessica* and *Pupilla muscorum* (M. Łanczont 1991). The appearance of these snails indicates a cold habitat that was not very humid and had a relatively rich vegetation on the substratum rich in carbonates. Considering its composition the fauna assemblage in Tarnawce is the second of this type that was found in Poland. The first one — slightly richer — was found in Dłubnia, north of Kraków (oral communication — S.W. Alexandrowicz).

Middle upper older loess (LSg2) is best documented in the studied area. It developed in the valley facies in Buszkowice and it is solid, carbonate with numerous traces of grassy plants' root systems; these are fine canals filled with plant detritus. A sample of this loess is TL dated at 166 ka BP. The poor assemblage of exclusively land malacofauna (most numerous species of *Pupilla loessica, P. muscorum* and also *Vallonia tenuilabris, Limacidae* and single species of *Vertigo parcedentata*) suggest that snails lived in the conditions of steppe-tundra. The lack of hydrophilous species of *Succinea oblonga elongata*, i.e. a snail that is almost always the most numerous species in the Carpathian and sub-Carpathian loess fauna, suggests a dry variety of cold climate that favoured humus accumulation and carbonate preservation. The sedimentation structures from the LSg2 slope facies in Tarnawce 1 seem to confirm a radical change in the character and dynamics of sedimentation (M. Łanczont 1993). The structures that are connected with various forms of wash-out can indicate continentalization of the conditions of cold climate. On the basis of TL dating results accumulation of LSg2 layers in Prałkowce can be related to the 157–149 ka BP interval. The development of interstadial pedogenesis transforming upper layers of LSg2 has been found in Tarnawce; these are the signs of zonal gleying and browning. However, in Buszkowice there is horizon of weak gleying enriched in colloides (up to 30%) and humus (0.32–0.36%).

Late upper older loess (LSg1) in Tarnawce 1 is as a whole changed by the interglacial pedogenesis. In Buszkowice these layers were reduced by river erosion at the end of Eemian (M. Łanczont 1994b).

On the LSg layers a lessivé forest soil developed (Tarnawce 1, Prałkowce), 2–2.5 m thick, with very well developed illuvium (Table 2). Samples of the material of this soil were dated in Prałkowce at 123 ka (from the B horizon) and 110 ka BP (from the A_3 horizon). In Prałkowce the soil is gleyed from above. The Prałkowce exposure shows that carbonate leaching connected with Eemian pedogenesis had various extents. In the concave from the whole profile is decalcified, and in the convex form only the upper layers are.

At the end of the Eemian interglacial forest communities underwent changes which are testified by the flora spectrum from the bottom layers of mineral-organogenic sediments of abandoned channels in the Tarnawce 2 profile (Fig. 9, Table 3). On the basis of the pollen analysis of two samples that has been carried out by Dr K. Bałaga (Table 3), it can be stated that

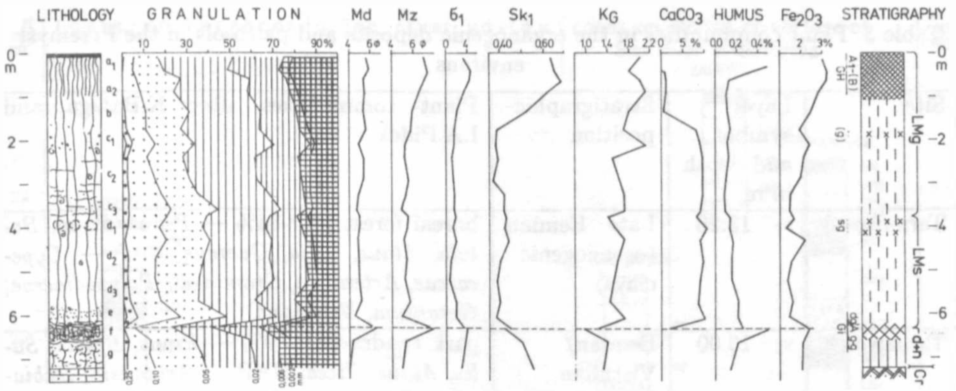


Fig. 9. Profile of loesses in Zalesie; explanations as in Fig. 5

forest communities of pines and spruces with birches and alders, lindens and oaks got transformed into loose pine-birch forests with willows and spruces and some *Polypodiceae* among the undergrowth in wet places; open areas were dominated by herbs with heliophites. The contribution of NAP in relation to the sum of AP and NAP is 41%. A considerable increase (up to 40%) of herbs in the forest communities has been recognized as characteristic of the Eemian/Vistulian transition (K. Mamakowa 1986).

Younger loesses of the Vistulian glacial cycle. Younger loesses (LM) are of considerable thickness (up to 15–17 m) that is varied in different geomorphological situations. Three interstadial soils that are important from the stratigraphic point of view give good basis for distinguishing four stratigraphic units of the second rank: the lowest, lower, middle, and upper.

On the slopes of Przemyśl Foothills the lower boundary of Vistulian loesses (Tarnawce 1, Prałkowce) is marked by the Eemian soil presented above, together with denudation surface developed on the weathered flysch substratum during early glacial coolings (Zalesie, Fig. 9). In the region of the former bottom of the San river valley the LM substratum is made of various river deposits of the middle terrace. In Dybawka (Fig. 10) these are decalcified sands and flood muds; in Buszkowice — strongly weathered loam with gravels TL dated at 117 ka BP; in Tarnawce 2 (Fig. 11) — already mentioned mineral-organogenic deposits with fossil flora; in Krasice (Fig. 12) — alluvial soil which substratum was dated at 125 ka BP (J. Butrym et al. 1988). In the small Krzeczkowski Stream valley (Fig. 10) LM appears on the 12 m high terrace above the debris cover and fluvial, flood, and channel deposits; the LM profile is not full there; it is lacking the lowest unit, i.e. LMn (S.W. Alexandrowicz, M. Łanczont 1995).

The lowest younger loess (LMn) from the early Vistulian period is

Table 3. Plant communities in the organogenic deposits and paleosols in the Przemyśl environs

Site	Layer symbol and depth in m	Stratigraphic position	Plant communities after K.Balaga and I.A.Pidek
Tarnawce 2	s_1 13.20	Late Eemian (ogranogenic clays)	boreal forest (AP-84% — *Pinus*, *Picea*, *Betula*, *Alnus*, *Tilia*, *Quercus*; NAP — *Cyperaceae*, *Artemisia*, *Gramineae*, *Polypodiaceae*, *Geranium*, *Valeriana*)
Tarnawce 2	s_1 13.00	Eemian/ Vistulian (ogranogenic clays)	park tundra (AP-59% — *Pinus*, *Betula*, *Salix*, *Alnus*, *Picea*; NAP — *Artemisia*, *Rubiaceae*, *Gramineae*, *Cyperaceae*, *Polypodiaceae*)
Krzeczkowa	e 0.60	Late Brørüp Interstadial (organogenic clays)	tundra, park tundra (NAP-30-63% — *Cyperaceae*, *Bryales*, *Gramineae*, *Compositae*, *Helianthemum*; AP-70-37% — *Pinus*, *Betula*, *Picea*, *Salix*, *Larix*; shrub: *Juniperus*)
Dybawka	k 8.95	Paleosol developed on the lowest younger loess (LMn)	boreal forest/park tundra (AP-66% — *Pinus*, *Betula*, *Salix*, *Tilia*, *Alnus*; shrub: *Ephedra*; NAP — *Cyperaceae*, *Artemisia*, *Caryophyllaceae*, *Compositae*, *Gramineae*, *Helianthemum*, *Polypodiaceae*, *Selaginella*, *Botrychium*)
Tarnawce 2	g 5.70	Paleosol developed on middle younger loess (LMs)	steppe tundra/dwarf-shrub tundra (NAP-72% — *Cyperaceae*, *Gramineae*, *Artemisia*, *Chenopodiaceae*, *Rubiaceae*, *Armeria*, *Potentilla*, *Compositae*, *Cruciferae*, *Selaginella*, *Botrychium*, *Pediastrum*; AP — *Betula*, *Pinus*, *Salix*, *Alnus*; shrub: *Juniperus*, *Ephedra*)

represented on the slopes by a thin layer (up to 0.5 m) of weathered, loamy deluvia of Eemian soil with gley spots, mixed with fresh silt. For that reason LMn is rich in clay fraction and iron oxides (Table 1). In the area of flood plain of the San river of that time its thickness is 1.5–2.0 m. It is carbonate-free, silty-clayey loess-like deposit interfingering with fine sands of fluvial accumulation. Interstadial soil rich in humus (Table 3) that resembles chernozem (Tarnawce 2) or gley soil (Krasice, Dybawka) developed on LMn layers. The results of TL loess datings in Krasice (Fig. 12) allow to connect this soil with early Vistulian interstadial that is distinguished as Odderade interstadial in Western Europe (K.E. Behre 1989). A clear analogy between gley soil developed on LMn in the Przemyśl region, with a TL dated for 80 ka interstadial soil from the loess profile in Radymno

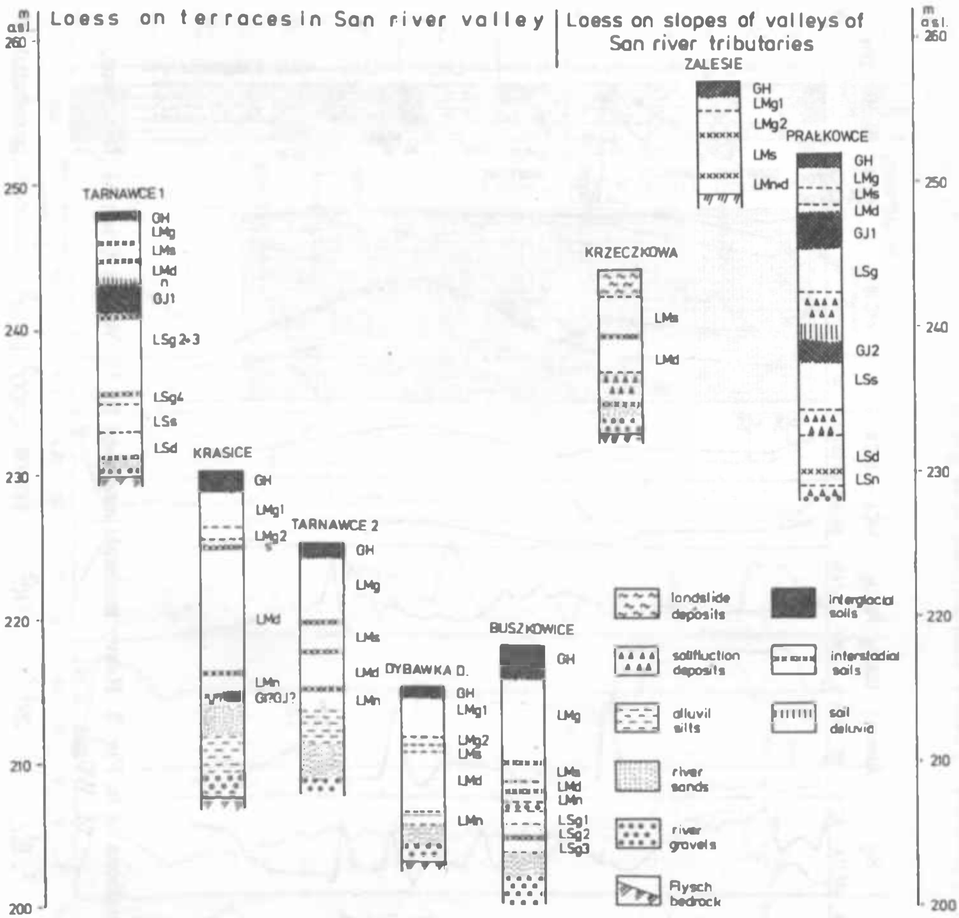


Fig. 10. Stratigraphic schemes of the described loess profiles from the Przemyśl Foothills territory

located in the edge zone of the middle San terrace, 20 km to the north of Przemyśl (S.W. Alexandrowicz et al. 1989) is worth noticing. They are developed in a similar way and they were probably formed in similar conditions. In the Dybawka region gley soil developed in the envrionment of cool, coniferous loose forest with open habitats of rich steppe vegetation and of humid tundra type with high contents of *Cyperaceae*, *Polypodiaceae*, and *Sphagnum*. A relatively low content of deciduous trees was probably limited to wet habitats at the bottom of the valley (M. Łanczont 1991). These were the plants of transient character form boreal forest to the forest-tundra and tundra; it can be correlated with the EV4 *Pinus-Betula* R PAZ typical for the Odderade interstadial in the central and southern Poland (K. Mamakowa 1994).

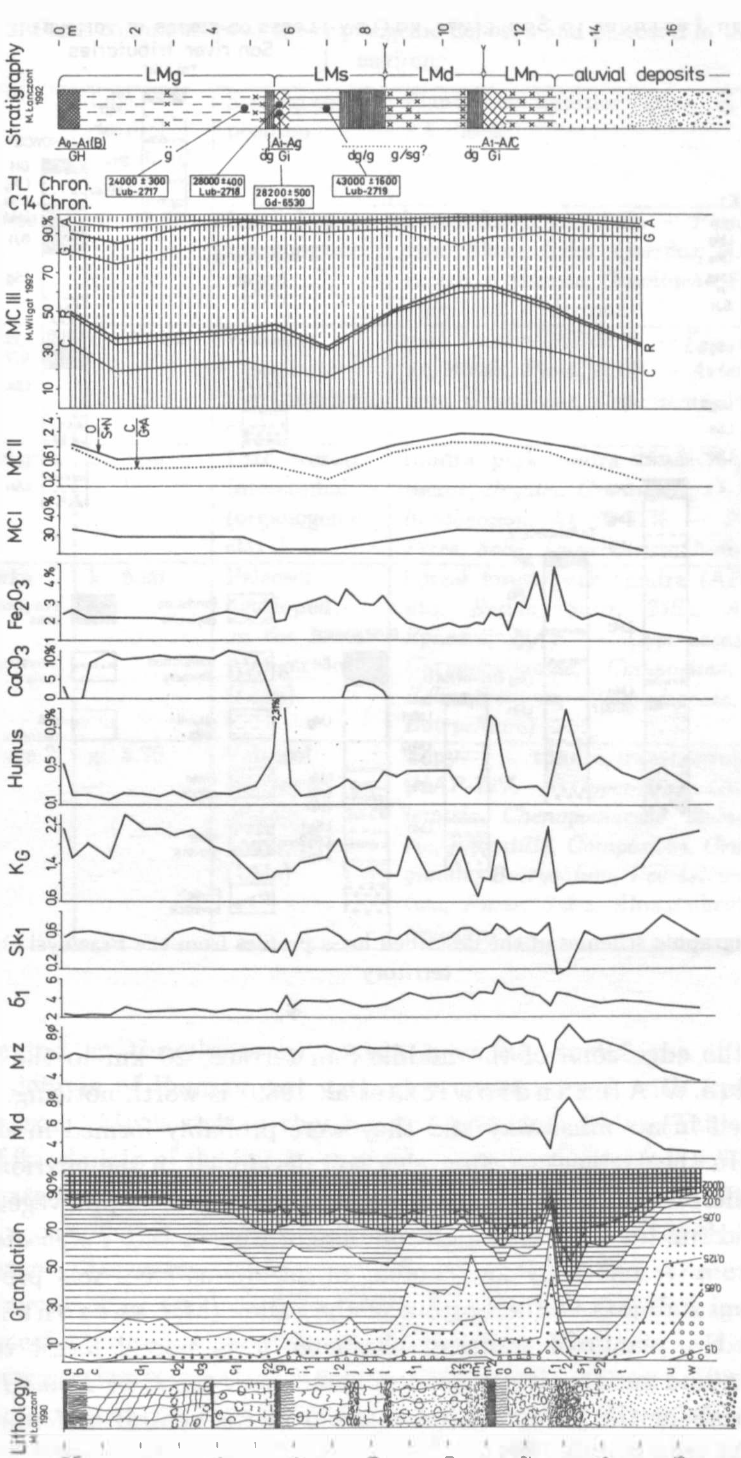


Fig. 11. Profile of loesses in Tarnawce 2; explanations as in Fig. 5. Heavy minerals analysed by M. Wilgat (vide M. Lanczont, M. Wilgat 1994)

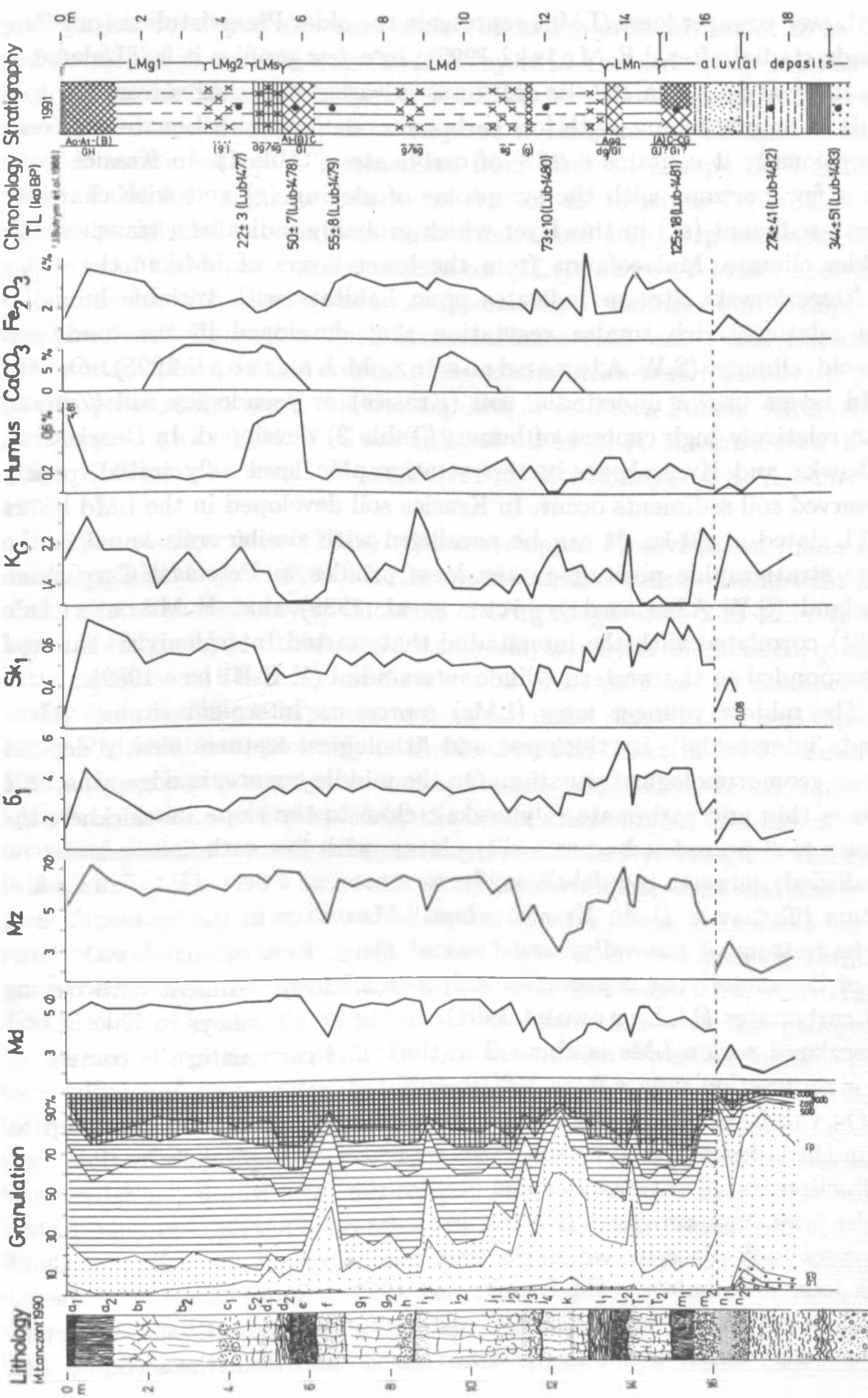


Fig. 12. Profile of loesses in Krasice; explanations as in Fig. 5

Lower younger loess (LMd) represents the older Plenivistulian (pre-Grudziądz stadial after J.E. Mojski 1993). In a few profiles it is TL dated in the interval 80–51 ka BP. Its thickness is varied and ranges from 0.6 to 8 m. It is mainly loamy, with low carbonate content or carbonate-free; only exceptionally it contains 8–12% of carbonates (Table 1). In Krasice there are a few horizons with the symptoms of gleying (g) and with character of soil sediment (sg) in this layer which probably indicates a transitionally milder climate. Malacofauna from the lower layers of LMd in the valley of Krzeczkowski Stream indicates open habitats with variable humidity and relatively rich tundra vegetation that developed in the conditions of cold climate (S.W. Alexandrowicz, M. Łanczont 1995). On the LMd layers brown interstadial soil (Krasice) or pseudogley soil (Zalesie) with relatively high content of humus (Table 2) developed. In Buszkowice, Dybawka and Krzeczkowa in this stratigraphic level only initial, poorly preserved soil sediments occur. In Krasice soil developed in the LMd layers is TL dated at 50 ka. It can be paralleled with similar soils found in the same stratigraphic position in the loess profiles in Przemyśl Carpathian Foreland (S.W. Alexandrowicz et al. 1989) that H. Maruszczak (1991) correlated with the interstadial that started Interplenivistulian and corresponded to the western Glinde interstadial (K.E. Behre 1989).

The middle younger loess (LMs) represents Interplenivistulian (Grudziądz interstadial); its thickness and lithological features clearly depend on the geomorphological situation. On the middle terrace, in edge zone, this loess is thin and carbonate (Dybawka); close to the slope its thickness increases to 3 m and it becomes silty-clayey, with low carbonate content or decalcified; deluvial and debris solifluction processes participated in its formation (Tarnawce 2). In Krasice where LMs occurs in the "contact" area of the bottom of the valley and "warm" slope, loess is mixed with deluvia of the underlying interstadial soil; it is a clayey sediment with humus and carbonates (M. Łanczont 1991). In the small valleys in Zalesie and Krzeczkowa region LMs is about 2 m thick and carbonate; the content of the main fraction ranges from 35% to 50%.

On the LMs layers interstadial subarctic gley soil or brown soil up to 0.5 m thick developed. As a rule it shows traces of diapir deformations and solifluction translocations; in some profiles the A horizon is partially reduced by later slope processes (Fig. 6). In Buszkowice interstadial soil-forming processes took place in two stages that were interrupted by the periods of weak loess accumulation (M. Łanczont 1994b). These layers from the later phase were dated by TL and ^{14}C methods at 35–34 ka BP and developed in the boggy environment of the dwarf-shrub tundra. In the second phase pedogenesis developed at a more varied humidity, probably about 28 ka BP; soil developed at that time on the LMs layers in Tarnawce (Fig. 11) was TL and ^{14}C dated. Thus, it can be assumed that the two stages of pedogenesis development mentioned above correspond to Hengelo and Denekamp interstadials mentioned by the researchers from Western Europe (K.E. Behre 1989). Palinological characteristics of the soil in Tarnawce 2 (Table 3) indicates periglacial envrionment with tundra and steppe species and some elements of the forest-tundra vegetation (M. Łanczont 1993); contribution of herbs with species such as *Cyperaceae*, *Gramineae* and heliophites was significant. Character of vegetation indicates cold continental climate. In this stratigraphic position similar plant communities were found in the profiles of peats and organic-mineral deposits of southern Poland (K. Bińka, K. Grzybowski 1994, T. Gerlach et al. 1993, K. Mamakowa 1968, 1994, K. Mamakowa, L. Starkel 1974, K. Mamakowa, A. Środoń 1977).

Upper younger loess (LMg) represents upper Plenivistulian (main stadial after J.E. Mojski 1993). In the studied area it constitutes at least half of the Vistulian loess cover; thickness of LMg ranges from 2 to 11 m. Lower layers of LMg with low thickness are silty-clayey, gleyed and bedded, contain little carbonates. Their accumulation took place parallely to disappearing wash-out and solifluction processes from the moist phase in the beginning of upper Plenivistulian, probably in the 28–24 ka BP interval (M. Łanczont 1993). Upper layers are represented by thicker proper loess. In some profiles LMg is bipartite; it is separated by the initial soil sediment that indicates an increased contribution of pedogenetic processes. In Dybawka and Zalesie it is the horizon of weak gleying with precipitation of manganese and iron compounds and aggregations of secondary carbonates (these are mainly fissure pseudomycelia, spherical concretions and pipe-like forms connected with the grass root systems — see M. Łanczont 1991, M. Łanczont, M. Wilgat 1994). In Zalesie numerous snail shells are connected with this pedogenetic horizon. According to prof. S.W. Alexandrowicz expertise, fauna is rich, especially when we consider the amount of specimens. Four species are especially numerous, i.e. *Trichia hispida*, *Succinea oblonga elongata, Lymnea truncatula, Columella columella*; they are accompanied by few species such as: *Clausilia dubia*, *Pupilla muscorum*, and *Euconulos fulvus*. This fauna assemblage indicates humid substratum with abundant vegetation. This habitat favoured catholic species, even though a species with higher thermal requirements is also present (i.e. *Euconulos fulvus*) that could live there because of the favourable slope exposition. The presence of numerous shells from amphibious snail *Lymnea truncatula* suggests periodical overflowing and formation of ephemeral, shallow water basins resembling paddles. This type of fauna corresponds well with weak climatic warming in the upper Plenivistulian. It probably can be paralleled with 25–21 ka BP interval during which fauna with higher ecological requirements developed on the loesses in the neighbourhood of Kraków (S.W. Alexandrowicz 1995).

The accumulation environment of the upper LMg layers is characterized by a fauna assemblage from Dybawka occurring above the horizon with traces of weak pedogenetic processes (M. Łanczont 1991). The fauna assemblage contains: *Pupilla muscorum, Pupilla loessica, Vallonia tenuilabris, Trichia hispida*, and *Clausilia dubia*. The indicative taxons are *Pupilla* and *Vallonia* that are representative for the environment of the cold subarctic steppe; the remaining species are found in temperate climate. The distinguishing feature for this assemblage is the lack of hydrophilous species *Succinea oblonga elongata* that commonly appears in loess. It is quite a unique malacofauna assemblage that points to a dry habitat in a severe climate but not the extreme one.

Postglacial soil (GH) developed on LMg in the studied profiles shows the features of brown soil or leached brown soil with the thickness of 1–1.8 m.

LOESSES AND THE DEVELOPMENT OF PLEISTOCENE TERRACES IN THE SAN RIVER VALLEY

Four terraces were preserved in the San river valley west of Przemyśl. They resulted from the rhythmic climate changes that overlapped the effects of neotectonic movements that raised the Carpathians (M. Klimaszewski 1936, 1948, L. Starkel 1965, 1971, K. Pękala 1988). Among the deposits that build the terraces there are loesses accumulated in the subaquatic and subaerial conditions (Fig. 13). On the basis of relationships between fluvial and eolian deposits as well as chronostratigraphic differentiation of the latter, the time when these terraces were still "active" (under development) can now be determined more precisely. The change in the genetic-facial character of loess from alluvial and/or boggy to subaerial allows for the separation of the "terrace-forming" stage from the stage during which the dust deposition environment was outside the range of flood waters.

The 75–80 m terrace must be excluded from the above considerations as the loess cover includes only upper Vistulian loesses. At places till cover from the Sanian 2 glaciation (J. Butrym et al. 1988) was preserved in between these loesses and fluvial deposits coming from the Sanian 1 glaciation. A stratigraphic hiatus between older deposits (gravels and till)

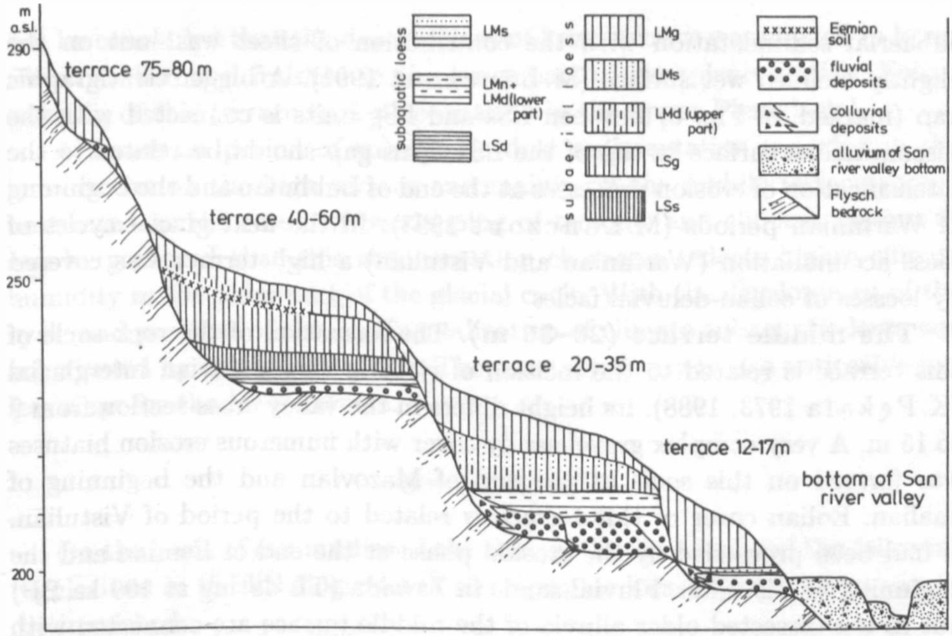


Fig. 13. Schematic cross-section of the loess cover on the terraces of the San river (Przemyśl Foothills)

and loess represents Mazovian interglacial, Saalian glaciation and a bigger part of Vistulian.

High terrace (40–60 m). The bottom of the loess cover on this terrace in Tarnawce is located at the height of 230 m a.s.l., i.e. 40 m above the present bottom of the San valley. The underlying thin series of river gravels is placed on the erosion socle built of flysch rocks, which was formed during recession stadials of the Sanian glaciation. After these gravels had been deposited, during Mazovian interglacial erosion processes in the Carpathians got intensified as a result of neotectonic movements (L. Starkel 1971, W. Zuchiewicz 1987); the bottom of the San river got deeper. In the lower Odranian, in the water saturated bog environment a loess-like deposit representing LSd was formed on the above mentioned terrace, on the river deposits reduced by erosion. In the case of this terrace it is very difficult to establish precisely when the change of the character of the sedimentation environment took place basing only on the studies of one profile (Tarnawce 1). It is difficult because of various stratigraphic gaps in the LSd layers that point to erosion episodes breaking silt deposition; beside that the stratigraphic profile of this unit is reduced (there is erosion surface in top). The features of the loess-like deposit representing LSs layers indicate subaerial sedimentation with the contribution of sheet wash-out on the slightly inclined wet surface (M. Łanczont 1991). A bigger stratigraphic gap (marked on Fig. 6) between LSs and LSg units is connected with the discontinuous surface in top of the LSs. This gap should be related to the intensification of erosion processes at the end of Lublinian and the beginning of Wartanian periods (M. Łanczont 1993). In the next glacial cycles of loess accumulation (Wartanian and Vistulian) a high terrace was covered by loesses of eolian-deluvial facies.

The middle terrace (20–35 m). The formation of the rock socle of this terrace is related to the incision of river in the Mazovian interglacial (K. Pękala 1973, 1988); its height differs in the valley cross-section from 9 to 15 m. A very complex gravel-sandy cover with numerous erosion hiatuses was formed on this socle at the end of Mazovian and the beginning of Saalian. Eolian cover of this terrace is related to the period of Vistulian. It had been proceeded by the erosion phase at the end of Eemian and the beginning of Vistulian. Fluvial sands in Zawada (TL dating at 109 ka BP) put in the dissected older alluvia of the middle terrace are connected with this type of erosion. The subaquatic sedimentation — alluvial and boggy — of loess on these fluvial deposits was started in the earliest Vistulian and finished in the beginning of lower Pleniglacial. The succeeding younger units of Vistulian loess are related to the subaerial environment; the loess from lower LMd layers in Krasice dated by TL at 73 ka BP is an example. The change seems to confirm the deepening of the bottom of the valley or decreasing range of the floods conditioned by climatic changes. In the period of Interplenivistulian there appeared a phase of more intensive incision of river caused by a weak wavy warming of the climate that became more humid at the same time (J.E. Mojski 1993); there are common proofs of this erosion recorded in the valley deposits in S Poland (J. Jersak et al. 1992, W. Laskowska-Wysoczańska 1971, L. Starkel 1988, 1995). In the area of terrace occurring above the flood plain, a weak deposition of eolian dust representing LMs took place. Later, during upper Pleniglacial thick layers of the most classically developed LMg were deposited.

Low terrace (12–17 m). No detailed data confirming the age were obtained for the loess covering the low terrace near Przemyśl. In Olszany under these subaerial loesses two series of deposits occur: a thin (0.6 m) layer of loess-like alluvial loams with horizon of interstadial gley soil in top, and periglacial, poorly rounded gravels (1–1.5 m). The rock socle of this terrace is 5 m high (unpublished data). In the west region of the study area, in Dubiecko, loess of the deluvial facies covering fluvial sands of low terrace was TL dated at 40–22 ka BP (J. Butrym et al. 1988). Hence, it can be concluded that the development of lower terrace was started in lower Plenivistulian and finished in the lower part of Interplenivistulian. Eolian covering of this terrace took place mainly in the upper Pleniglacial.

A transition period of subaquatic dust sedimentation recorded in the loess covers on the high terrace and mainly on the middle terrace should be treated as the result of overlapping of tectonic and climatic factors. It can be gathered that this sedimentation character reflects higher climate humidity in the older part of the glacial cycle. With the development of the cycle and progress of the continentalization of climate subaquatic loess was substituted by subaerial deposit. The same regularity is also noticeable but less clear for the lower terrace.

CONCLUSIONS

On the basis of our studies of the Przemyśl neighbourhood the following regularities in the lithological and stratigraphic loess differentiation can be distinguished:

1. Lithological properties of loesses are very variable in line with the differentiation of the geomorphological conditions of sedimentation; the result is that many genetic-facial varieties occur in the topographic scale. They are also clearly differentiated in the grain-size distribution. These are the loesses of the following facies: alluvial, boggy, deluvial, solifluction, colluvial, eolian and other transitional varieties. The loesses of deluvial facies that indicate a high role of wash-out processes in the formation of loess cover in the Przemyśl Foothills are predominant.

2. The studied loesses are of local origin. Their source material came mainly from fluvio-periglacial deposits in the bottom of the San river valley, and partly — especially in the case of deluvial loess — from local weathered flysch rocks. It can be proved by the heavy mineral composition, together with loess distribution and variability of its grain-size characteristics. The thickest covers are connected with close vicinity of the source areas defined as above and appear mainly on the Pleistocene terraces.

3. Loesses from Przemyśl region occur on the hipsometric level from about 210 to 280–320 m a.s.l.; thus, vertical dust transport during accumulation reached 70–110 m above the bottom of valleys. Upper extent of loess deposition was connected with climatic conditions, and especially with precipitation amount increasing with altitude, and probably also with decreasing concentration of dust transported from valley bottom.

4. Up to the beginning of 80's only younger Vistulian loesses were distinguished in the area of Przemyśl Foothills. At present three main

stratigraphic units — younger loesses, upper older loesses and middle, lower and the lowest older loesses — related to the glacial cycles of Vistulian, Wartanian and Odranian can be determined. Forest soils were formed in the interglacial periods. Brown leached soil was formed on the middle older loess in the Lublinian (= Saal.I/Saal.II) interglacial (in Prałkowce there is the only site in the eastern part of the Carpathians with the soil of this age in distinct stratigraphic position). However, in the Eemian interglacial on the upper older loess lessivé soil was formed, which was found in two sites (Tarnawce 1, Prałkowce).

5. Secondary stratigraphic units distinguished within the main ones are similar to these in uplands of SE Poland. It was possible to determine these units more accurately for the Vistulian loesses. They were divided into four strata separated by the three soils of interstadial rank. Pedogenesis was more intensive during early Vistulian and lower Pleniglacial. Interpleniglacial is documented by soil sediments and tundra soils quite frequently found in the Przemyśl loess profiles. Loesses from the upper Plenivistulian are bipartite; they are separated by the initial soil sediment indicating increased participation of pedogenetic processes connected with weak climate warming.

6. Loess covers on terraces are differentiated into layers accumulated in the subaquatic and subaerial conditions. On the basis of relationships between fluvial and eolian deposits as well as basing on the chronostratigraphy, it is possible to establish the upper time boundary for the terrace activity; it is most visible in the case of high and middle terraces. The stage of terrace development with subaquatic sedimentation of loess on the high terrace covered the layers from the lower part of Odranian (LSd) and on the middle terrace — the layers from early Vistulian (LMn) and the beginning of lower Pleniglacial (lower layers of LMd). Thus, subaerial (eolian) accumulation on the high terrace started in younger stage of the Odranian cycle, and on the middle terrace — in younger stage of the lower Plenivistulian.

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STRESZCZENIE

Utwory lessowe przemyskiego odcinka Pogórza Karpat występują głównie w dolinie Sanu oraz większych jego dopływów w niewielkich płatach o miąższości 5–10 m do ponad 20 m, w piętrze hipsometrycznym od około 210 do 280–320 m n.p.m. (ryc. 1). Rozmieszczenie i zmienność cech uziarnienia lessu oraz skład przezroczystych minerałów ciężkich wskazują na ich lokalne pochodzenie (ryc. 2, 3). Materiał wyjściowy pyłu lessowego stanowiły głównie fluwio-peryglacjalne, drobnofrakcyjne osady w dolinie Sanu, a częściowo — szczególnie w przypadku lessu deluwialnego — lokalne zwietrzeliny skał fliszowych. Najbardziej miąższe pokrywy są związane z bliskim otoczeniem tak określonych obszarów źródłowych i występują głównie na terasach plejstoceńskich.

Właściwości litologiczne i cechy strukturalne lessów są bardzo zmienne, odpowiednio do zróżnicowania warunków geomorfologicznych sedymentacji w terenie z rzeźbą o dużych deniwelancjach i nachyleniach stoków. Na tej podstawie wyróżniono oraz scharakteryzowano następujące facje lessów: aluwialną i bagienną, deluwialną, koluwialną, soliflukcyjną i eoliczną (ryc. 4). Najbardziej rozpowszechnione są lessy facji deluwialnej, świadczące o dużej roli procesów spłukiwania w formowaniu pokryw lessowych. Lessy facji koluwialnej, spotykane w niektórych mniejszych dolinach o stromych zboczach, zawierają domieszkę rumowiska skalnego pochodzącego z wychodni podłoża fliszowego,w górnych odcinkach stoków, powyżej zasięgu akumulacji lessowej.

Na Pogórzu Przemyskim do początku lat osiemdziesiątych wyróżniono tylko lessy młodsze, vistuliańskie. Badania prowadzone w ostatnich kilku latach, uwzględniające wyniki analizy cech litologicznych, gleb kopalnych, następstwa warstw oraz oznaczeń wieku metodami TL i ^{14}C, pozwalają wyodrębnić trzy podstawowe poziomy stratygraficzne lessów, które skorelowano z wyróżnionymi w schemacie opracowanym przez H. Maruszczaka (1991 b) dla Polski południowej. Są to lessy młodsze (LM), lessy starsze górne (LSg) oraz lessy starsze środkowe, dolne i najniższe (LSn+d+s) — odpowiadające cyklom glacjalnym wisły, warty i odry. Na lessie starszym środkowym w interglacjale lubelskim powstała gleba leśna typu brunatnej wyługowanej; w Prałkowcach znajduje się jedyne dotychczas stwierdzone we wschodniej części Karpat stanowisko z glebą tego wieku w jednoznacznej pozycji stratygraficznej (ryc. 5). Na lessie starszym górnym powstała gleba płowa, znana z dwu stanowisk — Prałkowce i Tarnawce 1 (ryc. 5, 6). Zróżnicowanie tych podstawowych jednostek na drugorzędne (ryc. 10) jest podobne jak na wyżynach Polski SE, a dokładniej udało się je określić dla lessów vistuliańskich (ryc. 7, 9, 11, 12).

Wyniki analizy stratygraficznego zróżnicowania lessów okolic Przemyśla dają podstawę do dokładniejszego określenia wieku teras w dolinie Sanu. Pokrywy lessowe na terasach są zróżnicowane na warstwy akumulowane w warunkach subakwalnych i subarealnych. Na podstawie relacji wzajemnej osadów fluwialnych i eolicznych oraz zróżnicowania chronostratygraficznego tych ostatnich można w szczególności ustalić granicę czasową aktywności terasy; najwyraźniej się to rysuje w przypadku terasy wysokiej i średniej (ryc. 13). Etap rozwoju terasy wysokiej z sedymentacją subakwalną lessu obejmował warstwy z dolnej części odranianu, a terasy średniej — warstwy z wczesnego vistulianu i początku dolnego pleniglacjału. Akumulacja subaeralna (eoliczna) rozpoczęła się więc na terasie wysokiej w młodszej części zlodowacenia odry , a na terasie średniej — w młodszej części dolnego plenivistulianu.