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Loesses and Alluvia in the Krzeczkowski Stream Valley in Przemyśl Environs (SE Poland)

Lessy i osady rzeczne w dolinie Krzeczkowskiego Potoku na Pogórzu Przemyskim (Polska SE)

Abstract. The structure of a Pleistocene terrace was studied in the small Krzeczkowski Stream valley situated in the Przemyśl section of the Carpathian Foothills. The deposits were analysed with regard to: lithofacial characteristics, molluscan fauna and pollen studies and dating by TL method. They were found to be of the Vistulian age, and the development of the terrace deposits (fluvial, deluvial, solifluction, eolian sedimentation) as well as climatic changes and ecologial conditions during sedimentation were determined. From the stratigraphic and paleogeographical view-point overbank muds with a very characteristic fauna association, parallelled with Brørup Interstadial are significant. River and slope sediments are covered with subaerial loess representing the southern range limit of these deposits in Poland.

Key words: Pleistocene terrace, fluvial accumulation, loess, molluscan fauna, Vistulian, Carpathian Foothills.

INTRODUCTION

In the Krzeczkowski Stream valley situated in the Przemyśl section of the Carpathian Foothills, there occurs one Pleistocene terrace of a relative height 10 to 12 m. From paleogeographical viewpoint of significant importance are subaerial loesses covering the slope and river deposits forming this terrace. Well-preserved snail shells occur in the whole sequence of the deposits. The Holocene valley bottom embedded in the Pleistocene terrace is formed from a series of loamy, sandy and gravel sediments, among which molluscan fauna remnants have also been found.

The lithological-stratigraphic relationships of the terrace deposits at Krzeczkowa have been investigated by M.Łanczont, and S.W.Alexandrowicz has analysed the composition of molluscan fauna. The dating by the TL method was done in the Lublin University laboratory by Dr. S.Fedorowicz from the Department of Quaternary Geomorphology and Geology of Gdańsk University. Pollen analysis of several samples taken from exposures of the terrace (layer "i" in profiles I and II) was made in the Department of Geography and Paleogeography, Maria Curie-Skłodowska University in Lublin, by Ms. A.I.Pidek M.Sc., whom we are thankful.

LOCALIZATION AND GEOMORPHOLOGICAL SITUATION

The Krzeczkowski Stream valley 8 km long and 1.5–3 km wide is located in the Cisowa river basin, a tributary of the San river, in the eastern part of the Przemyśl Carpathian Foothills. Tectonically, the catchment of the Krzeczkowski Stream belongs to a zone of folds of the marginal Skole nappe. In its geological structure there predominate: Cretaceous sandstones and shales of *Inoceramus* layers, lower and upper siliceous and Węgierka marls as well as Tertiary spotted shales (S. Gucik, A. Wójcik 1982). The river network in the catchment area runs transversely in relation to the substrate structures. A parallel system of ridges emphasises the relief structural orientation. A fragment of the oldest relief are remnants of a intramontane level (Fig. 1) over 500 m a.s.l. (K. Pękala 1969). Alongated ridges and flattened interfluves of the foothills (400–425 m a.s.l.) and riverside level (340–350 m a.s.l.) are its main morphological elements.

The Pleistocene terrace in the Krzeczkowski Stream valley occurs only in places in its medial and lower section (Fig. 1); in its upper part the valley is deeply V-shaped with steep slopes. The relative height of the terrace increases down the valley from 6–7 m to 10–12 m. At the Holocene bottom the largest area is that of a rendzina terrace of a relative height 4–5 m. There occur only a few fragments of a 1.5–2 m high terrace. The lowest terrace (0.5–1 m) forms narrow banks close to the river bed.

Interfluves and slopes are covered with weathering, solifluctional, deluvial, eolian and colluvial deposits. The weathering covers are represented by sandy debris-bearing loams, sandy-silty and sandy-clayey loams. Solifluction and deluvial-solifluction, debris-bearing loamy and debris-bearing sandy deposits cover the lower parts of slopes and encroach upon the surface of the Pleistocene terrace. Eolian loesses cover small areas of the lower part of the valley; they belong to the southern range periphery of loesses in Poland. In the catchment a number of rock-weathering slides occur (K. Pękala 1969). Colluvia are formed from unsorted material in which clayey loams and sharp-edged rock fragments predominate.

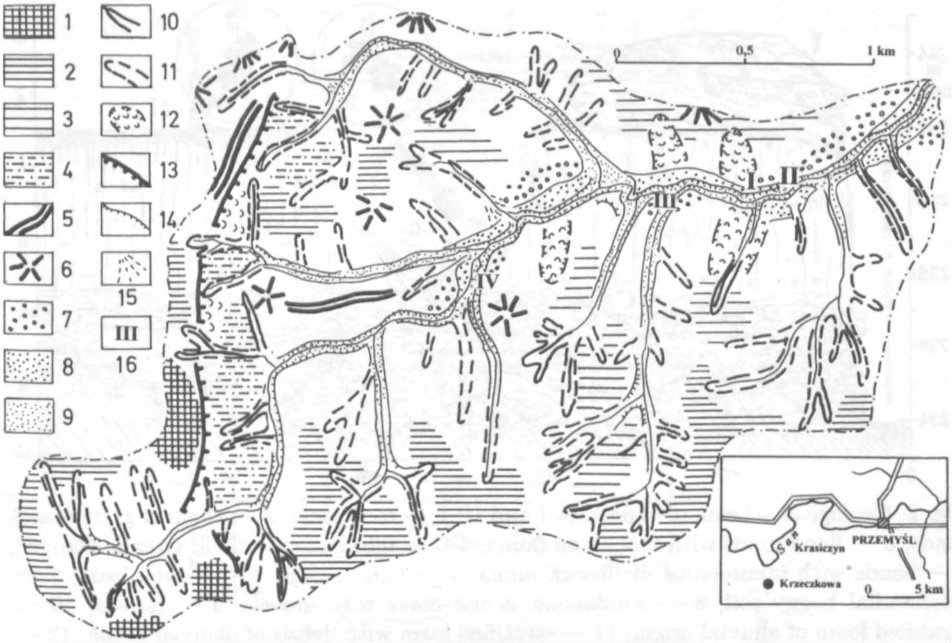

Fig. 1. Geomorphological scheme of the Krzeczkowski Stream catchment (partially after K. Pękala 1969); 1 — intramontane level (lower Pleistocene); 2 — foothills level (upper Pliocene); 3 — riverside level (early Quaternary); 4 — Pleistocene slope planations; 5 — rounded wide ridges; 6 — summits; 7 — Vistulian terrace; 8-9 — inundation terraces (Holocene); 10 — V-shaped valleys; 11 — through-like valleys; 12 — land slides; 13 — structural escarpment; 14 — egdes of terraces and river bluffs; 15 — alluvial fans; 16 — studied Pleistocene sites

PLEISTOCENE SEDIMENTS OF THE STUDIED TERRACE

DESCRIPTION OF PROFILES

The structure of the terrace was examined in erosional scarps on the north (Fig. 2) and south (Fig. 5, 7) sides of the Krzeczkowski Stream valley.

The main exposure studied is about 1 km from the stream mouth. The features of the terrace profile in this exposure are differentiated in its longitudinal section (Fig. 2), which made us examine two profiles illustrating the western (Fig. 3) and eastern (Fig. 4) part of the extensive exposure.

The letter symbols in Figs. 3, 4, 6 and 8 and lithological descriptions have been unified.

Description of exposure I (244 m a.s.l.).

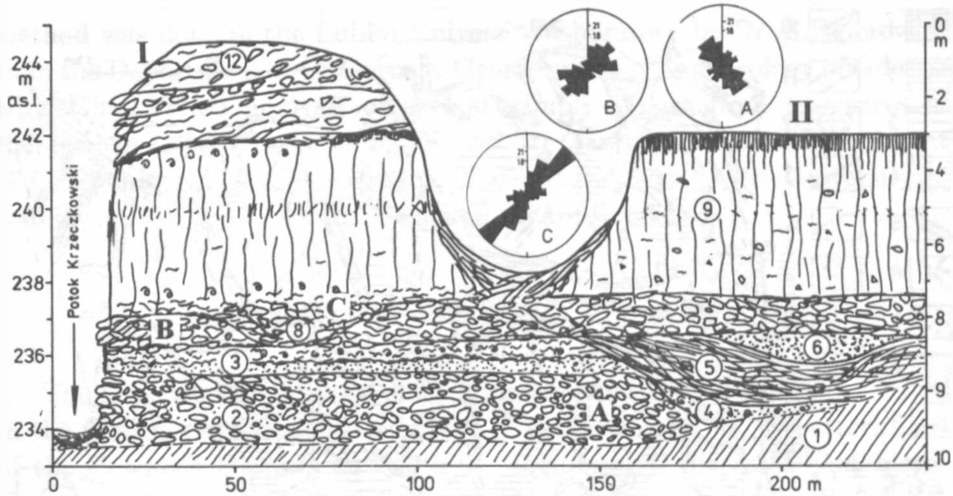

Fig. 2. Geological scheme of exposures I and II; 1 — rock socle; 2 — channel gravels and sands; 3 — flood muds with molluscan fauna; 4-6 — filling of cut-off old stream channel; 4 — sands with innumerous molluscan fauna; 5 — humus clays; 6 — clayey loam; 7 — interstadial boggy soil; 8 — solifluction debris cover with gravels; 9 — loesses; 10 — stratified loam of alluvial origin; 11 — stratified loam with debris of deluvial origin; 12 — colluvial loam; 13-14 — gravels and flood loams of rendzina terrace; 15 — gravels of the lowest terrace

a_1	0.0–2.00 m	Loamy colluvia with rock blocks and sand inserts, grey-yellow carbonate in the upper part and steelgrey flow structure in the lower part; HCl+. A sharp border.
b	2.00–2.60	Grey and dark-grey humus clayey-loamy deposit with fine gravels and small charcoals; HCl+ weakly. A distinct denudation border.
c_1	2.10–2.60	Loamy-silty deposits with dispersed local rock fragments, brown-yellowish with greyish spots with manganese ferruginous aggregates of fine „pepper berries" type; HCl+ relatively weakly. Contains poor molluscan fauna.
c_2	2.60–3.35	Silty-loamy deposits with single rock detritus, brown-yellowish with numerous concretions, spots and streaks of aggregates of Fe and Mn oxides; HCl+.
d	3.35–4.60	Greyish silty deposits with signs and numerous forms of manganese-ferruginous aggregations and carbonate pseudomycelia; HCl+.
e	4.60–5.85	Zonally gleyed grey silty deposits with numerous big brown-ferruginous spots in its lower part; HCl+.
f	5.85–6.07	Yellow silty deposits with grey and ferruginous spots; HCl+.
g_1	6.07–6.32	Laminated yellow-greyish deposits, weakly gleyed in its upper part; HCl+. It contains molluscan fauna. Discontinous lamination marked by differentiated colour of bright and dark thin layers dipping 13–18°/320°. A sample from a depth of 6.2 m dated by TL method for 80.1±12 ka (Lub-2891).
g_2	6.32–6.70	Stratified ferruginous-yellow silty-sandy deposits; HCl+.

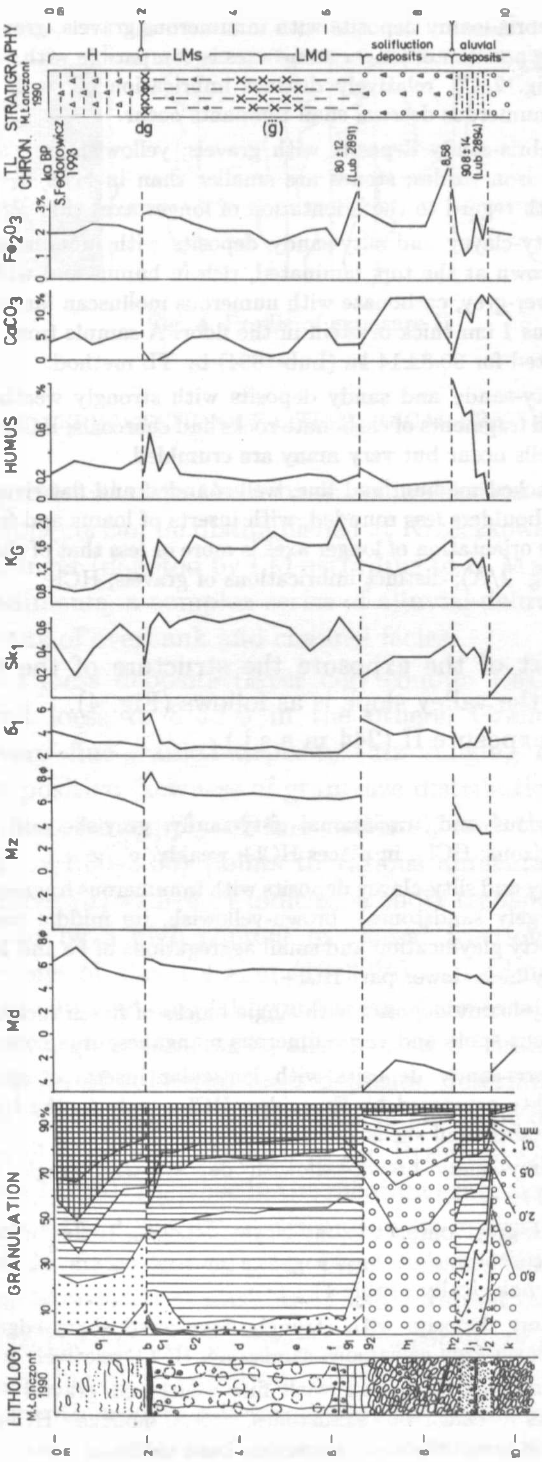

Fig. 3. Profile of exposure I

h_1	6.70–8.50	Debris-loamy deposits with innumerous gravels, grey and grey-yellow; the position of longer stone axes is compatible with the slope direction (Fig. 2/C), relatively distinct imbrication of small boulders; HCl+. Innumerous detrital snail remnants occur.
h_2	8.50–8.72	Debris-sandy deposits with gravels; yellowish-grey slightly cemented by iron oxides; stones are smaller than in layer h_1 and less-ordered with regard to the orientation of longer axes (Fig. 2/B); HCl+.
j_1	8.72–9.20	Silty-clayey and silty-sandy deposits with innumerous gravels; dark--brown at the top, laminated, rich in humus and without carbonates; lower-grey, carbonate with numerous molluscan fauna. A dark ferruginous 1 cm thick ortstein in the floor. A sample from a depth of 9.0 m dated for 90.8±14 ka (Lub-2894) by TL method.
j_2	9.20–9.50	Silty-sandy and sandy deposits with strongly weathered fine gravels and fragments of carbonate rocks and charcoals; HCl+. Numerous snail shells occur but very many are crumbled.
k	9.50–11.70	Packed medium and fine, well-rounded and flat river gravels, as well as boulders less rounded, with inserts of loams and ferruginous sands; the orientation of longer axes is more or less that of the valley direction (Fig. 2/A); distinct imbrications of gravels; HCl–.

In the east part of the exposure the structure of the terrace in the fragment closer to the valley slope is as follows (Fig. 4).

Description of exposure II (244 m a.s.l.)

a_2	0.0–1.08 m	Humus and transitional silty-sandy, greyish- and yellowish-brown horizons; HCl–, in places HCl+ weakly.
c-e	1.08–2.13	Silty and silty-clayey deposits with innumerous fragments of local rocks (largely sandstones), brown-yellowish, its middle part with signs of spotty gleyification and small aggregations of Fe and Mn oxides; HCl–, only in its lower part HCl+.
f	2.13–3.25	Silty-loamy deposits with single blocks of flysch rocks, grey with ferriginous spots and very numerous manganese-iron concretions; HCl+.
h	3.25–3.95	Debris-sandy deposits with lenticular inserts of gravels and sands slighty cemented by Fe oxides; HCl+, only in the top part HCl–. It contains snail shells.
i_1	3.95–5.00	Loamy-sandy brown-yellowish deposit with single rock fragments; HCl+.
i_2	5.00–5.70	Dark-grey compact loamy-clayey deposits; HCl–. In lenses with blurred contours dark-brown gyttja matrial occurs which was examined palynologically (Table 1).
i_3	5.70–5.90	Loamy deposits with strongly weathered sharp-edged fragments of greenish-grey calcareous sandstone; HCl+ relatively weakly.
i_4	5.90–6.30	Sandy-loamy deposits with fine weathered gravels of various flysch rocks — calcareous sandstones, cherts, quartzes; HCl+ weakly. In the whole layer relatively numerous snail shells.

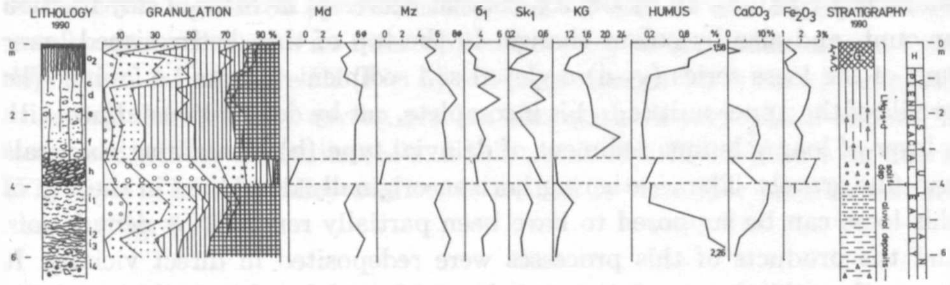

Fig. 4. Profile of exposure II

INTERPRETATION OF LITHOLOGICAL FEATURES

From the presented data three basic sedimentation segments of young Pleistocene sediments can be distinguished at Krzeczkowa. These are loesses identified as younger (denoted by LM according to H. M a r u s z c z a k 1986), slope debris sediments, a complex series of alluvial-deluvial sediments, and alluvial sediments of overbank and channel facies.

The studied loess deposits (layer c-g) contain $CaCO_3$ from 2–3% in layers of gleyed loess to 8–12% in the others. Granulometrically, they belong to a very fine-grained deposits (Mz ranging from 6.3 to 7.2ø). A considerable positive skewness of grain-size distribution (Sk_1=0.40–0.70) accounts for intensive supply of fine material, and the very leptokurtic distribution (K_G=1.30–3.30) points to various alimentation sources. Very low sorting indices (σ_1=2.5–4.5) indicate a short transport. These deposits are characterized by a high content of „loess" fraction (about 50%) and a considerable one of clay fraction (15–20%). An admixture of dispersed weathered fragments and single bigger blocks of the local flysch, supplied by denudation from higher slope parts, allows us to indclude this sediment into colluvial lithofacies of subaerial loess deposits, determined as a mountain variety (H. M a r u s z c z a k 1991a). Loesses of this type occur in small areas in steep slopes of some small valleys in the Przemyśl Carpathian Foothills (M. Ł a n c z o n t 1994a). Increase in the medium grain size, a smaller content of carbonates and the structure of discontinuous inclined lamination, found in the lower layers of the western part of the exposure (Fig. 3/g_{1-2}), indicate that this is due to periodical washing of the sediment on the slopes.

According to the signs od pedogenetic transformation loesses of profil II do not show a distinct differentiation. Among the loesses studied in exposure I two horizons with poorly advanced signs of pedogenesis of interstadial rank occur in the middle and upper layers. These horizons (d, c_1) are characterized above all by $CaCO_3$ content decrease, increase of clay fraction amount, and also by colour change. In the top of this distinguished lower unit of the loess series (g_2-d) a gleyed soil sediment (d) can be found. The profile of the upper unit (c_{1-2}) is incomplete, cut by denudation surface with a layer of loamy humus sediment of deluvial type (b), containing charcoals and fine gravels. The weathering horizon originally developed in the top of this loess can be supposed to have been partially removed by denudation, and the products of this processes were redeposited in direct vicinity. It seems that this interpretation can be confirmed by the similarity of the sediment features of layer b and the upper part of layer c_1. Also in the top of the layer of deluvial sediments a very distinct surface of discontinuity can be observed. It is coverded with a thick colluvial deposits consisting of several layers of loams of various lithological features. The whole series of colluvia is characterized by fresh and well-preserved sedimentation structures.

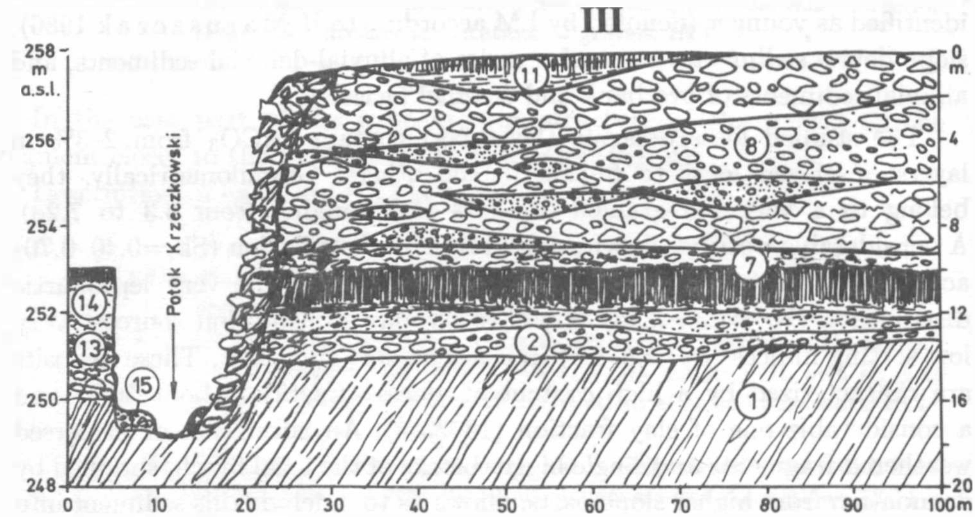

Fig. 5. Geological scheme of exposure III (explanations as in Fig. 2)

A series of coarse-grained deposits underlying loesses is composed of local rock debris with loam (h_1) or sand (h_2). Plated form of angular blocks and rock fragments is related to the weathering way of the local flysch. Weak segregation as well as the arrangement of rock fragments compatible with the slope inclination point to solifluction origin of the sediment; imbrication of small boulders seems to account for solifluctional slow flow of tongues of water-logged debris-loamy mass. The occurrence of inserts of river gravels and sandy lenses indicates that at the initial sedimentation stage the range of slope and river processes shifted. Distinct weathering in the top part of the cover signalized by descreasing $CaCO_3$ content and Fe_2O_3 increase may be connected with an interruption between its accumulation and loess deposition. In exposure III (Fig. 5) solifluction series 3.5 m thick, composed of several debris-loamy covers, reaches almost the topographical surface; it is covered with a discontinuous and thin patch of deluvial loam with debris (Fig. 5/11). In this valley section as well as in its upper part loesses are absent (Fig. 6, 7).

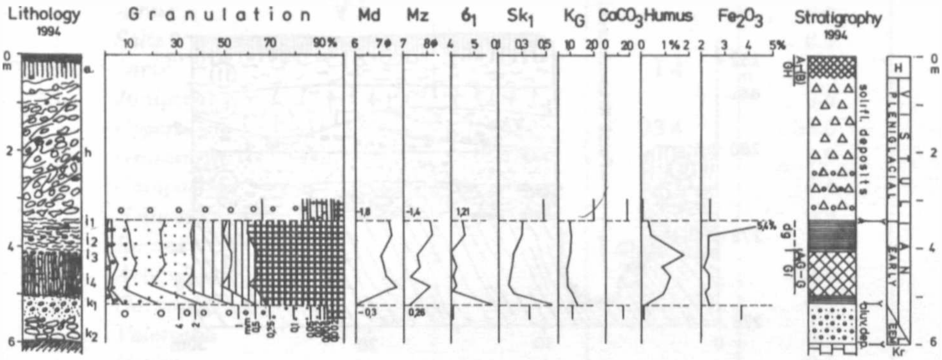

Fig. 6. Profile of exposure III

Alluvial deposits of the Pleistocene terrace show variability in the cross and longitudinal section of the valley. A constant unit is an 1–2 m series of channel gravels (k) on a rock socle. The erosion bottom under alluvia has been weathered to a depth of about 1.5 m; in exposure I and II it is below or on the level of the present channel and rises to 2–2.5 m up the valley (exposure III and IV). Between the layer of gravels (k) and the solifluction cover (h) differentiated deposits occur (Fig. 2, 3, layers 3–7; Fig. 3, 4, 6, layers j-i):

1. Overbank bipartite grey humus calcareous muds with charcoals and molluscan fauna (Fig. 2-I/3).

2. A series of sandy loams contaminated organically and humus clays filling a fossil channel cut in a strata of muds in the footslope zone (Fig. 2-II/4–6). Humus content increase and carbonate content decrease with the depth (Fig. 4, layers i_{1-4}) make the sediments look as an inverted soil profile and seems to account for intensive soil erosion and slope denudation. Soil processes were likely to develop simultaneously with sedimentation, which caused effacement of stratification traces.

3. Dark-grey clayey loam transformed pedogenetically and strongly gleyed represents an overbank facies (Fig. 5-III/7). It is an interstadial soil of boggy type (Fig. $6/i_{3-4}$), associated with reduction conditions, in prin-

cipal developed as one horizon of organic accumulation. It is rich in humus (0.9–1.7%) and contains many clay particles (36–40%). The features of this soil indicate that it was formed in a boggy area beyond the range of high water. The soil surface is erosion-denudational; it is covered with grey-brown clayey loam and rusty-yellow sandy loam layers with iron pseudofibres, with an admixture of disintegrating rock fragments (Fig. 6/i_{1-2}), pointing to strongly weathered sediment in periglacial environment.

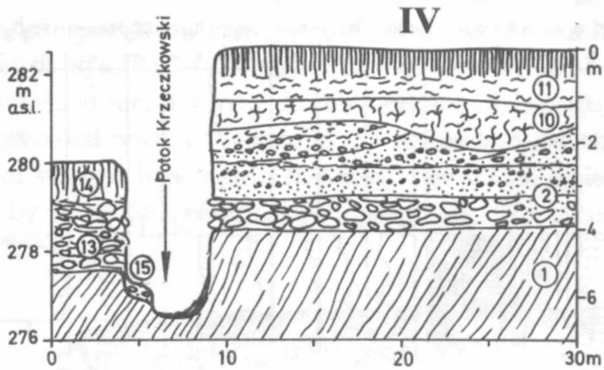

Fig. 7. Geological scheme of exposure IV (explanations as in Fig. 2)

RESULTS OF POLLEN ANALYSIS

From the sediments filling a fossil channel in exposure II samples for pollen analysis were taken (at depth: 4.9, 5.1, 5.2, 5.4, 5.6 and 6.25 m) (Table 1); the two first and last sample were almost pollen-free, and in the remaining three the frequency and preservation condition of pollen and spores were bad. Many grains unrecognizable due to destruction were defined as Varia. A very high percentage of taxa redeposited (among which *Pinaceae*, older than Quartenary ones, *Gleicheniaceae*, *Taxodiaceae* and other Tertiary sporomorphs predominated) may be evidence of a considerable activity of water eroding older sediments.

According to the opinion A.I.Pidek it is difficult to interpret the pollen spectra presented in Table 1 because of lack of indicatory microfossils. It is floristically poor sedgeswamp community (*Cyperaceae, Bryales*) with a considerable content of plants from family *Compositae* and grasses (*Gramineae*). The presence of *Helianthemum*, *Rumex*, *Artemisia*, and *Caryophyllaceae*, i.e. photophilous plants, points to occurring open habitats. Single pollen grains of *Valeriana*, *Urtica* and *Rubiaceae* suggest occurrence of relatively wet places. Tree sporomorphs constitute 37–69,7% of AP and NAP total. The main

Tab.1. Relative amounts of determined pollen grains and spores in the Krzeczkowa profile II*

	Samples from depth (in m)		
	5.20	5.40	5.60
AP	55.0	69.7	37.0
NAP	45.0	30.3	63.0
Pinus	47.0	58.0	31.0
Picea	4.4	3.4	1.4
Betula	3.5	1.4	3.2
Alnus			0.5
Salix			0.5
Larix		1.4	0.5
Juniperus			0.5
Cyperaceae	25.0	23.4	33.5
Gramineae	4.4		5.9
Compositae	4.4	4.1	6.4
Helianthemum	0.7		0.9
Rumex			1.4
Artemisia			0.5
Caryophyllaceae			0.5
Valeriana			0.5
Urtica			0.5
Rubiaceae			0.5
Varia	10.5	2.8	12.2
Bryales	8.1	4.0	11.6
Polypodiceae	0.8	2.7	0.9
Redeposited sporomorphs	22.6	27.5	26.3

* The basic sum for calculating the percentage is the pollen total of trees, shrubs and herbaceous plants, excluding redeposited spores and sporomorphs.

taxa are *Pinus*, *Picea*, *Larix* and *Alnus*; pine pollen occurring most numerously is largely destroyed, which can be explained by a distant transport or redeposition. Thus the presence of brushwood and loose park communities in open habitat cannot be excluded.

However, there is no basis to draw a conclusion about the development conditions of boggy soil at site III. In a sample taken at a depth of 4.8 m there occurred individually pollen of: *Pinus*, *Betula*, *Empetrum*, spores of *Bryales*, *Lycopoduim*, *Botrychium*, *Pediastrum*; from redepostion come *Coniferales* older than Quaternary ones, *Tsuga*, *Sequoia* and unidentified grains. This is a spectrum extremely poor with predominating sporomorphs in secondary deposits.

MOLLUSCAN FAUNA OF YOUNG PLEISTOCENE SEDIMENTS

Rich and differentiated molluscan assemblages occur in Quaternary sediments of the Krzeczkowski Stream valley. An interesting succession of these assemblages has been found in two profiles described above, situated close to one another (Fig. 2, I-II). It comprises four elements connected with the particular layers of Pleistocene deposits (Fig. 9, Pl–2–9): gravels, grey muds, silty sands and both rock detritus and loesses. The metioned succession of the fauna was previously presented by S.W. Alexandrowicz and M. Łanczont (1994).

Standard interpretation methods described by B. Sparks (1964), V. Ložek (1964) and S.W. Alexandrowicz (1987) were used in the presented analysis. Species of molluscs have been arranged in such ecological groups (1–10) as in climatic groups (C2-C5). Malacological spectra (MSS/MSI) and climatic spectra (C1) were compiled, respectively (Fig. 9–MS, C1). Additionaly, the climatic index (C_{ind}) was calculated for samples 1–9 as the weighted mean of the values (symbols) of the climatic groups (C2-C5). The number of taxa and of specimens in the particular assemblages is presented by a graph in logarithmic scale (Fig. 9–N).

Four species of snails were found in sandy matrix of gravels at the bottom of the profile of Pleistocene sediments (Tab. 2.1). Three of them are connected with open habitats including *Pupilla muscorum*, a species represented by the most numerous specimens. It is a quite poor fauna typical of a thanatocenose accumulated in a channel facies of a stream or a mountain river.

The fauna of grey muds was studied in 9 samples of three groups (Fig. 9 S): one from the lowermost part of the layer (2), four from its lower part (3) and four from the upper part (4). In the whole layer the assemblage is nearly the same (Tab. 2–2–4). It comprises 33 taxa including 25 species of land snails, 4 species of water snails, 3 species of bivalves and shells of slugs. Species connected with shady or partly shady habitats reach more then 10% of specimens, open country snails — 30–40%, catholic species — 30–50% and water molluscs — a few percent only (Fig. 9, MS–2–4). Each sample contained more than 25 taxa. The following species can be pointed out as the most characteristic components: *Discus ruderatus*, *Vitrea crystallina*, *Arianta arbustorum*, *Perforatella bidentata*, *Carichium tridentatum* and *Vertigo substriata*. There are snails living recently in Central and Northern Europe, connected partly with the continental type of the climate. They are accompanied by a few catholic species reaching recently the north polar circle (*Punctum pygmaeum*, *Nesovitrea hammonis*, *Euconulus fulvus*) and by two taxa typical of cold climate and humid habitats (*Columella columella* and *Vertigo parcedentata*) as well as by numerous shells of a loess snail — *Succinea oblonga elongata*. Water molluscs are found only in this assemblage. Besides species of a wide geographic range, taxa restricted to Central Europe and Southern Scandinavia (climatic group C2) occur in the discussed fauna (Fig. 9, C1).

Another rich assemblage (15 taxa, 320 specimens) has been noted in silty sands filling a small erosional channel (Fig. 2, II/4, Tab. 2,5). It is dominated by snails living in open environments, such as *Pupilla muscorum* and *Vallonia costata* accompanied by snails connected with dry, xerothermical places — *Pupilla sterri* (Fig. 9, MS). Species typical of loess (*Pupilla loessica*, *Vallonia tenuilabris*, *Succinea oblonga elongata*) as well as species described both from the recent fauna of Central/Northern Europe and from the Pleistocene loess series (*Trichia hispida*, *Clausilia dubia*) are an additional, important component of the mentioned assemblage.

The youngest element of the described succession has been distinguished in the rock detritus redeposited by solifluction (Fig. 2, I-II/8) and in the layer of loess, particularly in its lowermost and uppermost parts (Fig. 2, I-II/9). It is a relatively poor fauna (5–10 taxa and 20–60 specimens in a sample) containing snails typical of the cold climate. Open country snails and catholic species connected with humid habitats are the main components of this assemblage. Loess snails such as: *Succinea oblonga elongata*, *Vallonia tenuilabris* and *Pupilla loessica* as well as a few *Trichia hispida* and *Pupilla muscorum* are accompanied by a few taxa noted in loess series only sporadically (*Vallonia costata*, *Punctum pygmaeum*). The occurrence of *Vertigo arctica*, a snails poorly known from the Quaternary sediments in Poland, is noteworthy (Tab. 2, 6–9). Climatic groups C4 and C5 predominate in the mentioned fauna (Fig. 9, C1).

The described sequence of molluscan assemblages can be used for the stratigraphic interpretation of the mentioned profile. The fauna found in rock detritus and in loess is related to the Pleniglacial of the Vistulian. However, it is richer than many assemblages reported from loess series, particularly from the upper younger loess (S.W. Alexandrowicz 1991). An admixture of species living recently at different latitudes (both in temperate and boreal climatic zones) and a low content of taxa typical of dry subarctic steppes suggest, that the discussed sediments were accumulated under not extremely severe climatic conditions, probably during the older part of the Pleniglacial.

The preceding period is characterized by a fauna of grey muds. It is a relatively rich assemblage of open country and catholic species accompanied

Tab. 2. Molluscan fauna of Quaternary sediments

E	Taxon	1	2	3	4	5	6	7	8	9	10	11	12
1	*Discus perspectivus*										I	I	
1	*Discus ruderatus*		II	II	II								
1	*Vitrea diaphana*										I	I	I
1	*Vitrea transsylvanica*												I
1	*Oxychilus orientalis*												I
1	*Carpathica calophana*										I		
1	*Perforatella incarnata*										I		
2	*Semilimax kotulai*			I	I								
2	*Vitrea crystallina*		IV	IV	III						III	III	II
2	*Bradybaena fruticum*				I								
2	*Arianta arbustorum*		I	II	I						I	I	I
3	*Macrogastra tumida*										I	I	I
3	*Vestia gulo*										I		
3	*Perfortella bidentata*		II	II	III						I	I	I
4	*Pupilla sterri*				I	III							
5	*Columella columella*		I	II	I	I							
5	*Vertigo parcedentata*			III	I	II							
5	*Pupilla muscorum*	II	IV	III	III	V	II	III	I	I		I	I
5	*Pupilla loessica*		II	III	I	II	I	I	II	II			
5	*Vallonia costata*	I	V	V	IV	IV	I	III	III			I	
5	*Vallonia pulchella*	I	IV	III	III	II					II	II	III
5	*Vallonia tenuilabris*		I	III	I	III		II					
5	*Euomphalia strigella*											I	I
7	*Cochlicopa lubrica*		III	III	III	I					II	II	II
7	*Vertigo arctica*							II					
7	*Punctum pygmeum*			III	III	I			I				
7	*Nesovitrea hammonis*	I	III	III	III	I			I			I	I
7	*Euconulus fulvus*		II	II	II	I							
7	*Clausilia dubia*		I	III	II	III	I	I	I	I			
7	*Trichia hispida*		II	III	II	III	I	II	II	I	I		
7	*Trichia lubomirski*											I	
7	*Limacidae*		I	II	II			I	I		I		
8	*Carichium tridentatum*		IV	III	II						II	II	II
8	*Vertigo substraatia*		II	I	I								
8	*Succinea oblonga*										II	II	II
8	*Succinea oblonga elongata*		V	V	III	II	III	III	III	III			
9	*Vertigo genesii*		I										
9	*Succinea putris*			I	III								
9	*Zonitioides nitidus*											I	
10	*Lymnaea truncatula*		IV	III	II								
10	*Lymnaea peregra*		II	II								I	
10	*Anisus leucostomus*		II	I									
10	*Gyraulus rossmaessleri*		I	I	I								
10	*Pisidium casertanum*			I									
10	*Pisidium subtruncatum*		II										
10	*Pisidium milium*		I										

E — ecological groups of molluscs (explanations as in Fig. 9); 1–12 — symbols of samples; number of specimens: I — 1–3, II — 4–9, III — 10–31, IV — 32–99, V — 100–316.

by a few taxa of shadow-loving snails and water molluscs. Such a fauna is typical of cold-temperate and boreal climatic zones and can be related to an interstadial characterized by the development of open habitats with clumps of trees and patches of forests as well as with small water bodies at the valley bottom. It can be one of the Early Vistulian warming periods, probably the Brörup Interstadial.

Molluscan fauna of this age was described by A. Makowska (1969) from the profile in Podgłębokie near Lublin. It is dominated by water molluscs with a few species of land snails (*Pupilla muscorum*, *Succinea oblonga*, *Vallonia pulchella*). There are no contradictions in the climatic intepretation of assemblages from Krzeczkowa and Podgłębokie. On the other hand, the molluscan fauna of the Interpleniglacial (the Hengelo and the Denecamp interstadials) is quite different and contains only open country and catholic snails, partly cold-tolerant species. It is completely devoid of taxa connected with forests or even partly shady places (S.W. Alexandrowicz 1987, 1991).

The fauna of silty sands covering muds and underlying the rock detritus (Fig. 9, P1–4, S-5) indicates changes of the environment at the end of the mentioned interstadial. Snails living in shady and partly shady places as well as water molluscs are replaced by open country species with an admixture of xerophile species. The climate becomes more severe but not so cold as in the following Pleniglacial. In consequence this type of the fauna characterizes the transition period closing the interstadial (Brörup Interstadial).

Values of the climatic index grow progressively from the bottom upwards (Fig. 9, C_{ind}). It is an evidence of gradual changes of the climate becoming more and more cold during deposition of the described sequence of sediments.

HOLOCENE SEDIMENTS AND MOLLUSCAN FAUNA ASSOCIATED WITH THEM

A higher inundation terrace (4–5 m) was built by gravel and sandy sediments of channel facies and loamy alluvial soils with contemporary soil at the top. Almost along the whole valley bottom gravels lie on a rock socle on a relative height of 0.5 m (Fig. 5, 7). The lithological features of those sediments were examined in exposures situated at the middistance beetwen the described profiles I and III of the Pleistocene terrace, on the left (Fig. 8-A) and right side (Fig. 8-B) of the stream. In the right-bank terrace section fresh flood sediments with plant remnants occur. An lower inundation terrace (1.5–2 m) occurs in the lower section of the valley,

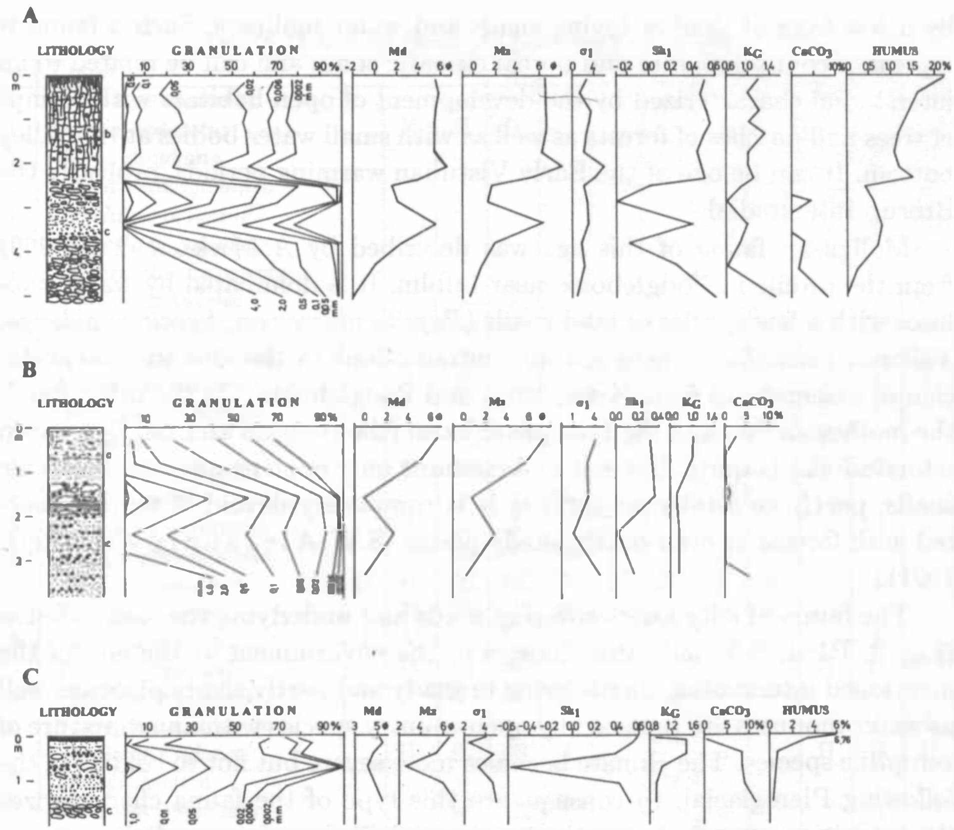

Fig. 8. Lithological profiles of Holocene terraces; A — left-bank terrace 4–5 m high, B — right-bank terrace 4–5 m high, C — terrace 1.5–2 m high

its formation should be associated with destruction of the terrace 4–5 m. A typical profile of this deposits is presented by the Fig. 8-C.

The molluscan assemblage found in gravels and muds forming the Holocene terrace at the bottom of the Krzeczkowski Stream valley contains more than twenty taxa (Tab. 2, 10–12). About a third of them are woodland snails or species living in shady habitats (Fig. 9, MS). The most important are: *Discus perspectivus*, *Vitrae diaphana*, *V. transsylvanica*, *Perforatella incarnata* and *Macrogastra tumida*. Catholic and open country snails are other components of this fauna. The occurrence of *Oxychilus orientalis*, *Carpathica calophana* and *Trichia lubomirski* (snails rarely noted in Quaternary sediments) is noteworthy. The mentioned assemblage is connected with wooded area and temperate climate. Such a fauna can be related to the Atlantic/Subboreal phases of the Holocene and in areas only slighty influenced by the human impact — even to the Subatlantic phase.

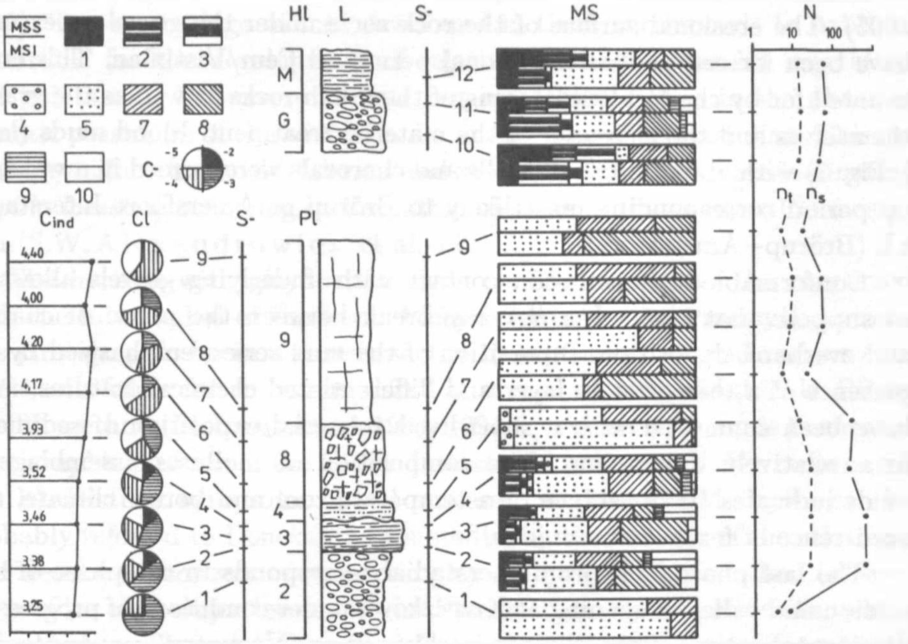

Fig. 9. Molluscan assemblages of Quaternary sediments in the Krzeczkowa Stream valley; L — layers distinguished in profiles. Pl — Pleistocene deposits (2–10 — layers as in Fig. 2-I-II), HI — Holocene deposits: G — gravels, M — muds; S — samples (as in Tab.1); MS — molluscan spectra: MSS — spectra of species, MSI — spectra of specimens, ecological groups of molluscs; 1 — woodland snails, 2 — species of partly shady habitats, 3 — species of moist forests, 4 — xerophile snails, 5 — open country snails, 7 — mesophile species of moderately humid habitats, 8 — mesophile species of humid habitats, 9 — species inhabiting dumps and marches, 10 — water molluscs; Cind — climatic index, Cl — climatic spectra: C2 — species reaching Southern Scandinavia, C3 — Species reaching Middle Scandinavia, C4 — cold-tolerant loess snails; N — number of elements; nt — number of taxa, ns — number of specimens

DEVELOPMENT OF EVENTS

Sediments building the Pleistocene terrace represent the last glacial cycle (Vistulian). That these sediments can be connected with the Vistulian cycle is, besides some suggestions resulting from the succession of fauna, indicated by: their morphological position, geological facts as well as the results of dating by the TL method.

The oldest event registered in the profile of terrace sediments at Krzeczkowa is connected with accumulation of the gravel cover (layer k, Fig. 3, 6) occurring in bottom of the series underlying the loess. Gravels should be referred to the accumulation phase of the earliest Vistulian (L. Starkel 1995). The erosional surface of the rock socle under the gravel cover must have been formed in the transitional period od Eem/Vistulian. This is accounted for by chemical weathering of the flysch rocks as well as the gravels themselves and the character of the material treatment. Flood muds (layer j, Fig. 3) with abundant snail shells and charcoals were formed in a warming up period corresponding most likely to Brörup or Amersfoort Interstadial s.l. (Brörup+Amersfoort).

Conformable sedimentation contact with underlying gravels allows us to suppose that there was not any break between the phase of channel and overbank deposition. Bipartition of the mud series, emphasized by the presence of a thin ortstein layer and differentiated chemical features, must have been connected with a short-lived subaerial exposition of sediments in a relatively dry period. The composition of molluscs assemblage in muds indicates the existance of a temperate cool and boreal climate, and occurrence of forest communities.

The last phase of Brörup Interstadial corresponds to the phase of side erosion and valley deepening at Krzeczkowa under conditions of progressing continentalization of the climate washing in open country was developing. Humus clays (layer i, Fig. 4) consisting of denudated soil material, filled then up the cut off stream channel (Fig. 2, II/4–6). In its surroundings, patches of loose pine-birch communities with spruce and tundra with steppe element occurred (Table 1). It is possible that sediments filling this depression constitute an equivalent of boggy soil in profile III (Fig. 5/7) developing in a higher not flooded part of the valley bottom. A solifluction debris series over alluvial-deluvial deposits (Fig. 2/8) indicates slope degradation in the conditions of cool and wet climate in pre-Pleniglacial phases of Vistulian. Admixture of river gravel is an evidence of alternating longitudinal and transversal transport. Debris solifluction at Krzeczkowa coresponds to deluvial and eolian processes on slopes of the nearest section of the San river valley. These processes resulted in development of the lowest younger loess consisting of fresh loess silt and slope material (M. Łanczont 1991, 1993).

The beginning of subaerial accumulation of loesses on weathered debris cover in the Krzeczkowski Stream valley at initial phases of the Plenivistulian (TL dating 80 ka BP) suggested that the previous bottom zone was transformed to the terrace, which might give evidence of erosion processes. The stratigraphic situation and age of this series of loesses indicate that they correspond to younger lower loess (LMd — layers g_2-d) (Fig. 3) and middle one (LMs — layers c_{1-2}) (Fig. 3). These loesses represent the lower Plenivistulian and Interplenivistulian respectively. Granulometrically, they are similiar to coeval layers in the San River valley (M. Łanczont 1995). The assemblage of molluscs found in them corresponds to habitats favourable for the development of relatively abundant tundra vegetation and points to a less severe climate but more humid than in the phase of climatic pessimum of the Vistulian, i.e. in the upper Plenivistulian. This assemblage differs from cold-tolerant and xerophile fauna (with predominating *Pupilla loessica*) occurring in Carpathian loesses of the younger Plenivistulian (S.W. Alexandrowicz et al. 1991).

The horizon with gleyfication signs on LMd layers can be connected with the interstadial of the lower Plenivistulian. In the Przemyśl environs this stratigraphic horizon is represented by soil sediments and various subarctic soils fairly rich in humus, dated at several sites for about 50 ka BP by the TL method (M. Łanczont 1993, 1994b), which corresponds to chronostratigraphic position of the Glinde Interstadial (compare H. Maruszczak 1991b). Distinct symptoms of soil processes in the top LMs layers can be probably referred to Denekamp Interstadial by the analogy of the relatively well developed horizon of subarctic gley or brown soil, described in several profiles of younger loesses in the Przemyśl Carpathian Foothills, which was dated by TL and ^{14}C method for about 28 ka (M. Łanczont 1993). Lack of younger upper loesses (LMg) in Krzeczkowa profile I can be connected with Holocene earth slide processes; layers of this loess must have been incorporated into the colluvial cover (layer a_1, Fig. 3).

Holocene sediments in the rendzina terrace in the Krzeczkowski Stream valley bottom can be connected with transition period from Atlantic to Subboreal phase; the fauna from gravels and alluvia represent an association of one type, characteristic for Carpathian forest habitats of the middle Holocene.

The course of events recorded in the younger Pleistocene terrace sediments at Krzeczkowa differs from that described in the nearby Stupnica river valley (right-bank tributary of the San west of Krzeczkowa), where rock socle is covered with slope loam containing single gravels (A. Henkiel, K. Pękala 1963), as well as in smaller valleys of the upper San river basin, where on rock socle a series, sometimes bipartite, of periglacial gravels, covered with solifluction debris and proluvial loam is noted (L. Starkel 1965).

CONCLUSIONS

1. The obtained results indicate that the terrace of the Krzeczkowski Stream corresponds to the younger Pleistocene low terrace distinguished in bigger valleys of the Carpathian part of the San River basin.

2. In the deposits of the Pleistocene terrace at Krzeczkowa, a site of molluscan fauna is found, which is unique in the Carpathian part of the San basin. This fauna represents the period of the early Vistulian together with Brörup Interstadial (assemblage with *Discus ruderatus*, *Vitrea crystallina* and *Vallonia tenuilabris*), as well as older Plenivistulian phases. Fauna successions are characterized by progressing evolution of climate more and more cold at the deposition time of sediments.

3. Sediments of Holocene rendzina terrace contain fauna with *Discus perspectivus*, *Vitrea diaphana* and *V. Transsylvanica* corresponding to the Holocene middle part and areas with a very small influence of human activity.

4. The sequence of early glacial debris solifluction and eolian Pleniglacial deposits at Krzeczkowa is representative for smaller valleys of the Przemyśl Carpathian Foothills. Such sequences occurred not only in the Vistulian glacial cycle but also of older glaciations, particularly in that of the Wartanian and Odranian (=Saalian s.l.). Thus at Krzeczkowa, in the Vistulian glacial cycle, we can find an arrangement of layers with features intermediate between those characteristics for higher hypsometric levels of Flysch Carpathians with solifluction-proluvial accumulation (A. Henkiel 1966, L. Starkel 1965) and the marginal zone of the Carpathians with evidence of intensive eolian action (T. Gerlach et al. 1993).

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STRESZCZENIE

W dolinie Krzeczkowskiego Potoku (ryc. 1), w przemyskim odcinku Pogórza Karpackiego, występuje jedna terasa nadzalewowa o wysokości względnej 10–12 m (ryc. 2, 5, 7). Budują ją osady zawierające liczne szczątki ślimaków, dobrze zachowane. Szczątki malakofauny stwierdzono także w osadach holoceńskich, wypełniających dno doliny. Utwory terasy nadzalewowej i zalewowej opracowano pod względem litologicznym (ryc. 3, 4, 6, 8), malakologicznym (ryc. 9, tab. 2) i palinologicznym (tab. 1).

W budowie terasy nadzalewowej wyodrębniono trzy podstawowe człony sedymentacyjne osadów młodoplejstocenskich: 1) żwiry korytowe, mułki powodziowe i złożona seria glin aluwialno-deluwialnych, związane z okresem od najwcześniejszego vistulianu do schyłku interstadału brörup; 2) wczesnoglacjalne osady stokowe pochodzenia soliflukcyjnego; 3) subaeralne lessy facji deluwialno-koluwialnej, reprezentujące dolny pleniglacjał (LMd) i interplenivistulian (LMs). W szczegółowo zbadanym profilu Krzeczkowa I brak lessów młodszych górnych (LMg), co można wiązać z degradacją holoceńską podczas procesów osuwiskowych. Być może resztki tego lessu kryją w sobie osady koluwialne pokrywające zbocze.

Z paleogeograficznego punktu widzenia istotne znaczenie ma bogaty zespół malakofauny w mułkach powodziowych terasy nadzalewowej. Skład fauny (*Discus ruderatus*, *Vitrea crystallina*, *Vallonia tenuilabris*) z gatunkami środowiska zacienionego, wskazuje na klimat umiarkowany, chłodny i borealny. Zespół tej fauny (tab. 2) odbiega od tych, które charakteryzują fazy ociepleń w ciągu młodszego vistulianu (hengelo-denekamp). Fauna (*Succinea oblonga elongata*, *Vallonia tenuilabris*, *Pupilla loessica*, *Trichia hispida* i *Pupilla muscorum*) znaleziona w osadach stokowych i lessach wskazuje na klimat dość wilgotny i zimny, ale nie ekstremalny oraz środowisko sprzyjające rozwojowi stosunkowo obfitej wegetacji tundrowej. Sukcesja faun wskazuje na postępującą ewolucję klimatu coraz bardziej zimnego w czasie depozycji osadów. Opisana sekwencja utworów wczesnoglacjalnej soliflukcji gruzowej i pleniglacjalnych osadów eolicznych w Krzeczkowej jest reprezentatywna dla mniejszych dolin Pogórza Przemyskiego. Sekwencje takie występowały nie tylko w cyklu glacjalnym vistulianu, ale także w czasie zlodowaceń starszych, a szczególnie wartanianu i odranianu (= saalian s.l.).

Osady holoceńskiej terasy rędzinnej zawierają faunę z *Discus perspectivus*, *Vitrea diaphana* i *V. transsylvanica*, odpowiadającą środkowej części holocenu i obszarom leśnym ze znikomymi oznakami działalności człowieka.