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[1]Institute of Geochemistry, Mineralogy and Petrology,
Faculty of Geology of the Warsaw University
[2]Institute of Geology, Faculty of Geology of the Warsaw University
[3]Institute of Geography, I. Franko University in Lvov
[4]Institute of Geologic Sciences of the National Academy of Sciences of Ukraine, Kiev
[5]Institute of Earth Sciences, Maria Curie-Skłodowska University in Lublin

ROMAN CHLEBOWSKI[1], LESZEK LINDNER[2], ANDRZEJ BARCZUK[1],
ANDREY BOGUTSKY[3], PETRO GOZHIK[4], MARIA ŁANCZONT[5],
JÓZEF WOJTANOWICZ[5]

Accumulation conditions of the younger upper loess of Sandomierz Basin, Mid-Carpathian Foreland and Podolian Upland (border between SE Poland and NW Ukraine) on the basis of the geological and mineralogical studies

Warunki akumulacji lessu młodszego górnego na obszarze Kotliny Sandomierskiej, Pogórza Karpackiego i Wyżyny Podolskiej (pogranicze SE Polski i NW Ukrainy) na podstawie badań geologicznych i mineralogicznych

INTRODUCTION

The aim of the recent study is an attempt at determination of the conditions of accumulation of the upper younger loess from the period of the last glaciation in the area of the Sandomierz Basin, Mid-Carpathian Foreland and the western part of the Podolian Upland (Fig. 1). This research is a continuation of the studies concerning the upper younger loess of the Lublin Upland and Volhynia Upland (Chlebowski et al. 2003a) and the earlier investigated upper younger loesses of the Małopolska Upland (Chlebowski and Lindner 1992) and the Middle Dnieper drainage basin (Chlebowski et al. 2000).

The present elaboration was performed as a part of the Grant of the Polish Research Committee (KBN) No 6PO4 E02918 on the basis of the geological analysis of 20 loess logs (1–20 in Fig. 1), from among which two, i.e. Charna (point 16 in Fig. 1) and Łokitka (point 18 in Fig. 1) till present have no complete elaborated lithological profiles, however, in these two cases, like in all others, it was possible to collect the loess samples for the mineralogical studies. The samples from 6 sites of the older sediments (items 21–27 in Fig. 1) outcropping in the investigated area were taken and investigated as well. Mineralogical characteristics of the dust fraction (0.020.063) of the upper younger loess (LMg according to the terminology of Maruszczak 1991) on the basis of the heavy minerals and certain components of the light fraction was the main subject of the elaboration. In the area of Ukraine this loess is named Bug Loess (Veklich 1979). Its mineralogical characteristics was performed according to the earlier proposed method (Chlebowski et al. 2002) and its results were presented in a form of histograms showing the percentage of each transparent heavy mineral against the background of the strip logs with the marked places of sampling for the studies (Figs 2–19). Detailed contents of all the components of the heavy mineral group and selected components of the light fraction for each studied sample were given in Table 1; moreover for the interpretation purposes the radar plots (Figs 20–26) were made by the computer technique for the mineral groups derived from all transparent heavy minerals. Such studies were mentioned earlier (Chlebowski et al. 1999). In certain cases they refer to the simultaneously performed studies of the heavy mineral compositions in certain complete loess profiles of this area (Racinowski et al. 1999).

GEOLOGIC-GEOMORPHOLOGICAL SITUATION OF THE STUDY AREA

The described area comprises Sandomierz Basin, Mid-Carpathian Foreland and the western part of the Podolian Upland. The surface of these units is to a higher or lower degree covered by loess patches. The uppermost (youngest) part of these patches, best accessible in the terrain studies, consists of the upper younger loess connected (by its age) with the full development of the last glaciation (Vistulian = Valdaynian).

SANDOMIERZ BASIN

Sandomierz Basin (SB in Fig. 1) is a part of the Mid-Carpathian Foreland, a peripheral deep fore-mountainous basin of complicated geological structure,

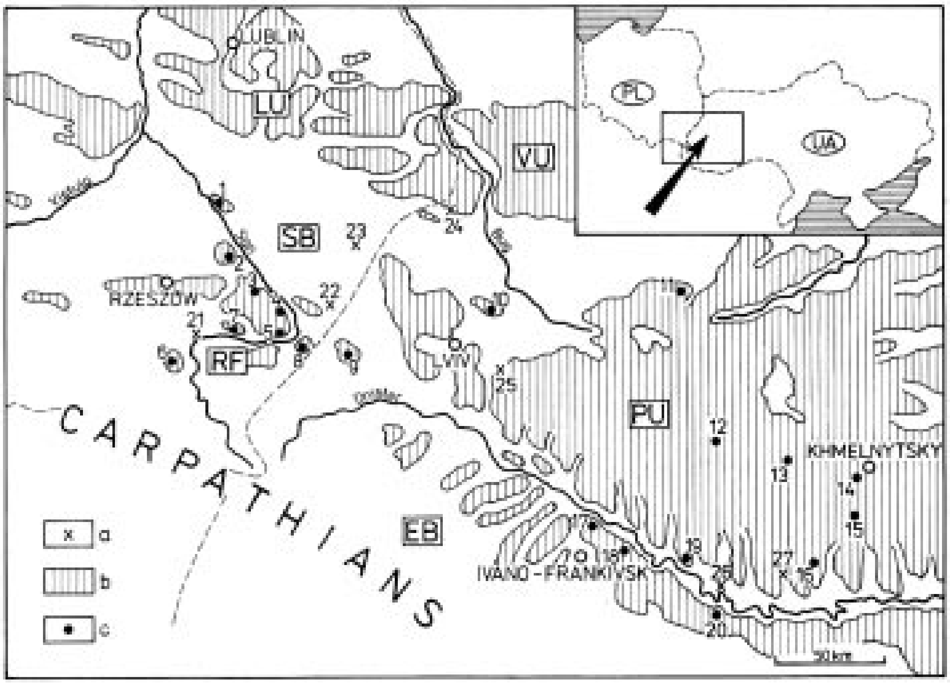

Fig. 1. Main areas of occurrence of loesses in south-east Poland and north-west Ukraine; LU – Lublin Upland; VU – Volhynian Upland; SB – Sandomierz Basin; RF – Rzeszów Foreland; EB – Eastern Beskidy; PU – Podolian Upland; a – analysed points of occurrence of the rocks and sediments of the loess bedrock: 21 – Chodorówka, 22 – Żmijowiska, 23 – Radruż, 24 – Przemysłów, 25 – Bibrka, 26 – Zalishchyky, 27 – Skała Podolska; b – loess; c – analysed logs: 1 – Krzeszów, 2 – Grodzisko, 3 – Jarosław, 4 – Radymno, 5 – Buszkowice, 6 – Humniska, 7 – Babice, 8 – Siedliska, 9 – Mostyska, 10 – Novo-Milatyn, 11 – Kulychyvka, 12 – Zbarazh, 13 – Podvolochysk, 14 – Sharovechka, 15 – Yarmolynce, 16 – Charna, 17 – Halych, 18 – Lokitka, 19 – Ustechko, 20 – Tovtri

Główne obszary występowania lessów na obszarze SE Polski i NW Ukrainy; LU – Wyżyna Lubelska; VU – Wyżyna Wołyńska; SB – Kotlina Sandomierska; RF — Przedgórze Rzeszowskie; EB – Beskid Wschodni; PU – Wyżyna Podolska; a – analizowane punkty występowania skał i osadów podłoża lessowego: 21 – Chodorówka, 22 – Żmijowiska, 23 – Radruż, 24 – Przemysłów, 25 – Birbka, 26 – Zalishchyky; b – lessy; c – analizowane profile lessowe: 1 – Krzeszów, 2 – Grodzisko, 3 – Jarosław, 4 – Radymno, 5 – Buszkowice, 6 – Humniska, 7 – Babice, 8 – Siedliska, 9 – Mościska, 10 – Novo-Milatyn, 11 – Kulychyvka, 12 – Zbarazh, 13 – Podvolochysk, 14 – Sharovechka, 15 – Yarmolynce, 16 – Charna, 17 – Halych, 18 – Lokitka, 19 – Ustechko, 20 – Tovtri filled by syn- and post-orogenic sediments. Its development took place in connection with the Miocene stage of evolution of the arc of the external Carpathians. The older internal part of the basin is filled by Miocene sediments of the molassa complex in full development, being intensively folded (Oszczypko 201). Presently these sediments occur beneath the Carpathian nappes and in front of the Flysch Carpathian overthrust, with extensive occurrence to the south of the city of Przemyśl. Two allochthonous units formed from these displaced sediments. These are the Stebnik Unit (with the thickness of 2200 m) belonging to the Lower and Middle Miocene and the Zgłobice Unit, formed by the Badenian-Sarmatian sediments, analogous to the autochthonous sediments of the same age (Kotlarczyk 1988). The youngest sediments of the Stebnik Unit are evaporates (gray-green mudstones with intercalations of gypsum and anhydrite) and Radyce conglomerates formed from the Carpathian material. Beds of the Stebnik Unit are widely developed in the area of Ukraine and they occur in two zones of the Mid-Carpathian Foreland: the Borysław-Pokucie and Sambor zones (Garecka, Olszewska 1997). External part of the Mid-Carpathian Foreland is filled by unfolded Middle Miocene marine sediments of the thickness of several hundred to several thousand meters. The beds filling the deep-sea part of the foreland are almost horizontal, and the thickness of their youngest unit, the Krakowiec clays, forming the pre-Quaternary bedrock, ranges from 1,100 to 1,500 m (Oszczypko 2001).

The Quaternary sediments form in this area almost continuous cover. In the heights between the valleys there occur the covers of the preglacial gravels. The border of the maximal extent of the continental San 2 glaciation (= Oka glaciation), which passed over the European continental divide and reached the right side of the Dniestr River, occurs in this area. The presence of this continental glaciation within the Carpathian valleys caused formation of the moraines, fluvioglacial sands and gravels, and marginal lake clays (Diemiediuk, Diemiediuk 1995; Przepiórski 1938, Łanczont et al. 1988; Teisseyre 1938; Wojtanowicz 1978). These sediments are usually covered by a sheet of the sediments of the younger part of Pleistocene, mostly loesses and loess-like formations. In the area of the Sandomierz Basin loesses occur mainly within the borders of the Kańczuk [?] Heights, hence frequently called the Fore-mountainous Loess Upland. These sediments form a common cover including the so-called middle (loess) terrace on the right side of the San River. The cover consisting of these sediments is thick, though the thickness is variable: from few to 20 meters (Malicki 1973). It is formed mainly by the younger loesses. In the zone between the San River and Dniestr River, the typical loesses were found rarely, instead there occur the dusty loess-like sediments. In this area the dusty sediments of the Upper Vistulian age have limited extension (Bogutsky et al. 1999a). In the remaining area loesses are the main type of the Pleistocene sediments in addition to the alluvial ones. The loesses cover the zones of the drainage divides and the vast surfaces of the terrace plains of the Dniestr River and its Carpathian tributaries. Thicknesses of the loess deposits are significant, with the maximum of the loess cover thickness of 50 m in the region of Halicz. The loesses are stratigraphically variable.

The Sandomierz Basin has the shape close to a triangle, with its longest WE side reaching 230 km, and its height of 90 km. The Carpathian overthrust is the southern border of the basin, marked in morphology by the structural-denudation threshold of Forecarpathian Plateau. The other borders are delineated in NE by the edge of the Lublin Upland and Roztocze with tectonic features and the erosion edge of the Małopolska Upland in NW. In the area of the Sandomierz Basin two main types of the earth's surface morphology occur. These are the fore-mountainous and central plateaus of the relative height of 40 to 80 meters and plains of the aqueous accumulation. The plateaus occurring in front of the Carpathians form a ledge of bulges of small relative differences in heights, usually reaching 150 to 210 m a.s.l., cut by a network of the valleys to the depths of 40 to 80 m. The width of the Kanczuga Plateau ranges from few to 30 km (Malicki 1973). The central plateaus form relatively compact belt of the heights cut by the valleys of the Carpathian rivers. The dimensions of the plateaus decrease westwards and their height decreases northwards. The divides and valleys contact along distinct edges 30 to 60 meters high. Within the plains of the water accumulation there occur the flood and above-flood (Holocene) terraces at the height of 150 to 210 m a.s.l, and the plains of the accumulative and erosion-accumulative (Pleistocene) terraces of the relative heights of 10 to 20 m (Wojtanowicz 1978).

MID-CARPATHIAN FORELAND

The western part of the Mid-Carpathian Foreland is called the Rzeszów Foreland (RF in Fig. 1), comprising Dynów Plateau and Przemyśl Plateau. This area is almost completely built of flysch beds of the Skole Unit, consisting of a series of scales and folds. The folds are frequently overthrusted. This overthrust tectonic style of this unit is best developed in the area to the east of the San River, where the steep folds of the nappe contain beds of Upper Cretaceous and the complete log of Paleogene (Alexandrowicz 1999). The calcareous beds of the Upper Cretaceous age, belonging to the typical flysch formation of Ropianka and including siliceous marls, Baculites marls from Węgierka, sandstone-shaly series of the Inoceramus beds are the main petrographic types of the rocks in this area. They are associated with non-flysch and non-calcareous black shales of Lower Cretaceous and younger, Tertiary (Eocene–Oligocene) sediments: menilite and hieroglyph beds and motley shales. The exotic Jurassic rocks, so-called Kruhel limestones of the Sztramberk type (Gucik, Wojcik 1982; Kotlarczyk 1988) occur in the flysch rocks of the marginal zone of the Skole Unit. To the west from the San River valley, the regular folds with the preserved flanks occur; in this area the beds of the Krosno Formation, the youngest lithostratigraphic unit of the flysch (Oligocene–Miocene) are increasingly common. In the region of Dubiecko, Bachórzec and Olszany there occur numerous patches of marine and brackish sediments of the Badenian age as the folded transgressive cover. They consist of the calcareous clayey shales intercalated by crumbling sandstones (Oszczypko 2001). In the southwest the area of the recent studies is built from the rocks of the Silesian and Sub-Silesian Units. The narrow stripe of the Sub-Silesian Unit rocks is formed by narrow, deformed overthrusted folds formed from motley shales and Węgłowice marls. The Paleogene complexes of the Silesian Unit have regular folded structure with broad synclines separated by steeply heaped anticlines The Krosno beds consisting of gray calcareous mica-bearing sandstones and gray marly shales are the most important components of this unit (Gucik, Wójcik 1982).

Among the Quaternary deposits, whose occurrence here is not common, one may distinguish the till and till-debris weathering and solifluction covers, related by their lithological features to the bedrock, covering the summits and slopes, and other deposits like deluvial (slope wash), frequently loess-like covers, and the colluvial ones. Thicknesses of these covers are not large, ranging from few to 8 meters. Glacial and fluvioglacial sediments form a separate group of deposits of limited extensions. From among the continental (lowland) glaciers only that of the South-Polish glaciation (San 2) covered the marginal part of the Carpathians, leaving there moraines up to the level of 420 m a. s. l., and entered with a lob the San River valley more than 10 km upwards (Klimaszewski 1936). In the area between the San and Dniestr Rivers it left well-preserved features of the glacial erosion and accumulation (Bogutsky et al. 2002). Sediments connected with this lob occur residually as boulders of the Scandinavian rocks, frequently in the secondary deposit, and small patches of moraine tills of limited thickness, which are usually hidden under younger Pleistocene deposits. Aeolian loesses, belonging to the southern periphery of the extension of these deposits in Poland, are relatively widespread in the Forecarpathian Plateau (Łanczont 1995). They occur up to the height of 280 or even 320 m a.s.l. as irregularly scattered patches of the average thickness of 3 to 5 meters. The most extensive of them, having the thickness even up to 20 m are linked with the Pleistocene terraces in the valleys of larger rivers, especially of San River, where they overlay the alluvial series on the rock ledges. The dust beds of the main phase of accumulation in the upper part of the Vistula periglacial have the dominating importance. The aeolian series on the terraces occur together with the solifluction-deluvial (slope wash) covers or were replaced by the latter.

The Przemyśl and Dynów Plateaus differ both morphologically and in their landscapes. The Przemyśl Plateau has many features of its structural sculpture of the resequent type, with the series of parallel N–S ridges reaching the heights of 500 to 600 m a.s.l., and separated by narrow and deep valleys. In the Dynów Plateau the features of the structural sculpture are poorer preserved. This area is lower (the maximal heights exceed slightly 400 m a.s.l.) and represents a massive, compact upland patch, which upper surface is a flat irregularly cut summit (Henkiel 1977/78). The ridges are even and broad and denivelations range from 80 to 250 m (Malicki 1973). The stepwise structure of the Earths surface sculpture is the most characteristic feature of the landscape of this zone of the plateaus. It is influenced by the peneplena dated for Upper Pliocene, developed at the relative height of 180 to 210 meters (380 to 410 m a.s.l.). Above this surface, at the heights of 450 to 600 m a.s.l., the fragments of the Lower Pliocene mid-mountainous level are preserved, and below this surface, from 60 to 100 meters above the bottoms of the main valleys, the valley-related and near-valley level developed in Quaternary (Starkel 1965, Zuchiewicz 1995). Bottoms of the river valleys, especially that of the main river of San, are another characteristic component of the Earths surface sculpture. Valley of the San River consists of two essential segments of different directions: close to N–S to Dynów and almost exactly W–E between Dynów and Przemyśl. Especially in the second segment the valley is very sinuous. In this segment there are short parts of the gorge type and longer ones of the shape of troughs with Pleistocene terraces (Klimaszewski 1967). The system of the Pleistocene terraces is not uniform. Essentially four terraces of the Pleistocene age occur, which are best developed in the valley of the San River. These terraces preserved accumulation covers on the rock ledges. The terraces have the relative heights: 75–80 m, 40–60 m, 20–35 m and 12–17 m.

The area of the East Beskidy Foreland (EB in Fig. 1) forms the eastern part of the Mid-Carpathian Foreland. It may be considered as the intermediate zone between the mountain ridge and Podolia plains, comprising plateaus relatively deeply cut by the valleys of the Carpathian rivers. In the geomorphological classification three main units of the Forecarpathians are distinguished: Near-Beskidy Forecarpathians, Near-Gorgany Forecarpathians and Pokucie-Bukowina Forecarpathians (Krawczuk 1999). Within these units two main types of the morphology are most important: the denudation-accumulative uplands and alluvial plains in valleys and dales, which might develop according to tectonic zones (e.g. the Upper Dniestr Basin or Stanisławów-Bystrzyca Basin). In the zone between San and Dniestr Rivers (Near-Beskidy Forecarpathians), there occur the elements of the old-glacial Earths surface sculpture with glacial and fluvioglacial forms (Bogutsky et al. 1999b). Flat and vast drainage divides and broad valleys of the rivers flowing down from the Carpathians to Dniestr River are the most impressive features of East Beskidy Foreland (Teisseyre 1933). These valleys usually formed along the relatively major tectonic discontinuities occurring in the basement of the Mid-Carpathian Foreland (Krawczuk 1999). The river valleys and the terrains between them have the directions SW – NE. The summit plains, occurring at the heights from 300 to 550 m a.s.l., form two main morphological levels, defined already by Teisseyre (1933). The upper morphological level, called the level of Krasna (Hofsztejn 1962), is dated for Late Pliocene, is preserved in fragments and its average height ranges from 100 to 160 m. Usually about 30 to 50 m lower there occurs the level of Łojowa, related to Early Quaternary; it occurs commonly and is the main landscape feature in the East Beskidy Foreland. The covers of the impoverished Carpathian gravels lay in many places on these levels. They are the oldest and uppermost terraces of the Dniestr River: the seventh one and the sixth one, located outside the margins of the river valley itself. Younger, Meso- and Neo-Pleistocene river terraces are typical forms formed within valleys, being developed along rivers. These are the terraces: the fifth (50–70 m of the relative height), the fourth (up to 45 m), the third (15–25 m) and the second one (5–8 m). The first terrace (2.5–5 m) is of Holocene age.

WESTERN PART OF THE PODOLIAN UPLAND

Western part of the Podolian Upland (PU in Fig. 1) is located between the middle part of the Dniestr River, upper part of the southern Bug River and partly in the drainage basins of the tributaries of the upper Pripiat River. Its border with the Eastern Carpathian Foreland is distinctly marked in morphology and generally it follows the tectonic discontinuities and flexures, which separate the Forecarpathian Depression and the SW margin of the East-European Platform (Krawczuk 1999). Locally deep chasm valley of the Dniepr River is considered as the natural border of these two regional units, albeit the Podolian landscapes comprise the stripe occurring on the right side of the Dniestr River, included to the Pokucie area. In the north, the western part of the Podolian Upland borders with Volhynia, and in the west it extends to the city of Lviv, to the elevation of Roztocze. The borders of Podolia are quite well outlined by the level of 300 m a.s.l. (Lencewicz 1937).

The consolidated bedrock of the Quaternary deposits, mainly of loesses, consists of Proterozoic and Early Paleozoic crystalline rocks, covered by Paleozoic, Cretaceous and Tertiary sedimentary rocks. Thickness of this sedimentary cover increases from the east to the west according to the inclination of the surface of the lowering of the crystalline basement toward the Forecarpathian Depression (Gerenczuk et al. 1964). Close to the pre-Quaternary surface there occur the Cretaceous sediments, having the largest thickness in the western part of the Podolia Upland (near Opole), according to the tectonic Halicz-Volhynia concave structure (Gerenczuk et al. 1964). The Cretaceous deposits of the Podolia Upland consist of two main facial-stratigraphic complexes. The first one comprises the beds of the Albian and Cenomanian age, having the largest extension. Lithologically they are organodetritic limestones and gaizes. The second complex is of Late Cretaceous age, and it consists of gray, light gray and white marls, sandy marls, limestones and sandstones (Gerenczuk 1972). The rocks of the Cretaceous age and the older ones (Jurassic and Devonian) outcrop e.g. in the high steep slopes of the valleys of Dniepr River and its major tributaries. Various types of rocks of the Tertiary age occur locally at the Podolian edge of the East European Platform and they are genetically connected with the development of the Miocene molassa sedimentation in the Forecarpathian Depression. Gypsum is the important component of these sediments.

Pleistocene sediments cover the area of the western part of the Podolian Upland with almost continuous though not very thick layer. They are only absent on the steep slopes of the area adjacent to the Dniestr River and within certain denudation forms. Loesses dominate in the Pleistocene deposits, covering terrains between rivers and weakly inclined slopes of the valleys, frequently with terraces; their thickness varies from few to 20 meters. Gravels forming terraces of the Dniestr River and its tributaries are another important type of the sediments forming covers. The higher terraces accumulated gravels consisting of the resistant rocks of the Carpathian Flysch (sandstones, quartzites, siliceous rocks), the lower ones are covered with gravels of the local rocks (Devonian sandstones, Silurian limestones, Cretaceous black flints).

The western part of the Podolian Upland is a plain terrain (Lencewicz 1937). An isolated rocky limestone ridge is a peculiar feature of its central part. It rises above the summit plains ca. 40 to 60 meters, extending from NNW to SSE, paralelly to the edge of Carpathians. This ridge is called Tovtry (or Miodobory); its width varies from 2 to 8 km and its length reaches more than 200 km. It is the relic of the barrier reef of the Beogene sea (Gerenczuk et al. 1964). The ridge is built from lithothamnium and coral limestones, susceptible to development of karst forms like caves and niches. Morphostructural image of the Podolia Upland was dominated by intensity of the development of the erosion processes. The Podolia Upland of the extension from NW to SE is a plateau consisting of a number of parallel flat or weakly hilly drainage divide stripes extending from the north to the south in accordance to the river directions. The maximal heights reach 450–470 m a.s.l. The network of rivers and dry valleys (called "balkas") is well developed. (Czyżewski 1972). The occurrence of the very deep valleys (more than 100 m) of the chasm or gorge type with distinct edges of the slopes and flat accumulation bottom is typical of the area adjacent to the Dniestr River. A whole series of the terraces (I–VII) occurs in the valley meanders (Hofsztejn 1960). The features of karst, both underground (caves) and surface ones (sink holes, dolinas, karst valleys) are characteristic of the region of the Tertiary gypsum and anhydrite occurrence (Peryt et al. 1994).

OUTLINE OF THE METHODS OF THE MINERALOGICAL STUDIES

The procedures and methods earlier elaborated (Chlebowski et al. 2002) were applied both for sampling and in all the laboratory and microscope investigations for obtaining the results comparable to the previous mineralogical research of loesses from the Lublin and Volhynia Uplands (Chlebowski et al. 2003a). Loess logs, sampled for the mineralogical studies (two samples from each), were numbered from 1 to 20 (Fig. 1). The numbers 21 to 27 in the same figure indicate the places of sampling of the bedrock occurring on the surface in the investigated loess area or closely to it. The latter are lithologically variable, represented by weathering wastes of shales and Krosno sandstones (Chodorówka – No. 21 in Fig. 1), aeolian-deluvial (slope wash) sands and dusts (Żmijowiska – No. 22 and Raduż – No. 23 in Fig. 1, moraine tills (Przemysłów – No. 24 in Fig. 1), Miocene sands (Bibrka – No. 25 in Fig. 1), river and deluvial-slope sands of early Wartanian (Zalishchyky – No. 26 in Fig. 1) and Older Quaternary green sands (Skała Podolska – No. 27 in Fig. 1).

Like in the case of the samples from the Lublin and Volhynia Uplands, here the mineralogical investigations were performed on the granular preparations of both heavy mineral and light fractions. The studies of the light fraction intended to obtain the additional information on the minerals whose densities may be variable and may be close to the density of the used heavy liquids or even lower, as for muscovite and glauconite (Krzowski 1993). Such minerals may thus occur in part or even as a whole not in the heavy fraction. The evaluation of the carbonate contents and recognition of the presence of microfossils (mainly foraminifers) or their remnants was made in the light fraction. The presence or absence of these components was marked in the appropriate columns of the tables summarizing the contents of the heavy minerals. The studies of the heavy fraction led to identification of all the mineral components, which were the basis of the distinguishing of the mineral groups (I–V according to the scheme presented earlier, see Chlebowski et al. 2002). Because in the next part of the present elaboration the authors will refer to these groups many times and they will be the basis of the graphical constructions (Figs 20–26) yielding the genetic interpretations of the investigated loesses, the authors will present below the detailed characteristics of these groups as it was done for the loesses of the earlier investigated uplands (Chlebowski et al. 2003a).

The mineral groups (I–V) were distinguished among the identified transparent heavy minerals according to various criteria this way, that the minerals of similar physical features like resistance or susceptibility to the weathering factors, should be included in one group of those numbered from I to I–V; the group V comprised the minerals of the flaky habit, which causes the good susceptibility to the aeolian factors (removal and transport by wins). The detailed classification of the transparent heavy minerals identified in loesses in the groups IV is shown in Tables 1–3. The minerals most resistant to the weathering factors were included in the **group I**; they may survive several sedimentation cycles. Minerals resistant to the weathering factors, however in a lesser degree than the minerals of the group I are in the **group II.** Minerals poorly resistant to the weathering factors which may be crushed easily are in the **group III**; they cannot sustain any long transport, being thus good indices of the close source of their primary occurrence. The minerals least resistant to weathering (both physical and chemical), and being very sensitive to changes of the geochemical properties of the environment of their occurrence which may cause their decomposition and may influence their physical (the optical ones inclusively) and chemical features, were included in the **group IV**. Minerals of this group, mainly glauconite, like the minerals of the group III (amphiboles and pyroxenes) are exceptionally good indices of the source and origin of the clastic material. The **group V** comprises the heavy minerals of tabular or flaky habit, which causes that they are more susceptible to blowing out and aeolian transport; mica minerals (muscovite and biotite) and chlorite are here the most common components.

The population of the heavy minerals usually is abundant in opaque minerals, which all were included in the **group VI**, not considered in the present elaboration.

The distinguished groups (I–V) of the transparent heavy minerals presented above were the basis of the graphic presentation of the concentrations of these minerals in loesses and genetic interpretation of these deposits (Chlebowski et al. 2002). The graphic constructions in the form of the five-axial radar plots are presented in Figs 20–26. They made possible on the one hand to characterize the individual loess logs, and on the another one to compare the studied samples with the loess samples of other regions (Chlebowski et al. 2002, 2003a. b).

DESCRIPTION OF THE LOGS

Loess log Krzeszów (No. 1 in Fig. 1)

The loess log at Krzeszów occurs in the area of the Sandomierz Basin on the right side of the San River near the edge of the Tarnogród Plateau. It is localized in the northern side of the upper part of the "Church" Ravine and it was described by Wojtanowicz (1971, 1997). It cuts relatively small loess patch of the thickness of 14.5 m.

These loesses lay on fluvioglacial sands and tills of the Odranian Glaciation; loess-like muds and Miocene Krakowiec clays occur below the sands. For the present elaboration the uppermost part of this log, comprising the younger upper loess of the Vistulian Glaciation (V3 in Fig 2) of the thickness of 7.0 m was cleaned and sampled. This loess has vertical jointing and distinct porosity, its colour is light-yellow, the calcium carbonate content is within the ranges of 6 to 8%. Lower parts of this loess contain significant amounts of sand. Two samples for the mineralogical studies were taken from this loess. The upper sample Krz 1 comes from the depth of 3.0 m and the lower one Krz 2 – from the depth of 4.0 m below the terrain surface formed by he recent soil H of the thickness of 0.6 m. The fraction from 0.05 to 0.01 mm dominates in this loess (43–47%), whereas the fraction > 0.1 mm occupies 4.9%.

The composition of the heavy minerals in the both samples is relatively different, which is expressed by very high content of the flay minerals, mainly biotite, in the mineral composition of the first sample and a distinct prevalence of garnets in the second sample. Micas (group V) and garnets (group II) clearly prevail over all the other transparent heavy minerals and their different contents in the both investigated loess samples may be caused by the secondary factors. These might have been the diagenetic processes which caused degradation of a part of garnets *in situ* in the deposited sediment in places of an intensive activity of the exogenic factors (sample Krz 1). A phenomenon of blowing out of the earlier deposited dusty sediment might have occur (sample Krz 2), causing removal of the lighter and more susceptible to deflation flaky minerals (micas inclusively), accompanied by simultaneous relative enrichment of these parts of loess in minerals of larger density (i.e. heavier) like garnets.

The other components of the heavy fraction, i.e. the minerals resistant and very resistant to the weathering factors, occur in both samples in similar amounts, similarly to the less resistant minerals (amphiboles and pyroxenes) and the not resistant ones (glauconite).

Significant amounts of carbonates were found in the studies loesses, though they are distributed in the log rather non-uniformly, being much more abundant in the sample rz 1, like the relatively common shells of carbonate microfossils (foraminifers).

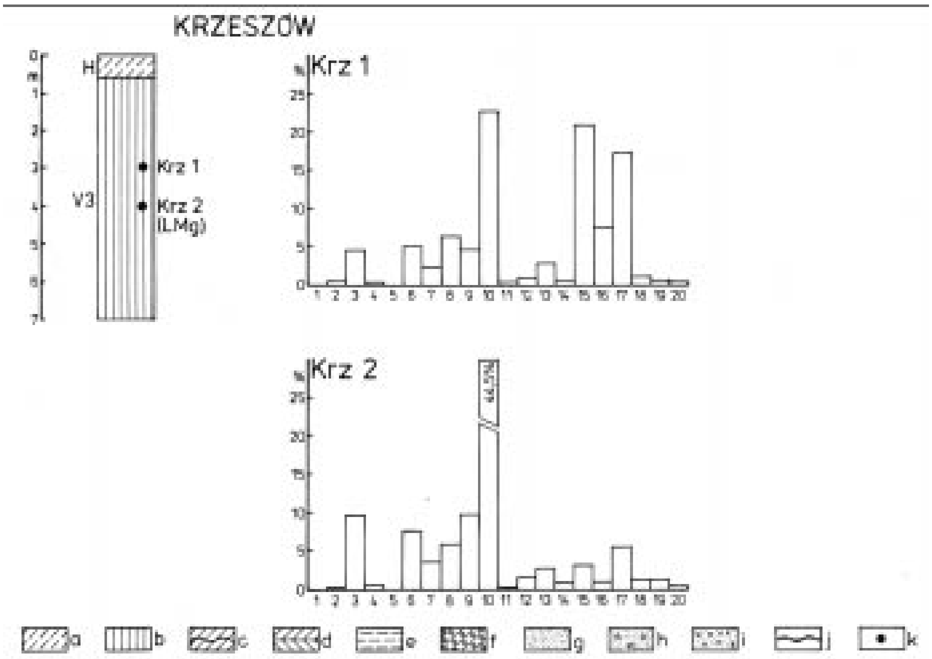

Fig. 2. Loess log of Krzeszów after Wojtanowicz (1997, simplified) and results of the mineralogical studies of the samples Krz 1 and Krz 2. Lithological explanations: a – recent soil, b – loesses, c – interstadial soils, d – soil complexes and interglacial soils, e – muds and loess-like deposits, f – tills, g – sands, h – sands and gravels, i – gravels and cobbles, j – sedimentation gaps, k – localization of the investigated samples. Determinations of the age levels: D – Devonian, Trz – Tertiary, S1 – Sanian 1, tl – Tiligul = S2 – Sanian 2, so – Sokal = M – Mazovian, l – Luck = Z – Zbójnian, dn – Dnieper = O – Odranian, ko – Korshev = Lu – Lubavian (Lublinian), ts – Tyasmin = Wa – Wartanian, ho – Horokhov = E – Eemian, vl – Valdaynian = V – Vistulian (V1, V2, V3 stadials), du – Dubno = interstadial V2/V3, bb – Bug = LMg (stadial V3), hl = Holocene. Mineral composition: 1 – anatase, 2 – andalusite, 3 – zircon, 4 – kyanite, 5 – monazite, 6 – rutile, 7 – staurolite, 8 – tourmaline, 9 – epidotes, 10 – garnets, 11 – sillimanite, 12 – apatite, 13 – amphiboles, 14 – pyroxenes, 15 – biotite, 16 – chlorite, 17 – muscovite, 18 – glauconite, 19 – topaz, 20 – sphene

Profil lessowy Krzeszów według Wojtanowicza (1997, uproszczony) i wyniki badań mineralogicznych próbek Krz 1 i Krz 2; objaśnienia litologiczne: a – gleba współczesna, b – lessy, c – gleby interstadialne, d – kompleksy glebowe i gleby interglacjalne, e – mułki i utwory lessopodobne, f – gliny zwałowe, g – piaski, h – piaski i żwiry, i – żwiry i bruki głazowe, j – łuki sedymentacyjne, k – położenie analizowanych próbek; oznaczenia poziomów wiekowych: D – dewon, Trz – trzeciorzęd, S1 – Sanian 1, tl – Tiligul + S2 – Sanian 2, so – Sokal = M – Mazovian, l – Luck = Z – Zbójnian, dn – Dniepr = O – Odranian, ko – Korshev = Lu – Lubavian (Lublinian), ts – Tyasmin = Wa – Wartanian, ho – Horokhov = E – Eemian, vl – Valdaynian = V – Vistulian (V1, V2, V3 stadials), du – Dubno = V2/V3 interstadiał, bb – Bug = LMg (V3 stadiał), hl = Holocen; Skład mineralny: 1 – anataz, 2 – andaluzyt, 3 – cyrkon, 4 – dysten, 5 – monacyt, 6 – rutyl, 7 – staurolit, 8 – turmalin, 9 – epidoty, 10 – granaty, 11 – sillimanit, 12 – apatyt, 13 – amphibole, 14 – pirokseny, 15 – biotyt, 16 – chloryt, 17 – muskowit, 18 – glaukonit,19 – topaz, 20 – sfen

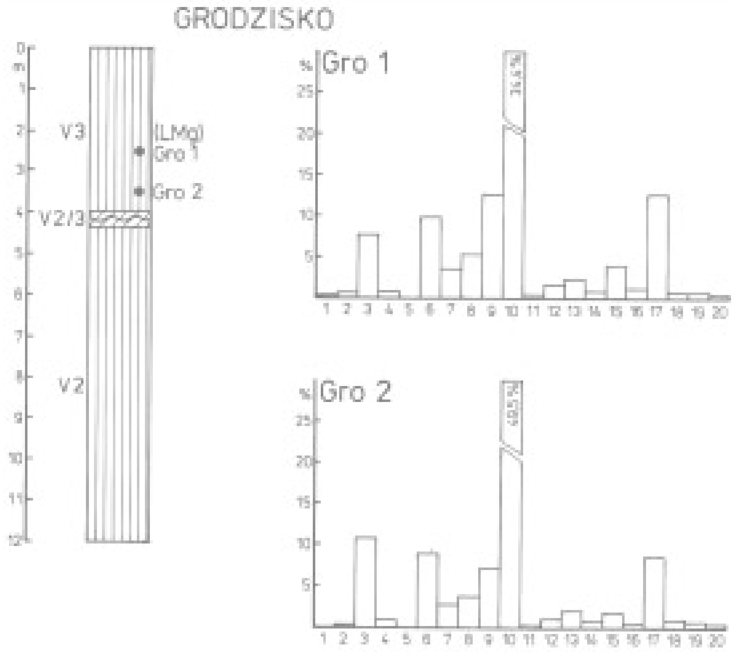

Fig. 3. Loess log from Grodzisko after Wojtanowicz (1997, simplified) and results of the mineralogical studies of the samples Gro 1 and Gro 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Grodzisko według Wojtanowicza (1997, uproszczony) i wyniki badań mineralogicznych próbek: Gro 1 i Gro 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

Loess log Grodzisko (No 2 in Fig. 1)

This log, described by Wojtanowicz (1997) as "Grodzisko Dolne", is localized in the central part of the Sandomierz Basin, in the Kolbuszowa Plateau, in its southeaster margin, in the southern part of the village. A 12-meters-thick bed of the dusty loess-like deposits outcrops in this log.

The lower part of this log (12.0–4.5 m) consists of the loess-like deposits related by their age to the middle part of the Vistulian Glaciation (Fig. 3). The level of the initial soil (V2/V3, 4.45–4.0 m) of the younger interstadial of the Vistulian Glaciation formed on them. This soil is covered by the loess-like deposits (4.0–0.0 m) correlated in age with the youmger upper loess of the youngest stadial of the Vistulian Glaciation. Two samples from these deposits were taken for the mineralogical studies. The upper sample Gro 1 comes from the depth of 2.5 m and the lower one Gro 2 – from the depth of 3.5 m below the terrain surface.

Granulomerically these deposits bear the "loess" fraction (0.05–0.01 mm) in the amount of 39–40%, and the finest fraction (>0.002 mm) takes 7–8%. According to Wojtanowicz (1997) these deposits represent the deluvial (slope wash)-aeolian sediments formed under periglacial conditions of the last glaciation.

The composition of the heavy mineral fraction in both investigated samples is very similar, with very distinct prevalence of the resistant and very resistant minerals and lower content of the flaky minerals, usually accumulated due to aeolian transport, what may confirm the influence of the deluvial (slope wash) factor on the type of the sediment. The minor content of the minerals poorly resistant to the mechanic destruction (amphiboles and pyroxenes) and trace amounts of glauconite, which is least resistant to weathering and under the deluvial (slope wash) conditions may be deteriorated especially quickly, could confirm this supposition. The aeolian processes causing the blowing of the earlier deposited sediments (sample Gro 2) are recognizable in minor degree, which is expressed by small prevalence of muscovite in the sample Gro 1 and prevalence of garnets in the sample Gro 2.

The studied loesses contain moderate amounts of carbonates, among which the shells of microfossils (foraminifers) were found.

Loess log Jarosław (No. 3 in Fig. 1)

The loess in Jarosław is localized within the open pit of the brick-works in the western part of the town. This log, described in details by Maruszczak (1980), is localized in the lower part of the slope of the Rzeszów Forecarpathians at the border with the San River valley.

Yellow-brown spotty non-calcareous loess (16.0–14.7 m) related to the period of the Wartanian Glaciation is the oldest Pleistocene sediment in this log (Fig. 4). The twofold complex of the buried soil (14.7–12.6 m) of the Eemian Interglacial age (E) formed on this loess. Above the soil, another loess bed outcrops in the described log (12.4–10.4 m), which was probably accumulated during two older stadials (V1+V2) of the Vistulian Glaciation. Initial fossil soil 10.4–9.4 m) occurs on this loess, representing probably the younger interstadial (V2/3) of the last glaciation. Above the next loess bed (9.41.0 m) accumulated, considered as the equivalent of the younger upper loess (LMg), whose formation is related to the last stadial of the Vistulian Glaciation. The younger part of this loess was sampled for the mineralogical studies: the upper sample Ja 1 was taken at the depth of 1.5 m and the lower sample Ja 2 – at the depth of 3.0 m below the recent soil (H, 1.0 m thick) surface.

In its granulometric composition this loess has a distinct abundance (38.0–45.0%) of the fraction from 0.05 to 0.01 mm with limited content (9.0–12.0%) of the fraction >0.05 mm.

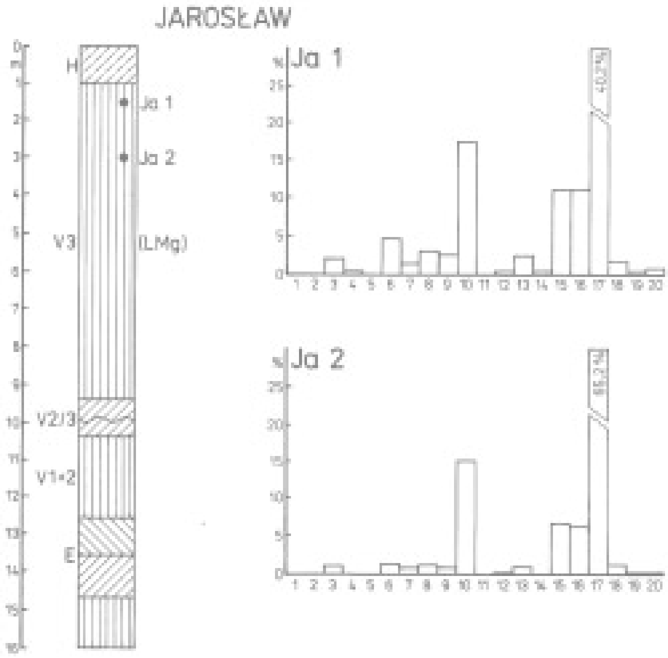

Fig. 4. Loess log from Jarosław after Maruszczak (1980, simplified) and results of the mineralogical studies of the samples Ja 1 and Ja 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Jarosław według Maruszczaka (1980, uproszczony) i wyniki badań mineralogicznych próbek Ja 1 i Ja 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

The compositions of the heavy mineral fractions in the both studied samples are very similar, with high contents of the flaky minerals, peculiarly muscovite. Garnets are important components, but other minerals resistant to weathering, and especially those very resistant, are present in minor amounts. However, the less resistant minerals, especially amphiboles, are present as well as glauconite, which is very susceptible to deterioration. These facts may evidence relatively close alimentation sources especially rich in mica minerals.

Significant amounts of carbonates were found in the studied loesses; the shells of microfossils (foraminifers) were recognized frequently.

Loess log Radymno (No. 4 in Fig. 1)

The named loess profile occurs in the northeast part of the Rzeszów Forecarpathians at its border with the Sandomierz Basin. It outcrops in the open pit of the brick-works near the road Radymno–Jarosław and it is localized in the edge zone of the middle above-flood terrace of the San River, covered by

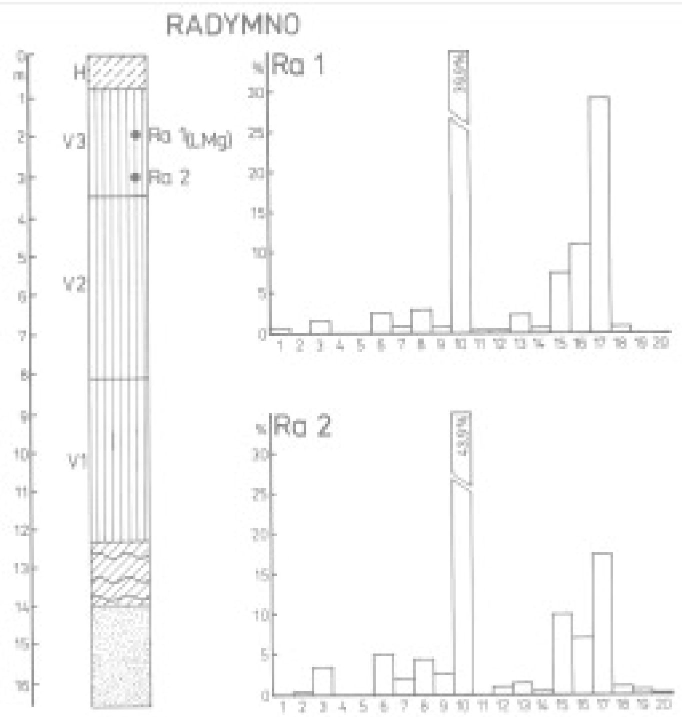

Fig. 5. Loess log from Radymno after Maruszczak (1980, simplified) and results of the mineralogical studies of the samples Ra 1 and Ra 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Radymno według Maruszczaka (1980, uproszczony) i wyniki badań mineralogicznych próbek Ra 1 i Ra 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

loesses. This log was studied by Laskowska-Wysoczańska (1971, Malicki (1973) and Maruszczak (1980).

River sands of the flood and river bed facies (16.5–14.0 m) are the oldest Pleistocene sediment in this log (Fig. 5). The well-preserved three-level gley soil (14.0–12.3 m) occurs above the sands, representing the climatic conditions of the transition period from Eemian interglacial to the beginning of the Vistulian Glaciation. This soil is covered by thick (12.3–3.5 m) bed of the lower (V1) and middle (V2) subaqual and swamp loesses, connected with the older stages of this glaciation. Next loess bed (3.5–0.8 m) occurs above in the described log, being correlated with the youngest stadial (V3) of the last glaciation, i. e. with accumulation conditions of the younger upper loess (LMg). Two samples were taken from this loess for mineralogical studies. The upper sample – Ra 1 – was taken from the depth of 2.0 m and the lower sample Ra 2 – from the depth of 3.0 m below the terrain surface formed by the soil H of the thickness of 0.8 m.

Granulometrically this loess is characterized by significant content (48.0–57.0%) of the grain fraction between 0.05 to 0.01 mm and not very high content of the grains of the diameter >0.05 mm (8.0–9.0%).

The mineral composition of the heavy fraction is almost identical in the two samples, with domination of the two mineral groups: the flaky minerals (group V) with prevailing muscovite and the minerals resistant to the weathering factors with distinct prevalence of garnets (group II). Other mineral components belonging both to the groups most resistant and least resistant to the weathering factors occur in very minor amounts.

The studied loesses are relatively rich in carbonates with frequently found carbonate shells of microfossils (foraminifers).

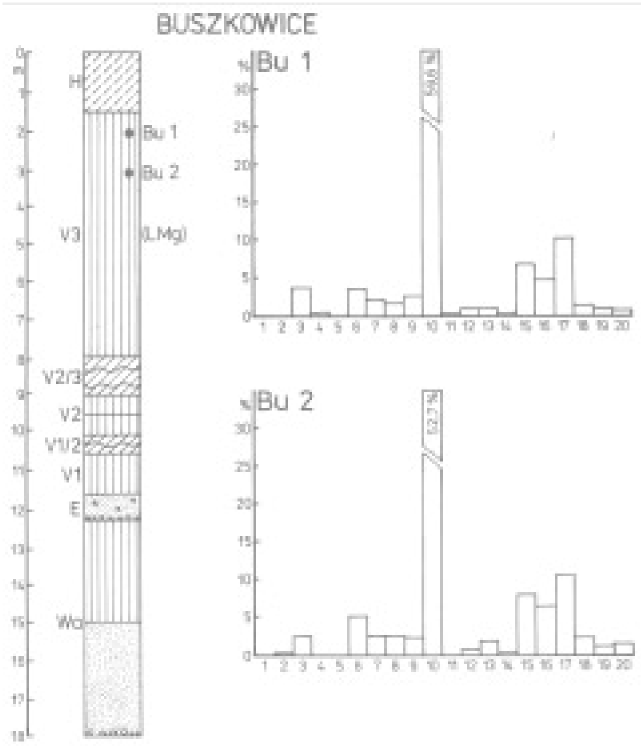

Fig. 6. Loess log from Buszkowice after Łanczont (1994, simplified) and results of the mineralogical studies of the samples Bu 1 and Bu 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Buszkowice według Łanczont (1994, uproszczony) i wyniki badań mineralogicznych próbek Bu 1 i Bu 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

Loess log Buszkowice (No. 5 in Fig. 1)

This log occurs in the area of the open pit of the brick-works located in the northern margins of the city of Przemyśl. According to Łanczont (1994) it comprises loesses raising above the Pleistocene middle terrace of the San River with the relative height of 20–25 m.

In the log localised in the near-slope part of this terrace the 18-meter high sequence of the Pleistocene sediments outcrops (Fig. 6). River sands and gravels (18–15 m) form its oldest part; they are covered by carbonaceous loess (15–12.2 m) of the Wartanian Glaciation (Wa). Gravel with sand (12.2–11.5 m) attributed to the river accumulation during the Eemian Interglacial (E) occur above the loess. An overlying complex of loesses and initial buried soils (11.5–7.8 m) represents the older (V1) and middle (V2) stadial of the Vistulian Glaciation and the subsequent interstadials (V1/2 and V2/3). The uppermost part of the log consists of thick (7.8–1.5 m) bed of the younger upper loess (LMg) correlated with the last stadial (V3) of the Vistulian Glaciation. Two samples for the mineralogical studies were taken from this loess. The upper sample Bu 1 comes from the depth of 2.0 m and the lower one Bu 2 the depth of 3.0 m below the terrain surface.

The composition of the heavy mineral fraction is almost identical for both studied samples. They have garnets (>50%) distinctly prevailing over the total of all the other components. The second group with high content are flaky minerals, among which muscovite content is slightly higher than that of biotite and chlorite. The very resistant minerals either occur in small amounts or some of them are absent. However, the poorly resistant minerals (amphiboles) and the very poorly resistant ones (glauconite) are present.

The studied loess log contains carbonates distributed non-uniformly: in the upper parts, i.e. in the sample Bu 1 neither carbonates nor the carbonaceous shells of microfossils were found, however in the deeper parts, the second sample Bu 2 inclusively, the high carbonate concentrations occurred together with relatively numerous carbonate shells of foraminifers.

Loess log Humniska (No. 6 in Fig. 1)

At Humniska near Brzozów, in the southern part of the Dynów Upland the investigated loess log was described by Gerlach et al. (1991). This log occurs in the abandoned pit of the brick-works localised on the left side of the Stopnica River valley, a tributary of Wisłok. From the geomorphological point of view this log is on the Pleistocene terrace of this river, on which loesses form a cover.

This cover (Fig. 7), according to the quoted authors, consists of three fully separated loess levels (units). The oldest of these levels (11.5–10.3 m) is represented by yellow, relatively homogeneous younger lower loesses accumulated

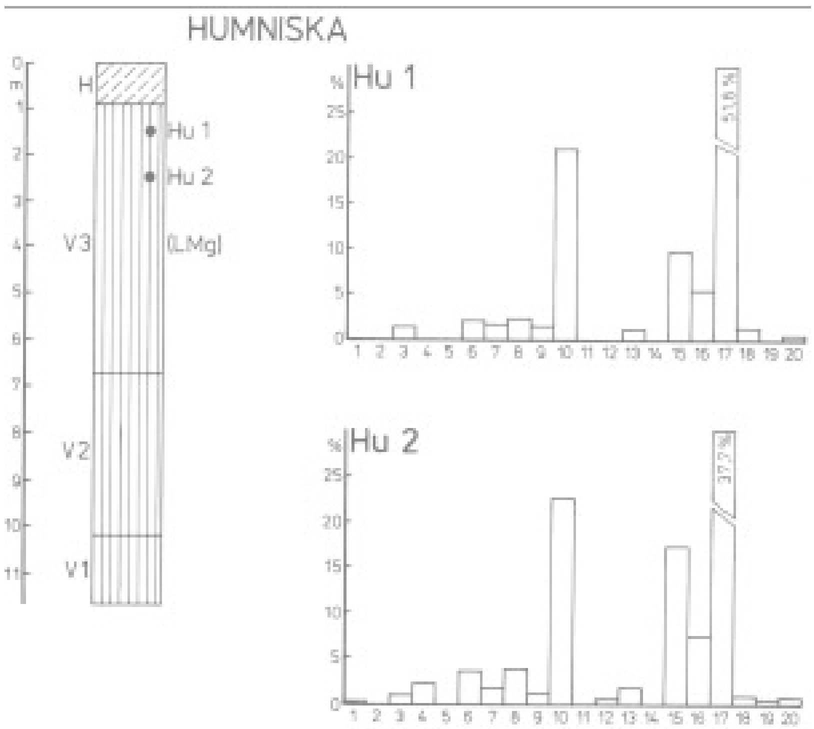

Fig. 7. Loess log from Humniska after Gerlach et al. (1991, simplified) and results of the mineralogical studies of the samples Hu 1 and Hu 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Humniska według Gerlacha i in. (1980, uproszczony) i wyniki badań mineralogicznych próbek Hu 1 i Hu 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

during the first stadial (V1) of the Vistulian Glaciation. It is covered by the younger middle loess (10.3–6.8 m) accumulated during the second stadial of the same glaciation. Above the thickest younger upper loess (LMg) occurs (6.8–0.9 m), considered as formed during the last stadial (V3) of the Vistulian Glaciation. Two samples were taken from these from this loess for the mineralogical studies. The upper sample Hu 1 was collected at the depth of 1.5 m and the lower one Hu 2 – at 2.5 m below the terrain surface formed by the recent soil H of the thickness of 0.9 m. In the sampled loess the grain fraction 0.05–0.01 mm prevails (42.0–51.5%), and the fraction >0.05 mm takes 8.2%. The composition of the heavy mineral fraction in both studied samples is the same with distinct prevalence of the flaky minerals (group V), especially muscovite, and garnets (group II). Peculiarly high content of muscovite was found in the sample Hu 1 (more than 50% of all the components), which could suggest the secondary enrichment of the roof parts of the loess bed in this mineral due to the blowing of the earlier accumulated dusty sediment. Simultaneously in these parts, from which locally the flaky minerals were blown out, the heaviest minerals (garnets) were relatively accumulated, not being submitted to redeposition. The contents of garnets are very high in the studied loesses, but the sample Hu 2 has their content even higher; other minerals occur in very low amounts.

The studied samples were carbonate-free, the shells of microfossils were not found as well.

Loess log Babice (No. 7 in Fig. 1)

The loess log Babice is localised near the road Przemyśl–Dynów, at the margin of the town of Babice, about 0.5 km to the west from the log of the Pleistocene sediments at Babice-Zawada described by Pękala (1988). For the purposes of the present research the log at Babice was elaborated by M. Łanczont. The loesses outcropping here form an aeolian cover raising over the Pleistocene middle terrace of the San River.

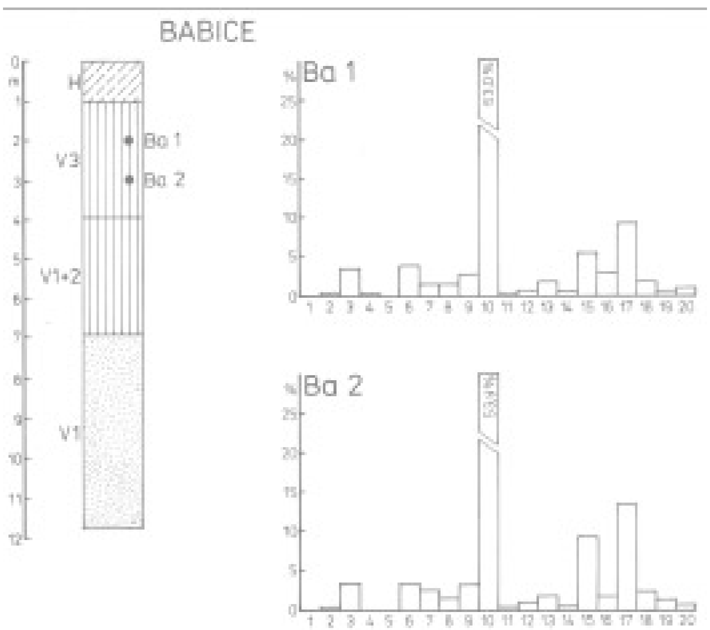

Fig. 8. Loess log from Babice after Łanczont (unpublished, simplified) and results of the mineralogical studies of the samples Ba 1 and Ba 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Babice według Łanczont (mat. niepublikowane, uproszczony) i wyniki badań mineralogicznych próbek Ba 1 i Ba 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

The river sediments represented by sands (12.0–7.0 m), attributed by their age to the early part (V1) of the Vistulian Glaciation, are the oldest deposit of this log (Fig. 8). Above, the Early- and Middle-Vistulian loess (V1+2) of relatively low thickness (7.0–4.0 m) occurs. Higher (4.0–1.0 m) the upper younger loess (LMg) is preserved, which was accumulated during the last stadial of the Vistulian Glaciation. This loess is strongly gleized in its lower part, and in its upper part it has light yellow colour and poorly carbonaceous. The latter loess was sampled for the mineralogical investigation. The upper sample Ba 1 was taken at the depth of 2.0 m and the lower one – at the depth of 3.0 m below the ground surface formed by the soil H of the thickness of 1.0 m.

The compositions of the heavy mineral fractions in the both studied samples are almost identical, with distinct prevalence of garnets (more than 50% of the total transparent heavy minerals). Flaky minerals (mainly muscovite and biotite) are present in significant amounts, but other components, especially the minerals most resistant to weathering occur in low concentrations, unlike glauconite (least resistant to weathering), whose presence is remarkable in both samples.

Variable concentrations of carbonates were found in the studied samples – they are scarce in the upper part of the log, however, deeper (the sample Ba 2) loess is strongly carbonaceous. The shells of microfossils (foraminifers) are found sporadically in both samples.

Loess log Siedliska (No. 8 in Fig. 1)

The loess log at Siedliska occurs to the east of Przemyśl in the easternmost part of the Rzeszów Foreland. Lately it was investigated in details by Łanczont (1997). It is localized in the north-eastern wall of the open pit of clays abandoned long ago.

This log consists of the Pleistocene sediments of the total thickness of 17 m (Fig. 9). Sands (17.5–16.9 m) representing probably the fluvioperiglacial flow during the Sanian 1 Glaciation (S1) are its oldest part. The sub-moraine loess (16.9–14.8 m) attributed to the anaglacial part of the Sanian 2 Glaciation and the overlying till (14.8–2.5 m) cover the sands. Interstadial soil (2.5–2.2 m) of the brown soil type developed on this till, representing probably the penultimate stadial (V2/3) of the Vistulian Glaciation. Thin loess bed (2.2–0.8 m) occurs above this till and soil, being probably connected with the last stadial (V3) of the Vistulian Glaciation. This loess contains average 11.8% carbonates, 0.1% humus and 1.74% iron oxides, which suggest the deposition in cold and dry climate. This loess bed determined as the younger upper loess (LMg) was sampled for the purposes of the mineralogical studies. The upper sample Si 1 was taken at the depth of 1.0 m and the lower one Si 2 – at the depth of 2.0 m below the ground surface formed by the recent soil H. In the summit plain lo-

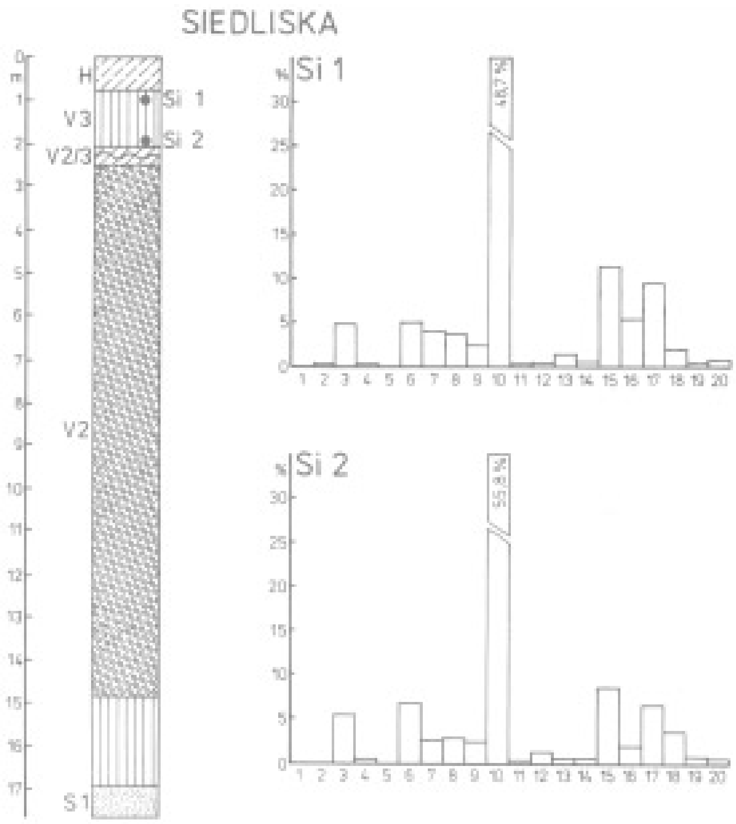

Fig. 9. Loess log from Siedliska after Łanczont (1994, simplified) and results of the mineralogical studies of the samples Si 1 and Si 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Siedliska według Łanczont (1997, uproszczony) i wyniki badań mineralogicznych próbek Si 1 i Si 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

cations, in the granulometric characteristics of the loess one may mention the distinctly smaller grain size and poorer sorting than in the lower parts of the slopes.

The compositions of the heavy mineral fractions in both studied samples are almost the same, with distinct domination of garnets (group II) over all other components of this fraction, and the sample Si 2 is even richer in this mineral. The flaky minerals (group V) are another remarkable component; among them biotite and muscovite dominate distinctly over chlorite. Among other components glauconite occurs in both samples, though it is the mineral least resistant to the weathering factors.

Disseminated carbonates and microfossil shells were found in the studied samples of loess; the general carbonate content of the considered loess may be caused from the carbonate aggregates unevenly distributed in the loess sediment.

Loess log Mostyska (No. 9 in Fig. 1)

The loess log in Mostyska is localized in north-eastern Ukraine ca. 27 km to the east from Przemyśl, in the zone of the northern edge of the Chyrów–Gródek plateau. This log was labelled by Bogutsky et al (2000) as Mostiska II.

In this log (Fig. 10) Tertiary Krakowiec clays are the bedrock of the Quaternary deposits. Till of the San 2 Glaciation (4.5–3.4 m), affected by the younger weathering processes, occurs above the clays, next being covered by the thin loess layer (3.4–3.0 m) from the Wartanian Glaciation). In the roof of this loess the buried initial soil (3.0–2.6 m preserved, attributed to the younger interstadial (?) of the Vistulian Glaciation. This soil is overlain by the bed of the younger upper loess (2.6–0.4 m) with traces of the congelifluction distur-

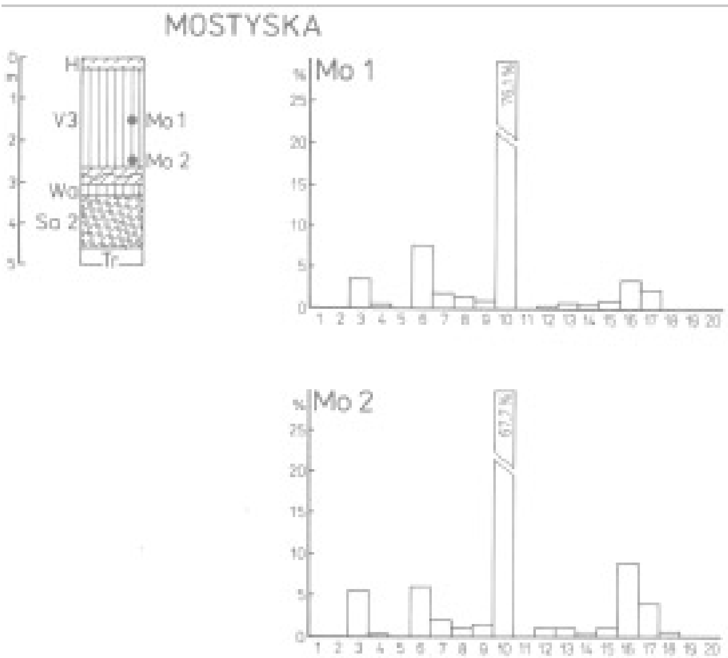

Fig. 10. Loess log from Mostyska after Bogutsky et al. (2000, simplified) and results of the mineralogical studies of the samples Mo 1 and Mo 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Mościska według Boguckiego i in. (2000, uproszczony) i wyniki badań mineralogicznych próbek Mo 1 i Mo 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

bances in its bottom part. This loess is connected with the youngest stadial (V3) of the Vistulian Glaciation. From this loess two samples were taken for the mineralogical studies. The upper sample Mo 1 comes from the depth of 1.5 m and the lower one labelled Mo 2 – from the depth of 2.5 m below the terrain surface formed by the recent soil H of the thickness of 0.4 m.

The compositions of the heavy mineral fractions in both investigated samples are identical, with a distinct domination of garnets (more than 76% in the sample Mo 1 and more than 67% in the sample Mo 2) in the totals of the fractions. Among the minerals most resistant to weathering zircons and rutiles are most common, and the flaky minerals are represented mainly by chlorite and muscovite. The minerals poorly resistant (amphiboles and pyroxenes) and the very poorly resistant ones (glauconite) occur in very minor amounts.

Neither carbonates nor shells of microfossils (foraminifers) were found in the investigated loesses from the Mostyska log.

Loess log Novo-Milatyn (No. 10 in Fig. 1)

The loess log in Novo-Milatyn occurs in the northern wall of the open pit of the local brick-works localized on the surface of the loess island in the drainage basin of the upper Bug to the north-east of Lvov. From the physico-geographic point of view the area of the loess island ic included to Lesser Polesie. The loess log occurring there was described in 2001 by Bogutsky.

The Horokhov (ho) soil complex (10.0–8.6 m) is the oldest Quaternary deposit of the described log (Fig. 11). Its lower part consists of illuvium of the Eemian (E) interglacial soil, and the upper part – of the dark-grey level of the buried interstadial soil from the initial part of the Valdayniak Glaciation (vl) i.e. the Vistulian Glaciation (V). A thin loess bed (8.6–7.5 m) from the initial part of the named glaciation is above the described soils, next covered by the interstadial soil (7.5–7.0 m) of Dubno (du). This soil is overlaid by thick (7.0–1.2 m) loess of Bug (bg = LMg) with a level of the interphase (?) buried soil of Krasilov in its upper part. Two samples for the mineralogical studies were taken from this loess. The upper sample NM 1 was collected at the depth of 3.0 m and the lower one NM 2 at the depth of 4.0 m from the terrain surface formed by the Holocene soil hl = H of the thickness of 1.1 m.

The compositions of the heavy mineral fractions in both samples is quite similar; garnets (group II) distinctly dominate and muscovite and chlorite are abundant among the flaky minerals (group V). Other components occur essentially in low concentrations, though among the very resistant minerals zircon and rutile are present ion appreciable amounts and among the poorly resistant – amphiboles. The 1.5 to 2.0% contents of glauconite, the mineral least resistant to the weathering factors, are worth noting.

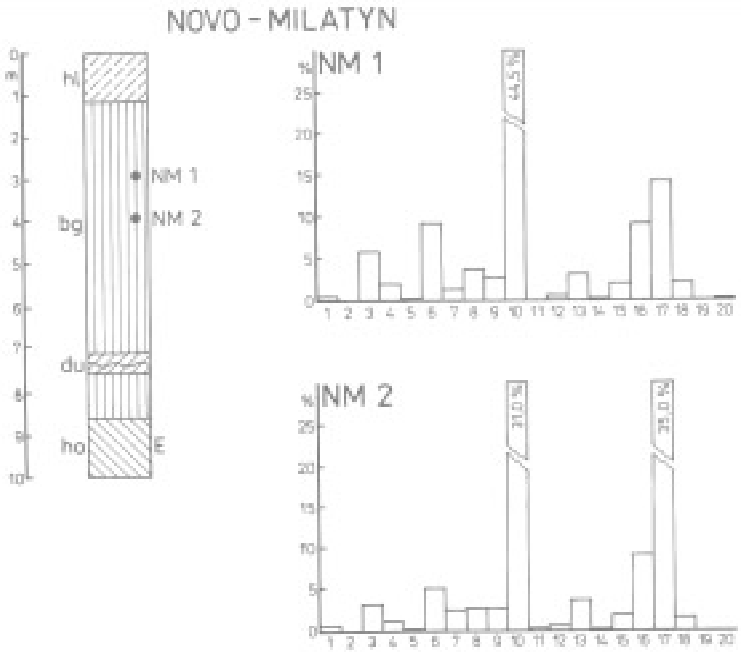

Fig. 11. Loess log from Novo-Milatyn after Bogutsky (unpublished, simplified) and results of the mineralogical studies of the samples NM 1 and NM 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Novo-Milatyn według Boguckiego (mat. niepublikowane, uproszczony) i wyniki badań mineralogicznych próbek NM 1 i NM 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

The investigated loesses are quite strongly carbonaceous, especially in deep parts (sample NM 2), and the microfossils (foraminifers), most probably redeposited from the weathering wastes of the Cretaceous rocks to loesses, are abundant.

Loess log Kulychyvka (No. 11 in Fig. 1)

The loess log of Kulychyvka occurs in the northern part of the Podolia Upland to the north from Krzemieniec. This log was a subject of numerous elaborations, mainly due to the numerous archaeological findings preserved in it. Lately it was described in details by Bogutsky and Sitnik (2001).

Muds or sands (6.0–4.6 m) are the Pleistocene oldest sediments in this log (Fig. 12). Interstadial soil (4.6–4.15 m) of Dubno is preserved above these sediments. This soil is covered by loess bed (4.15–1.8 m) of Bug (bg = LMg) with numerous turbulences, and slope and cryogenic deformations; this bed bears thin laminae of sandy material. Two samples were taken for the minera-

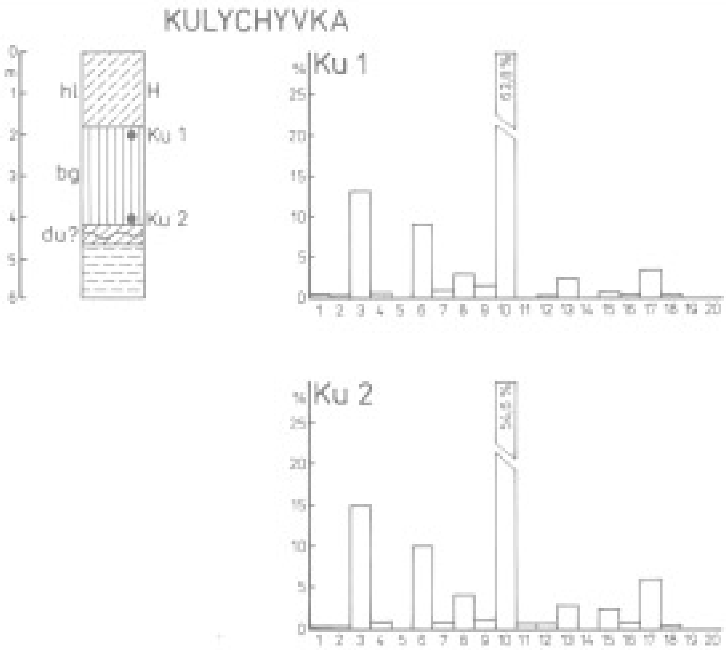

Fig. 12. Loess log from Kulychyvka after Bogutsky and Sitnik (2001, simplified) and results of the mineralogical studies of the samples Ku 1 and Ku 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Kulychyvka według Boguckiego i Sitnika (2001, uproszczony) i wyniki badań mineralogicznych próbek Ku 1 i Ku 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

logical investigations. The upper sample Ku 1 was collected at the depth of 2.0 m and the lower one Ku 2 – at the depth of 4.0 m from the surface of the terrain formed by the Holocene soil hl = H of the thickness of 1.8 m.

The compositions of the heavy mineral fractions are identical in both samples; the minerals resistant to weathering (mainly garnets) and very resistant to weathering (mainly zircon and rutile) dominate. The remaining components occur in minor amounts, and the scarce contents of the minerals poorly resistant to weathering, and especially the flaky minerals, may suggest that other factors, e.g. slope processes, were the factors forming these loess sediments in addition to the aeolian mechanisms.

The investigated loesses have low carbonate contents, though the microfossils (foraminifers) are found relatively frequently.

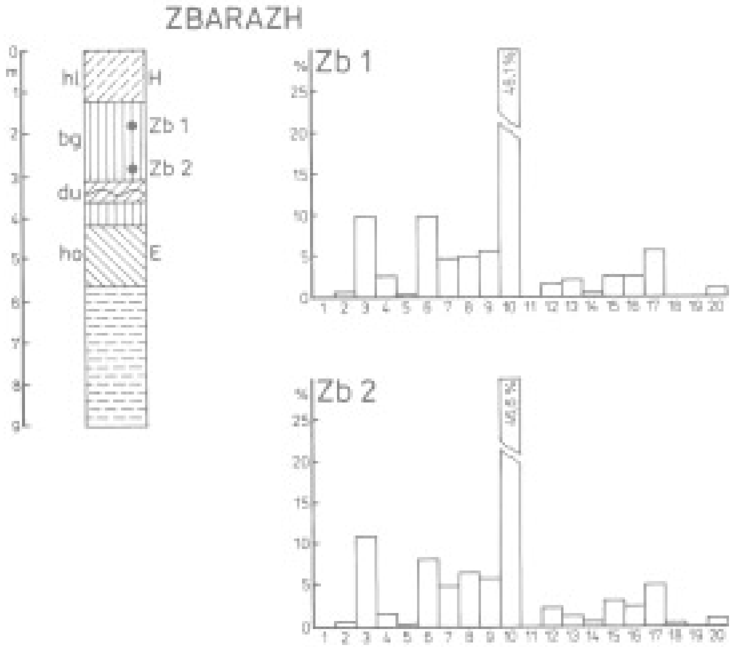

Fig. 13. Loess log from Zbarazh after Bogutsky (unpublished, simplified) and results of the mineralogical studies of the samples Zb 1 and Zb 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Zbarazh według Boguckiego (mat. niepublikowane, uproszczony) i wyniki badań mineralogicznych próbek Zb 1 i Zb 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

Loess log Zbarazh (No. 12 in Fig. 1)

The loess log of Zbarazh is situated in the western wall of the open pit of the local brick-works. It comprises the Younger Pleistocene loesses of the western part of the Podolia Upland and it was elaborated by Bogutsky in 1985.

Muds (9.0–5.6 m) are the oldest part of this log (Fig. 13); the Horokhov soil complex (ho = E) of relatively significant thickness (5.6–4.2 m) formed on these muds. The soils were covered by thin (4.2–3.6 m). Early Valdaynian loess bed and the thin (3.5–3.1 m) interstadial soil of Dubno (du). Loess of Bug (bg = LMg; 3.1–1.2 m) with numerous carbonate concretions and fragments of the interphase soil of Krasilov occurs above. Two samples for mineralogical investigations were taken from this loess. The upper sample Zb 1 comes from the depth of 1.8 m and the lower one, Zb 2 – from the depth of 2.8 m from the terrain surface formed by the Holocene (hl = H) soil of the thickness of 1.2 m.

The mineral compositions of the heavy fractions of the investigated samples are identical. The minerals resistant to the weathering factors (mainly garnets i.e. group II) and the very resistant ones (mainly zircon and rutile – group I) prevail. Other components, especially the minerals poorly and very poorly resistant, occur in very scarce amounts. The flaky minerals (group V) are present in limited contents as well, which, with the domination of the resistant minerals, may indicate an important role of the slope processes in accumulation of loesses.

Loesses in the studied log are distinctly carbonaceous; the shells of microfossils (foraminifers) were found frequently.

Loess log Podvolochysk (No. 13 in Fig. 1)

This log was elaborated by Bogutsky and Voloshyn in 1979. It occurs in the area of the open pit of the brick-works, located in the western part of the town, which is in the central part of the Podolia Upland.

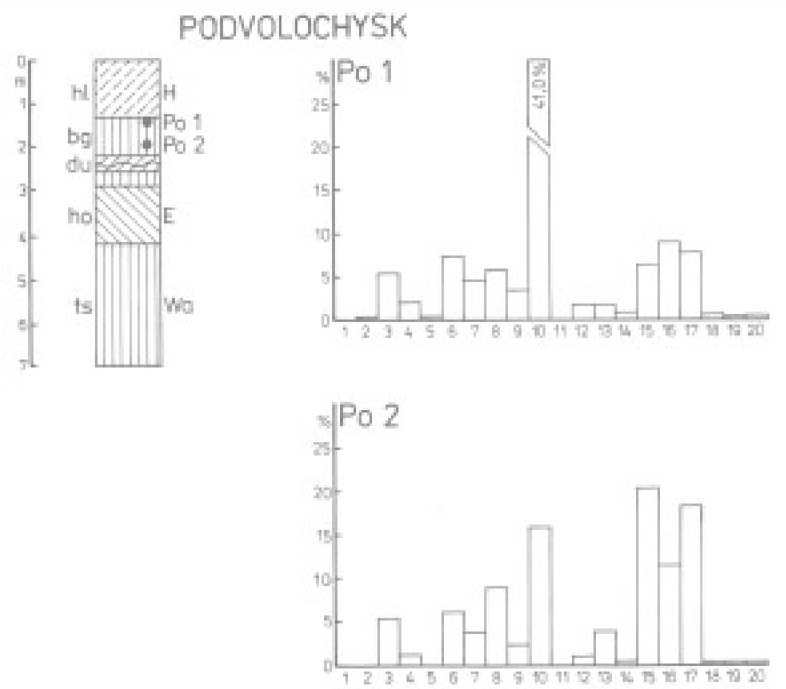

Fig. 14. Loess log from Podvolochysk after Bogutsky and Voloshyn (unpublished, simplified) and results of the mineralogical studies of the samples Zb 1 and Zb 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Podvolochysk według Boguckiego i Wołoszyna (mat. niepublikowane, uproszczony) i wyniki badań mineralogicznych próbek Po 1 i Po 2; objaśnienia litologii, wieku i składu mine-

Middle Pleistocene loess (7.0–4.2 m) determined as loess of Tyasmin (ta = Wa) is the lowermost part of this log (Fig. 14), above which the Horokhov (ho = E) soil complex (4.2–2.9 m) is preserved. Higher thin (2.9–2.5 m). Early Valdaynian loess occurs with the preserved overlying interstadial (2.5–2.2 m) soil of Dubno (du). This soil is covered by thin (2.1–1.4 m) loess of Bug (bg = LMd). From this loess two samples for mineralogical studies were taken. The upper one (Po 1) comes from the depth of 1.5 m and the lower one (Po 2) from the depth of 2.0 m below the terrain surface formed by Holocene soil (hl = H) of the thickness of 1.4 m.

The mineral composition of the heavy fraction of both samples is similar, if we consider the number of components, but differs slightly in the percentages of the components. The resistant minerals especially garnets (group II) distinctly prevail in the sample Po 1, but in the sample Po 2 the flaky minerals (group V) dominate. Other components occur in smaller concentrations.

The studied loesses are relatively strongly carbonaceous, however the microfossils (foraminifers) are found sporadically.

Loess log Sharovechka (No. 14 in Fig. 1)

The loess log at Sharovechka occurs in the area of the open pit of the abandoned brick-works, localized about 2 km to the south-west from the town of Khmelnytsky near the road leading to Tarnopol. This log was described in 1984 by Bogutsky.

The lowermost part of the log (Fig. 15) consists of Middle Pliocene loess (13.0–11.9 m) named the level of Tiligul (tl) and correlated in age with the Sanian 2 Glaciation (S2). Higher the level of the buried soil occurs (11.9–10.8 m), belonging to the Sokal level (so), attributable by its age to the Mazovian interglacial (M). It is covered by the buried soil of the Luck level (l), connected with the Zbójnian interglacial (Z). This soil is overlaid by thin (9.7–9.5 m) Dnieperian loess (dn), attributable to the Odranian Glaciation (O). Higher there occurs the complex of the buried soil of Korshov (ko) of significant thickness (9.9–7.3 m), correlated with the Lublinian interglacial (= Lubavian, Lu). This soil is covered by bed of loess (7.3–4.5 m) of Tyasmin (ts) from the period o the Wartanian Glaciation (Wa). In the roof of this loess the soil complex (4.5–3.8 m) of Horokhov (ho = E) is developed, and higher there occurs loess of Bug (3.8–1.5 m; bg = LMg). Two samples were collected from this loess for the mineralogical studies. The upper sample Sha 1 was taken at the depth of 2.5 m and the lower one named Sha 2 – at the depth of 3.5 m from the terrain surface formed by the Holocene soil (hl = H) of the thickness of 1.5 m.

The composition of the heavy mineral fractions in both studied samples is almost identical, with domination of garnets (more than 50% of the total com-

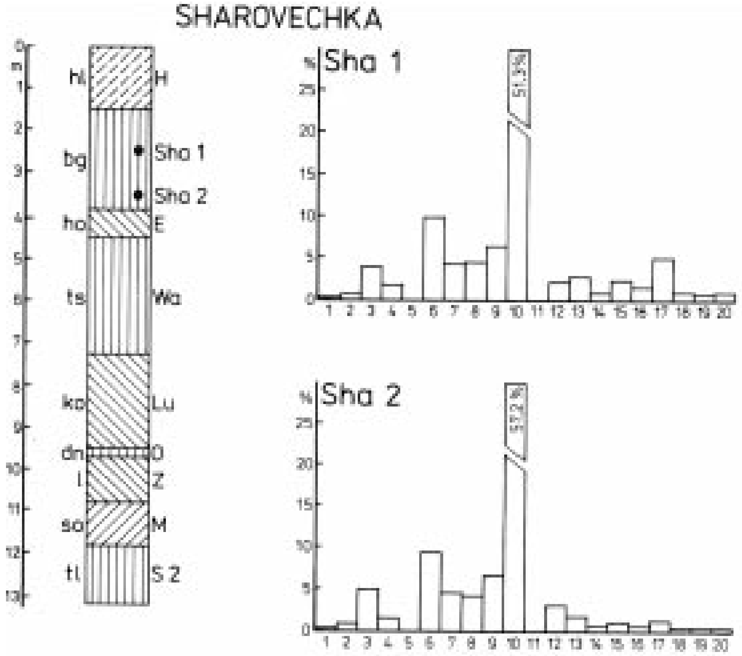

Fig. 15. Loess log from Sharovechka after Bogutsky (unpublished, simplified) and results of the mineralogical studies of the samples Sha 1 and Sha 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Sharovechka według Boguckiego (mat. niepublikowane, uproszczony) i wyniki badań mineralogicznych próbek Sha 1 i Sha 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

ponents) from the group of the minerals resistant to the weathering factors, and with high contents of rutile among the most resistant minerals. The content of the flaky minerals is low or scarce, like the content of the minerals poorly resistant to weathering. These facts, together with the very high amounts of the minerals resistant and very resistant to weathering, may indicate the participation of the slope processes in accumulation of these loesses.

The studied loesses are strongly carbonaceous with relatively frequently found microfossils (foraminifers) in the light fraction.

Loess log Yarmolynce (No. 15 in Fig. 1)

This log occurs in the northern wall of the abandoned open pit of the brickworks localized at the town of Yarmolynce to the west from the road from Khmelnytsky to Kamianets Podilsky. It was described by A. Bogutsky.

Muds (8.0–7.6 m) from the time of the Dnieperian Glaciation (dn = O) are the oldest Pleistocene sediment in this log (Fig. 16). The buried soil (7.6–

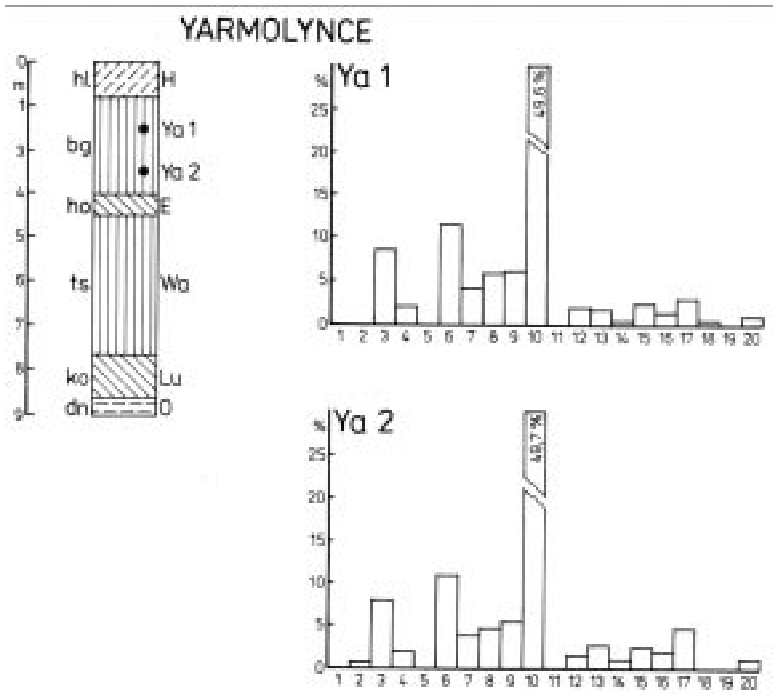

Fig. 16. Loess log from Yarmolynce after Bogutsky (unpublished, simplified) and results of the mineralogical studies of the samples Ya 1 and Ya 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Yarmolynce według Boguckiego (mat. niepublikowane, uproszczony) i wyniki badań mineralogicznych próbek Ya 1 i Ya 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

6.6 m) of the Korshov complex (ko), correlated with the Lublinian = Lubavian (Lu) interglacial developed on the muds. A thick loess bed (6.6–3.5 m) of Tyasmin (ts), correlated with the Wartanian Glaciation (Wa), accumulated above, covered by the buried soil of Horokhov (ho = E) of lesser thickness (3.5–3.0 m). This soil is overlain by the bed (3.0–0.8 m) of loess of Bug (Bg = LMg). Two samples were taken from this loess for mineralogical studies. The upper sample Ya 1 comes from the depth of 1.5 m and the lower one Ya 2 – from the depth of 2.5 m below the terrain surface, formed by the Holocene soil (ho = H) of the thickness 0.8 m.

The compositions of the heavy mineral fractions in both samples are identical, with dominating garnets (more than 49%) and the minerals most resistant to weathering (mainly rutile and zircon). Other components occur in low amounts, the flaky minerals inclusively. This fact as well as trace amounts of the minerals very poorly resistant to the weathering factors (group IV, glauconite) and the poorly resistant ones (group III, pyroxenes and amphiboles), as well as the dominating role of garnets (group II) may evidence the significant development of the slope, non-aeolian processes in accumulation of the studied loesses.

The concentration of carbonates in both studied loesses is high, and the shells of microfossils (foraminifers) are quite abundant, especially in the sample Ya 1.

Loess log Halych (No. 17 in Fig. 1)

The loess log of Halych occurs in the open pit of the brick-works localized in the north-eastern part of this city near the mouth of the Lukva river to the Dniestr River. This log is considered as the reference one for the loesses of the north-eastern foreland of East Beskidy, the northern part of the Ukrainian Carpathians. Lately this log was described in details by Bogutsky et al. (2001).

The soil of Luck (l) correlated with the Zbójnian interglacial (Z) is the oldest Pleistocene bed (26.0–24.5 m) of this log (Fig. 17). Very thick Dnieperian (dn) loess (24.5–10.2 m) determined as connected in age with the climatic minimum of the Odranian Glaciation (O) occurs above. Both in the lower part of the loess and in the upper one the levels of the interstadial initial soils, in places overlapping one another, are preserved. Higher there is the thick (10.2–6.7 m) complex of soil of Korshov (ko), characterizing the climatic conditions of the Liblinian = Lubavian (Lu) interstadial. Thin loess layer (9.0–8.5 m) occurs within this complex, indicating the cooling of climate between two warm (optimum) periods of this interglacial. This complex is covered by the bed (6.7–5.0) of the loess of Tyasmin (ts = Wa) with the complex (5.0–3.4 m) of the soil of Horokhov (ho = E) in its uppermost part. In the described log, this soil is over-raised by thin (3.4–3.0 m). Early-Valdaynian (Early-Vistulian) loess with the overlying soil of Dubno (du) with the typical thickness (3.0–2.5 m). The uppermost part of the log (2.5–0.8 m) consists of the Bug loess (bg = LMg) with the preserved mammoth remnants. Two samples for the mineralogical studies were collected from this loess. The upper sample (Ha 1) comes from the depth of 1.0 m and the lower one (Ha 2) – from the depth of 2.0 m below the terrain surface, formed by the Holocene soil (hl = H) of the thickness of 0.8 m.

The Bug loess (the younger upper loess) of the Halych log has variable content (45.0–63.0%) of the grain fraction 0.05–0.01 mm and a distinct increase of the fine-grained sand fraction content in the upper part of the log.

The composition of the heavy mineral fractions in both samples is almost identical, with a distinct domination of the resistant minerals (mainly garnets – more than 47% in the sample Ha 1 and ca. 40% in the sample Ha 2) and the very resistant ones (mainly zircon and rutile). Other components, including the flaky minerals, occur in small amounts.

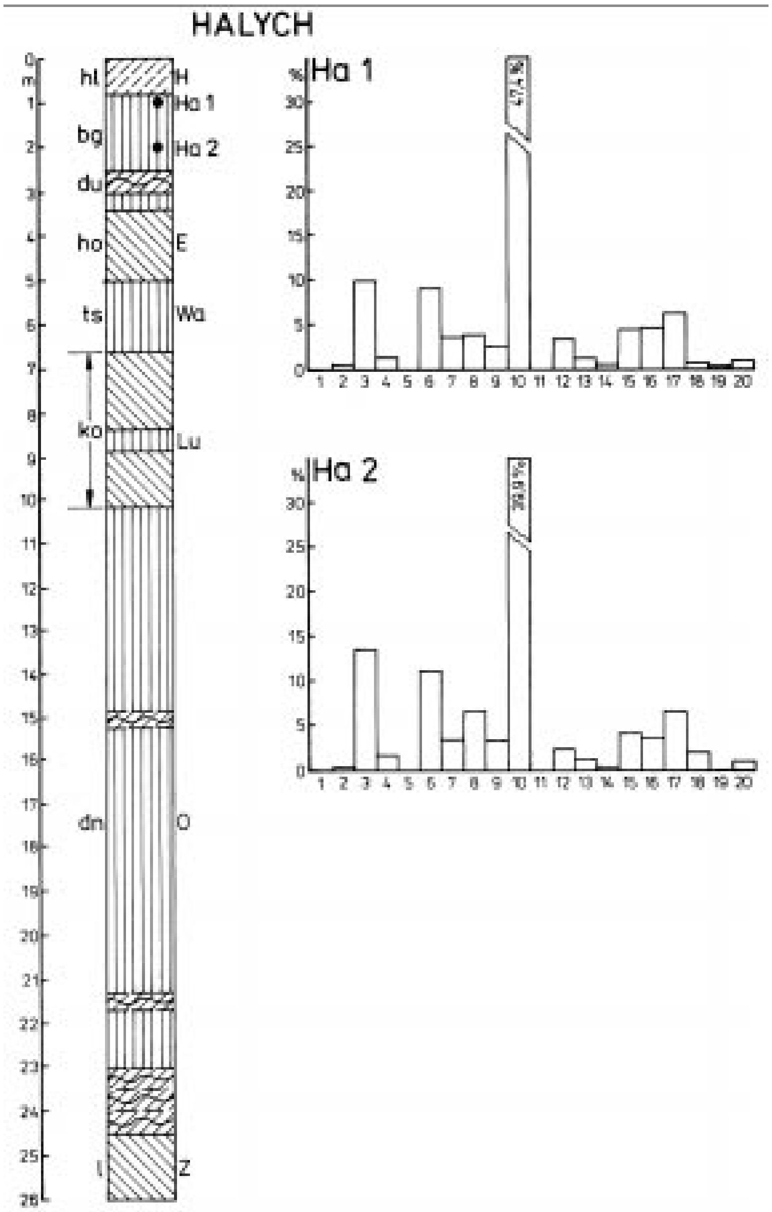

Fig. 17. Loess log from Halych after Bogutsky et al. (2001, simplified) and results of the mineralogical studies of the samples Ha 1 and Ha 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Halych według Boguckiego i in. (2001, uproszczony) i wyniki badań mineralogicznych próbek Ha 1 i Ha 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

The studied loesses are strongly carbonaceous, but the shells of microfossils (foraminifers) are found sporadically.

Loess log Ustechko (No. 19 in Fig. 1)

This log is localized in the zone of the northern slope of the Dniestr valley, to the west from the village. This log was described by Lindner in 1999.

This profile (Fig. 18) consists of red aleurites and Devonian sandstones called "the Podolian Old Red" in its lowermost part, above which the poorly preserved fragments (5.0–4.5 m) of the initial buried soil (Dubno du?) are visible. Higher the relatively thick (4.5–1.0 m) loess of Bug (b = LMg) occurs. This loess has distinguishing red-yellow colour and significant number of thin layers of sandy material in its lower part. Two samples from the mineralogical studies were collected from this loess. The upper sample Us 1 comes from the depth of 3.0 m and the lower sample Us 2 from the depth of 4.0 m below the terrain surface formed by the Holocene soil (hl = H) of the thickness of 1.0 m.

The compositions of the heavy mineral fractions in both studied samples are very similar. The prevalence of the resistant minerals (mainly garnets – 50%

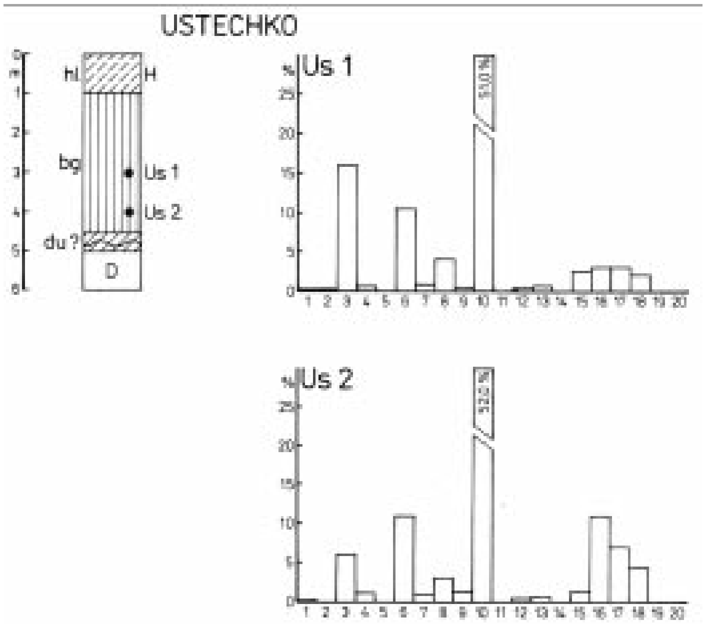

Fig. 18. Loess log from Ustechko after Lindner (unpublished, simplified) and results of the mineralogical studies of the samples Us 1 and Us 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Ustechko według Lindnera (mat. niepublikowane, uproszczony) i wyniki badań mineralogicznych próbek Us 1 i Us 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

of the total components) and the very resistant ones (mainly zircon and rutile) is very distinct. The higher content of the flaky minerals (mainly muscovite and chlorite) in the sample Us 2 – is a distinguishing feature, and the presence of the mineral least resistant to weathering (glauconite, 2.0–4.3%) is apparent here in both samples.

The studied loesses, especially the sample Us 2 have appreciable contents of carbonates and quite frequent shells of microfossils (foraminifers).

Loess log Tovtri (No. 20 in Fig. 1)

The loess log of Tovtri is localized in the eastern part of the East Beskidy Foreland on the drainage divide Dniestr–Prut. The log was decribed by Bogutsky in 2001.

The Middle Pleistocene loess of the Tyasmin (ts) level is the oldest (9.5–7.6 m) Pleistocene sediment of this log (Fig. 19). This loess documented the climatic conditions of the Wartanian (Wa) Glaciation. Above, the buried soil (7.6–5.8 m) of Horokhov (ho = E) occurs, being covered by thick (5.8–1.4 m)

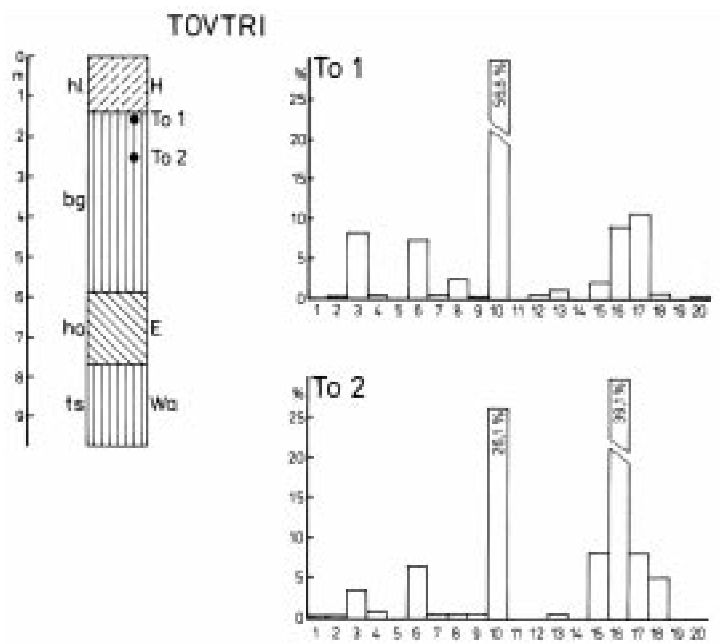

Fig. 19. Loess log from Tovtri after Bogutsky (unpublished, simplified) and results of the mineralogical studies of the samples To 1 and To 2; Explanations of lithology, age and mineral composition as in Fig. 2

Profil lessowy Tovtri według Boguckiego (mat. niepublikowane, uproszczony) i wyniki badań mineralogicznych próbek To 1 i To 2; objaśnienia litologii, wieku i składu mineralnego przy ryc. 2

loess bed of Bug (bg = MLg). Two samples were collected from this loess for mineralogical studies. The upper sample To 1 comes from the depth of 1.5 m and the lower one To 2 from the depth of 2.5 m below the terrain surface formed by the Holocene soil (hl = H) of the thickness of 1.4 m.

The mineral compositions of the heavy fractions of both investigated samples is similar in the number of the components but variable in percent amounts of these components. The minerals resistant to the weathering factors prevail (mainly garnets: more than 65% in the sample To 1 and ca. 26% in the sample To 2). Next in abundance are the flaky minerals (group V), among which especially chlorite in the amount of 39.1% is the main mineral of the sample To 2. Biotite (8.1%) occurs in the same sample in appreciable amount, but muscovite in both samples appears in similar amounts (ca. 8–10%). In the sample To 2 glauconite is present in the significant amount of 5% (group IV).

Carbonates occur in the loesses of the studied profile in scarce amounts and the shells of microfossils were not found at all.

INTERPRETATION OF THE RESULTS

The presented results of the investigations showed large differentiation of the quantitative contents of the components of the heavy mineral assembly in the studied loess logs and the local relations of the heavy minerals to the contents of the individual components in rocks and sediments in the surroundings and basements of the loess beds. This concerns some components of the light fraction as well in the analysed samples of the upper younger loess, in which the presence of the redeposited remnants or well-preserved shells of microfossils (foraminifers) was recognized; these microfossils are directly related to certain rocks of the local basement.

The investigated rocks and sediments (or their weathering wastes) are represented by various lithological types: sandstones and shales (Chodorówka – point 21 in Fig. 1), sands (Żmijowiska – point 22 in Fig. 1, Radruż – point 23 in Fig. 1, Bibrka – point 25 in Fig. 1, Zalishchyky – point 26 in Fig. 1, Skała Podolska – point 27 in Fig. 1), moraine till (Przemysłów – point 24 in Fig. 1). The heavy mineral fractions were investigated in all these deposits in the selected fine-grain classes; it was found, that they have very variable compositions (Table 3).

Glauconite is the dominating component of the assembly of the heavy minerals (57.8% of the total heavy minerals) in the weathering wastes of the easily crumbling sandstones, mudstones and shales from Chodorówka (point 21). It occurs as grains of various degree of weathering. This caused, that this mineral obtained not only a secondary chemical differentiation, but also the physical features e. g. density, which resulted in its appearance beside the heavy mineral fraction, together with quartz and feldspars in light fraction. Other components occur in low amounts: the minerals resistant to the weathering factors like garnets (6.4%) and the very resistant ones: zircon (8.2%), rtutile (7.5%), staurolite (3.4%) and tourmaline (3.4%). In these deposits representing the so--called "Inoceramus beds" (Rajchel 1989) accessible in many logs of the Flysch Carpathians both on the surface and in boreholes (Wdowiarz et al. 1974) the mineral composition was investigated many times, and in certain parts of these beds high contents of glauconite was found as well.

The sandy deposits from the locations of Żmijowiska (point 22 in Fig. 1) and Radruż (point 23) bear in their composition mainly the resistant minerals (garnets – 37.3% and 11.6%) and the very resistant ones: zircon (17.4% and 23.6%), rutile (14.7% and 18.0%), tourmaline (7.5% and 8.5%). Moreover, the appreciable amounts of the very poorly resistant minerals, mainly amphiboles were found 4.5% at Żmijowiska and 5.5% at Radruż. In the deposits from both locations the flaky minerals occur in moderate contents (ca. 8% at Żmijowiska and ca. 19% at Radruż).

Moraine tills are another deposit forming bedrocks of loesses in the studied area (Przemysłów – point 24 in Fig. 1). Composition of the heavy mineral fraction of these deposits is very variable, both in the number of components, with the simultaneous participation of all the mineral groups distinguished in the present paper, which probably is typical of all the moraine sediments (R. Chlebowski et al. 2003). High contents of amphiboles (22.3%), derived from weathering wastes of various magmatic and metamorphic rocks present in tills, are the characteristic feature. Garnets (15.2%) and epidotes (5.6%) are similarly abundant. Moreover, these deposits contain appreciable contents of the very resistant minerals: zircon (9.8%), rutile (5.0%) and tourmaline (4.8%); flaky minerals (ca. 17%) are commonly present as well. These minerals, like amphiboles, garnets and epidotes, came from the weathering wastes of crystalline rocks, abundantly present in moraine tills. Glauconite, also very common (11.5%), was seemingly derived from the weathering wastes of the erratics of the local bedrocks, incorporated in the moraine tills by the expanding continental glacier. The above-characterized mineral composition is typical of moraine tills, because the abundance of the varieties of the foreign rocks and their weathering wastes and presence of the weathering wastes of local bedrocks is reflected in the total composition of the heavy mineral assemblage.

Other locations of the bedrocks: Bibrka (point 25 in Fig. 1), Zalishchyky (point 26 in Fig. 1) and Skała Podolska (point 27 in Fig. 1) are relatively distant one from another; albeit lithologically they are similar (sands), they differ in the contents of heavy minerals. The sands of the Bibrka profile have high content of the minerals very resistant to weathering, with domination of zircon

(44.3%) and rutile (16.8%) and abundance of the least resistant minerals (glauconite 22.8%). Other minerals occur in subordinate and trace amounts. In the sands of Zalishchyky garnets dominate (ca. 48–49%) and the most resistant minerals are abundant (zircon 17–21%, rutile 6–11%), and in some parts glauconite is very common (ca. 14%).

The distinctly green sands in the log of Skała Podolska contain very high amount of glauconite (59.1%), abundant garnet (17.2%) and flaky minerals, mostly biotite (12.0%) and muscovite (10.4%).

Besides the characterized components, in certain fine-grained clastic sediments one found single shells of microfossils (foraminifers), e. g. in sands at Zalishchyky, and in sands at Skała Podolska the microfossils occur in very large quantities.

On the basis of the distinguished mineral groups (I–V) of the transparent heavy minerals of loesses (Tables 1 and 2) and for bedrocks (Table 3), the radar plots were prepared, presenting the contents of these mineral groups in the studied samples (Figs 20–26). Loesses in the area of Mid-Carpathian Foreland and western Podolian Upland display very large mineralogical differentiation, expressed by very variable participation of the mineral groups I–V in individual logs, with simultaneous domination of the mineral group II (mainly garnets) and V (flaky minerals) in most of the logs. This is especially well visible in the plots for the loesses of Mid-Carpathian Foreland and the area between the San and Dniestr Rivers (Figs 21–22), on which both axes (II and V) by dominating mode illustrate the contents of these mineral groups. The minerals came from the weathering wastes of the deposits of the Carpathian Flysch and fine-grained mud sediments of the San River valley; these regions may be considered as the main alimentation areas for loesses of the discussed terrain.

This source of the loess material accumulated in the above-named regions, especially in the San River drainage basin, was indicated earlier (Krysowska-Iwaszkiewicz, Łanczont 1992; Łanczont, Wilgat 1994; Łanczont 1997; Racinowski et al. 1999). This material could come either directly from the weathering flysch rocks, or from the sediments of rivers and brooks cutting these rocks. Relatively low contents of the minerals of the group III (amphiboles and pyroxenes) in the local loesses confirms a limited role of the glacial sediments as the source of the loess material (cf. Łanczont 1997).

Younger upper loess in the most analysed cases of its occurrence in the area of the Sandomierz Basin and Mid-Carpathian Foreland preserved in more or less isolated patches called loess islands. In cases of the loess islands of Krzeszów and Grodzisko the occurrence of this loess (having in the log of Grodzisko the features of a deluvial (slope wash)-aeolian sediment) distinctly depends on morphology of bedrock, displaying more or less distinct culminations. The increasing thickness of the analysed loess on the eastern side of these

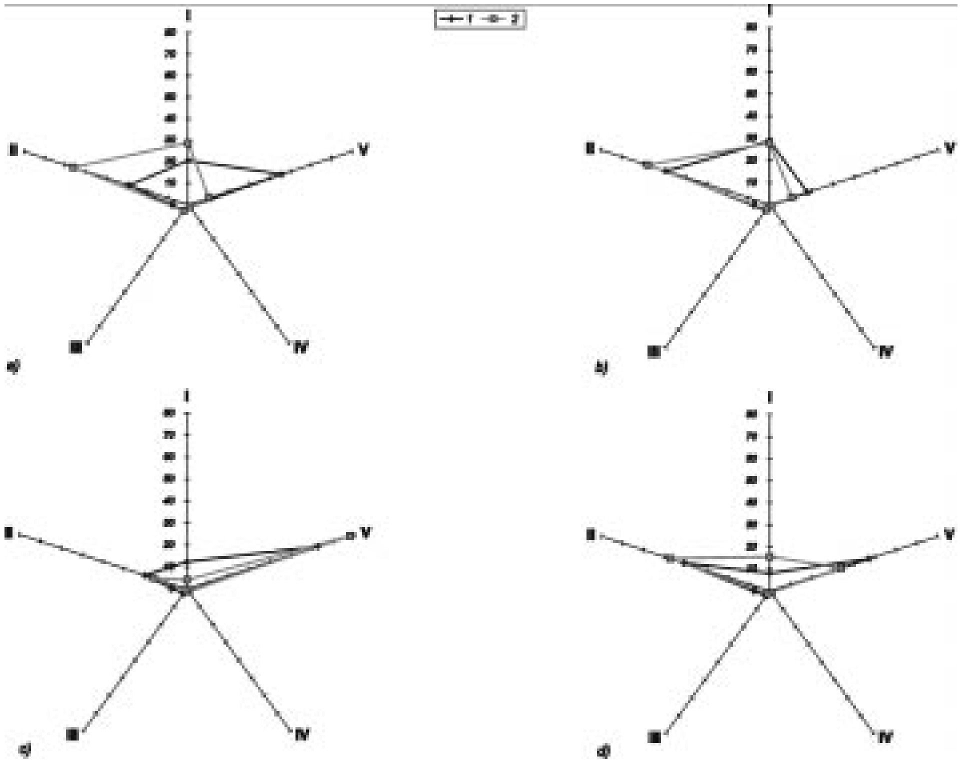

Fig. 20. Graphs with the content of groups I–V transparent heavy minerals in loesses from: a – Krzeszów, b – Grodzisko, c – Jarosław, d – Radymno
Wykresy zawartości grup (I–V) przezroczystych minerałów ciężkich w lessach z profili: a – Krzeszów, b – Grodzisko, c – Jarosław, d – Radymno

culminations is explained by its accumulation mainly on the lee side of these culminations (cf. Chlebowski, Lindner 1975, 1976). In the case of the younger upper loess in the zone of the Rzeszów Foreland and in the eastern part of the Dniestr drainage basin at the foothills of the Eastern Beskidy the localisation of this loess is mainly on vast slopes or bottoms of valleys. In the second case this loess forms the uppermost part of the loess logs located on the river terraces. This loess accumulated as a rule at the heights of 300 m a.s.l. and distinctly increased its thickness towards the axes of the valleys. Above the given height the loess sediments are replaced by weathering covers of the flysch rocks. These facts and the frequent occurrences of the local loess patches on the slopes of valleys and river terraces exposed to the east used to be interpreted as the result of the accumulation of this loess by winds blowing from the east (cf. Łanczont 1993).

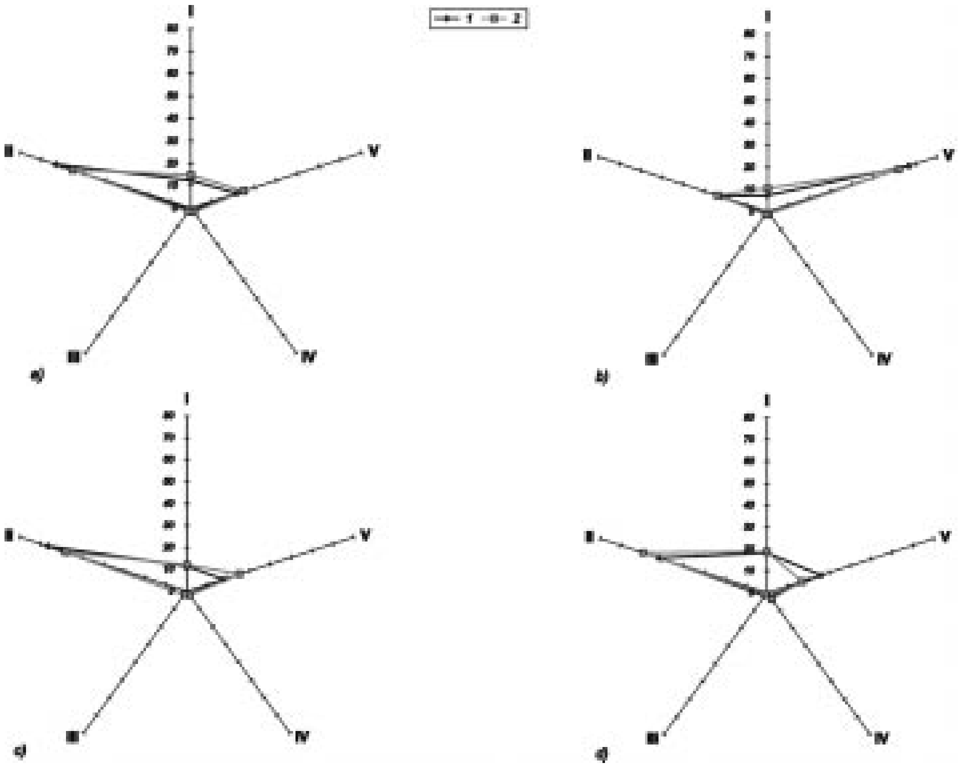

Fig. 21. Graphs with the content of groups I–V transparent heavy minerals in loesses from: a – Buszkowice, b – Humniska, c – Babice, d – Siedliska
Wykresy zawartości grup (I–V) przezroczystych minerałów ciężkich w lessach z profili: a – Buszkowice, b – Humniska, c – Babice, d – Siedliska

Analysis of the materials presented in this paper, especially the undoubted genetic connection of the mineral composition of the heavy fraction of the younger upper loess with the composition of this fraction in the rocks of the Carpathian Flysch and the situation of occurrence of this loess in the drainage basin of the middle San River and upper Dniestr indicate its accumulation due to the activity of south-western winds (Fig. 27), with subordinate influence of western and north-western winds. Absence of the loess covers in this area above 300 m a. s. l. and their accumulation on the slopes and in the bottoms of valleys may suggest, that those were the strong and warm foehn-type winds characteristic of winter and spring seasons, removing the superficial layers of the dusty-sandy weathering wastes from the high parts of the flysch outcrops occurring in the south. These weathering wastes together with the simultaneously blown out sediments of the locals terraces of rivers became the main

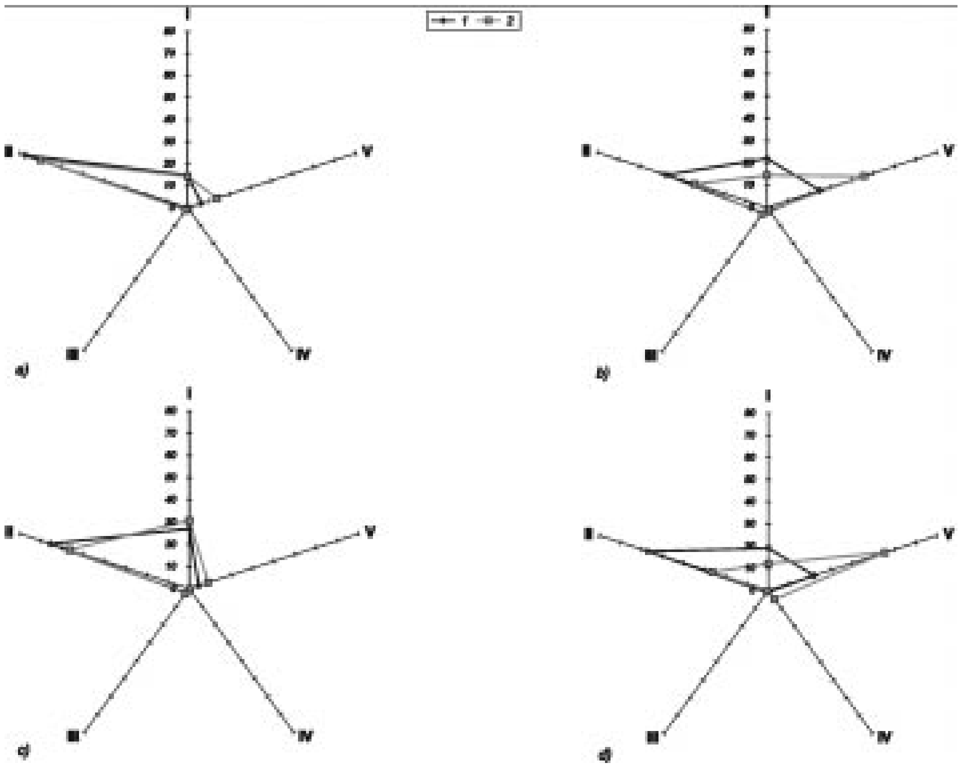

Fig. 22. Graphs with the content of groups I–V transparent heavy minerals in loesses from: a – Mostyska, b – Novo-Milatyn, c – Kulychyvka, d – Tovtri
Wykresy zawartości grup (I–V) przezroczystych minerałów ciężkich w lessach z profili: a – Mostyska, b – Novo-Milatyn, c – Kulychyvka, d – Tovtri

source of the loess material in the area of Mid-Carpathian Foreland and the southernmost part of the western Podolian Upland. The collected data evidenced that in the case of the Sandomierz Basin, and central and northern part of the Podolian Upland the mineral composition of the heavy fraction of the Younger Upper loess indicates its greater differentiation and complications of this composition if compared to e. g. loesses of other regions, such as Lublin and Volhynia Uplands.

Mineral compositions of loesses from Podolia and the considered regions of the Dniestr valley are shown in Figs 22–24 and they display very distinct similarities to each other, expressed in domination of three mineral groups: those labelled I, II and V, thus the minerals most resistant to the weathering factors (groups II and I) and minerals most susceptible to the aeolian transport i. e. the flaky minerals (group V). Locally certain deviations from this general

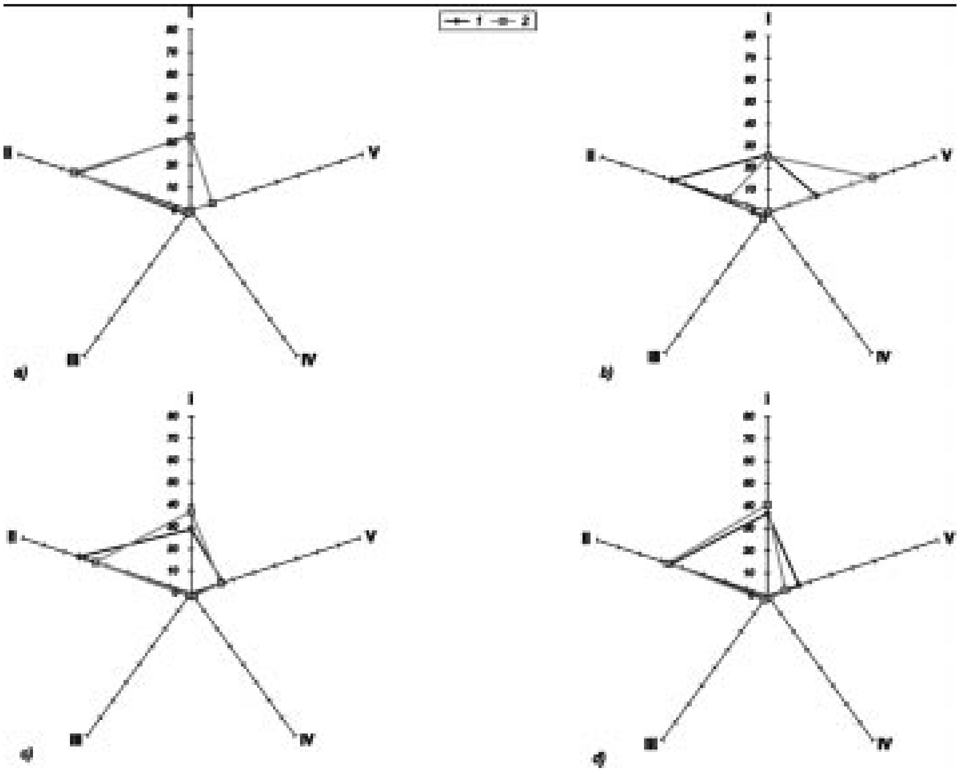

Fig. 23. Graphs with the content of groups I–V transparent heavy minerals in loesses from: a – Zbarazh, b – Podvolochysk, c – Halych, d – Lokitka
Wykresy zawartości grup (I–V) przezroczystych minerałów ciężkich w lessach z profili: a – Zbarazh, b – Podvolochysk, c – Halych, d – Lokitka

scheme was found, like distinct prevalence of the minerals from the group V over those of the group I, with the maintained general tendency of domination of the groups II and V over other groups.

The mineral composition of the bedrocks and their weathering wastes is strongly differentiated, which is well illustrated by the results shown in Table 3, and especially clear image is given by the radar plots (Figs 25–26). The plots visualize the differences between the complete compositions of the heavy mineral fractions of the bedrocks and loesses, and, on the other hand, the individual axes of these plots show distinctly the genetic connections of the both deposits. The axes yield the determination of the probable alimentation regions for the mineral components of loesses.

The sandy deposits at Zalishchyky (Fig. 26b) and loesses in the log of Charna are the peculiar example of influence of the mineral composition of

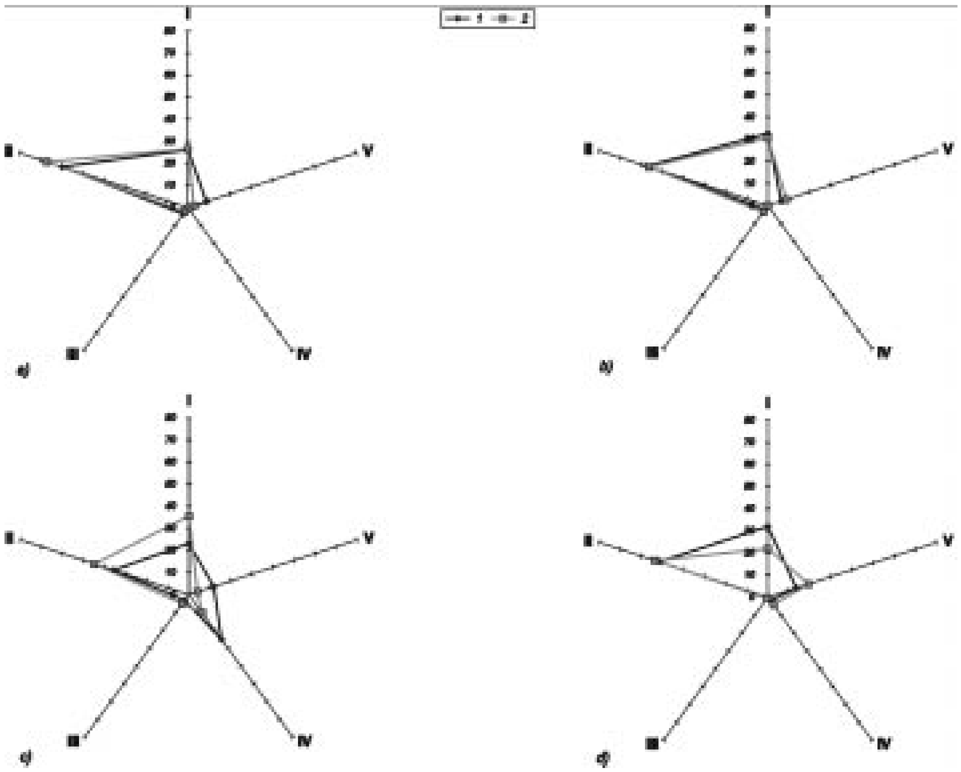

Fig. 24. Graphs with the content of groups I–V transparent heavy minerals in loesses from: a – Sharovechka, b – Yarmolynce, c – Charna, d – Ustechko
Wykresy zawartości grup (I–V) przezroczystych minerałów ciężkich w lessach z profili: a – Sharovechka, b – Yarmolynce, c – Charna, d – Ustechko

close bedrock on the mineral composition of the local loesses. The mineral composition of the green sands of Zalishchyky is characterized by domination of the groups I and II, and by very high content of glauconite (group IV).

In the loess log at Charna, localised few tens of kilometres to the south from Zalishchyky (point 16 in Fig. 1) the mineral composition of loess with great accuracy repeats the mineral composition of sands from the named location, however, with a little higher content of minerals of lesser density (glauconite, group IV) and those of flaky habits, susceptible to the aeolian activity (group V), than in the sands.

Other analysed deposits of the bedrock – moraine tills from the area of Przemysłów (point 24 in Fig. 2), for which the plot is given in Fig. 25a are characterized by significant presence of all the mineral groups (I–V). Their components come thus both from the weathering wastes of the magmatic and

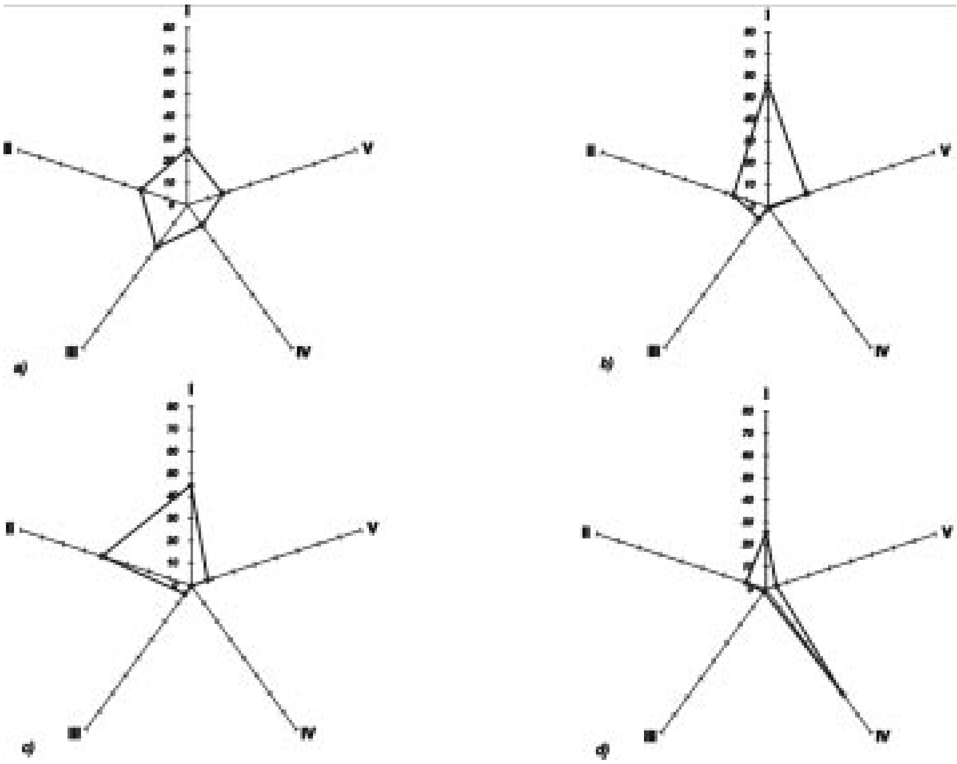

Fig. 25. Graphs with the content of groups I–V transparent heavy minerals in samples: a – till from Przemyslow, b – sandy-silty deposits from Radruż, c – sands from Żmijowiska, d – sandstones from Chodorowka

Wykresy zawartości grup (I–V) przezroczystych minerałów ciężkich w lessach z profili w próbkach z: a – gliny zwałowej z profilu Przemysłów, b – piaszczysto-pylastych osadów z profilu Radruż, c – piasków z profilu Żmijowiska, d – piaskowców z profilu Chodorowka

metamorphic rocks, commonly present in moraine tills (mineral groups I, II, III and V), and from the weathering wastes of the local of close bedrock (the group IV). The mineral compositions of the younger upper loesses from the logs localised to SE from the tills (the points: 11, 12, 13, 14 and 15 in Fig. 1) are the reflection of the mineral compositions of these tills. This is expressed by the great participation of the mineral groups I, II and V (Figs 21–23) and by disappearance of the minerals poorly resistant to transport (minerals of the groups III and IV).

The mineral composition of the sandy covers at Bibrka (point 25 in Fig. 1) are the different example of distinct differences between them, all the other bedrock deposits (Table 3 and Fig. 26a) and the mineral compositions of the loesses from the neighbouring logs. In the sands two mineral groups are pre-

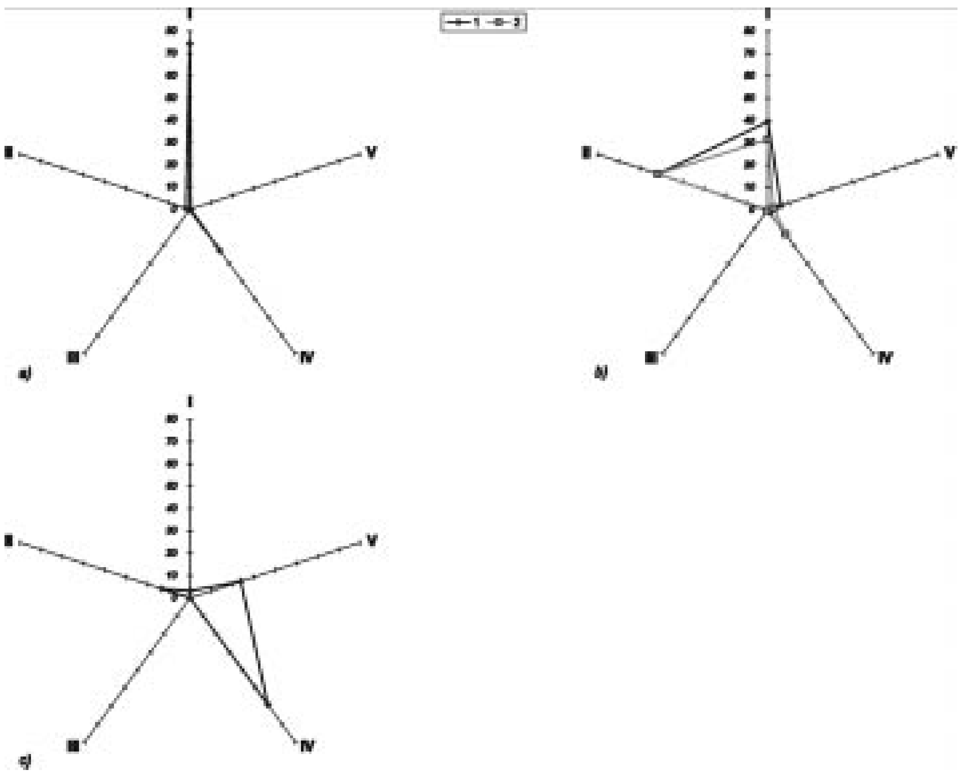

Fig. 26. Graphs with the content of groups I–V transparent heavy minerals in samples: a – sands from Bibrka, b – sands from Zalischyky, c – sands from Skala Podolska

Wykresy zawartości grup (I–V) przezroczystych minerałów ciężkich w lessach z profili w próbkach z: a – piasków z profilu Bibrka, b – piasków z profilu Zalischyky, c – piasków z profilu Skała

sent: I and IV. It is probable that these sands are the products of multiple outwashing and blowing of other deposits, which originally were rich in the minerals most resistant to the weathering factors (group I) and local bedrock deposits rich in glauconite (group IV). The lack of the influence of the local mineral composition of these deposits in the mineral composition of loesses may appear from the fact that these deposits were outside the loess-forming aeolian activity.

In the case of the younger upper loess preserved in the area of the central and northern part of the Podolian Upland the tendency to the closer relations of the mineral compositions of the heavy minerals from this loess and the mineral compositions of bedrocks or the deposits of the nearest neighbourhood is apparent. In fact, already in the case of the Sandomierz Basin (locations at Krzeszów and Grodzisko) as well as the north-western part of the Podolian Upland (Novo-Milatyn and Kulychyvka) the distinct increase of the contents of the

minerals of the group III (amphiboles and pyroxenes) is visible as the result of the participation of the material coming from the glacial and fluvioglacial sediments in the area between the San, Dniestr and Bug Rivers, or in the drainage basin of the upper Pripyat River.

Considering the above facts and the characterized relations of the mineral composition of the heavy fraction of the analysed loess in the central and southern part of the Podolian Upland with the deposits of its bedrock in the drainage basin of the Dniestr River (outcrops at Zalishchyky and Skała Podolska), one should take into account the possibility of two different directions of inflow of the loess-forming material. The weathering wastes of the local direct bedrocks or surroundings of the loesses in the area of the Podolian Upland might have been one of the sources, and the valley sediments of the Dniestr River and its tributaries could be another source; the inflow of the material from Carpathians may be omitted here. Thus one should conclude, that the local younger upper loess could be accumulated both by winds blowing from north-east and from south-west (Fig. 27). In the northern part of the described area the first of the above directions prevailed, like the case of the loesses occurring further to the north in the Lublin and Volhynian Uplands (Chlebowski et al. 2002, 2003a).

The question, whether suggestion formulated in this paper that two different directions of alimentation of the loess-forming material to the described area could take place in the same time or in different periods of accumulation of the younger upper loess, is the separate problem. This is in part a new approach, at least in relation to the north-western and south-western directions of the loess-transporting winds. In the present authors' opinion, the time of accumulation of the younger upper loess comprising at least more than ten thousand years during the extreme of the last glaciation, could include even so differing in the scale of the year's seasons from winter to summer conditions of the atmospheric circulation, that the significant differences in the strength and directions of winds transporting the loess material might occur in the area of Mid-Carpathian Foreland. The suppositions on different and even opposed directions of the loess-transporting winds during the accumulation of the younger upper loess were expressed by the present authors on the basis of the analogous investigations in the area between the lower parts of the Dniestr and Dnieper Rivers (Chlebowski et al. 2003b).

CONCLUSIONS

The performed mineralogical studies of loesses occurring in the areas of the Sandomierz Basin, Mid-Carpathian Foreland and western Podolian Upland, on the basis of the assemblage of the transparent heavy minerals and certain

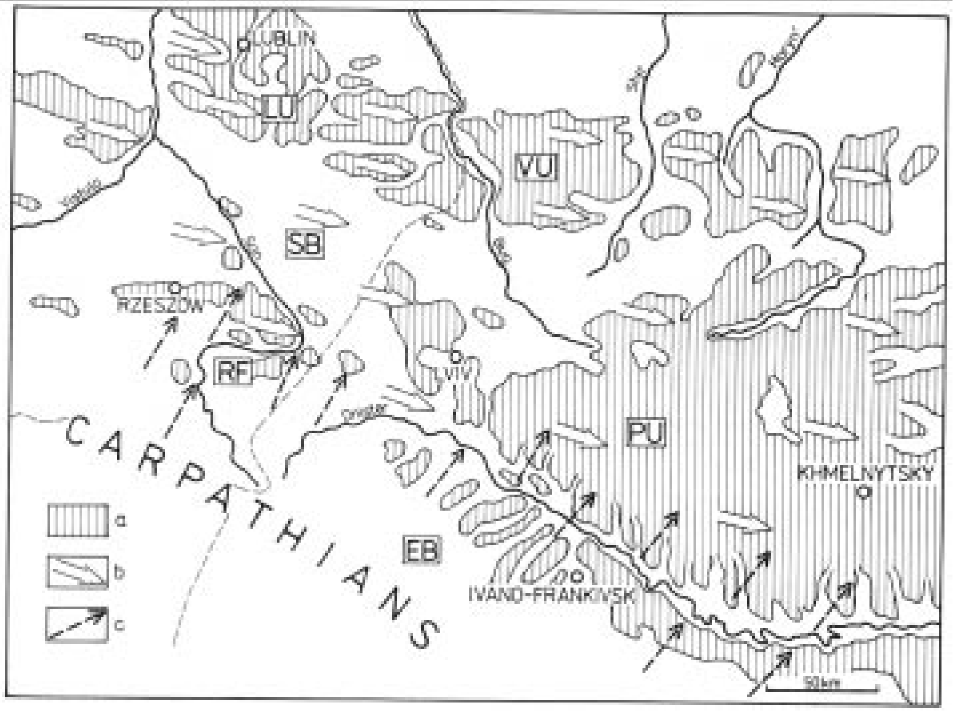

Fig. 27. Conditions of accumulation of loesses in south-east Poland and north-west Ukraine; a – younger upper loess, b – main directions of wind, c – local directions of wind
Warunki akumulacji lessów w południowo-wschodniej Polsce i północno-wschodniej Ukrainie; a – młodszy górny less, b – główne kierunki wiatru, c – lokalne kierunki wiatru

components of the light fraction, revealed general similarities and detailed differences. The similarities are expressed by the presence of the same mineral assemblage in the studied loess logs of the investigated areas, and the differences are shown as local variations in the contents of individual mineral groups (I–V), distinguished among the transparent heavy minerals, and as influences of the surrounding environments like the components coming from the weathering wastes of the local bedrocks. Domination of the two mineral groups: garnets (group II) and micas (group V), is the main mineralogical feature of the described loesses in the whole area of Mid-Carpathian Foreland and western Podolian Upland.

The minerals least resistant to the weathering factors and coming from the locally occurring bedrock deposits, e. g. glauconite, which is not usually transported over long distances, are the most important components of the loesses.

Moreover, the redeposited microfaunal components (mainly foraminifers), which also may survive only short transport due to their fragility, are meaningful here. Their frequent presence in many logs of the studied area evidences the occurrence of the bedrocks and their weathering wastes containing these fragile components, e. g. Cretaceous deposits (Paruch et al. 2003).

In the detailed conclusions of the mineralogical studies one may state:

1. Loesses in the area of the Sandomierz Basin, Mid-Carpathian Foreland and western Podolian Upland display great mineralogical differences expressed by various participation of the distinguished mineral groups (I–V) in individual logs, with simultaneous domination of garnets (group II) and micas (group IV) in all the logs.

2. The dominating participation of the named two mineral groups in the case of the loesses in the area of Mid-Carpathian Foreland directly concerns the mineral compositions of the near basement consisting of the rocks of the Krosno Beds in the Carpathian Flysch. This confirms the earlier opinion on the active influence of many local sources of the loess-forming material on the mineral compositon of loesses during their accumulation in the areas of southern Poland and western Ukraine. (Chlebowski, Lindner 1992; Chlebowski et al. 2000, 2002, 2003a). This opinion was confirmed by the studies of other authors, who recognized the direct genetic connection of the loesses from Mid-Carpathian Foreland with the adjacent alimentation areas, comprising both weathering wastes of the flysch beds, containing typically large amounts of garnets and micas in the composition of their heavy mineral fractions (Gerlach et al. 1991), and the fluvioperiglacial, fine-grained sediments of the San River valley (Krysowska-Iwaszkiewicz, Łanczont 1992; Łanczont 1995). The vertical differentiation of the mineral composition found in certain logs (between the samples no. 1 and No. 2) most probably resulted from the fact, that the dusty material could be blown out from different local alimentation areas by wind of various velocity, changing in time. This regularity in the loess log at Halicz was stated by Racinowski, Łanczont and Bogutsky (1999).

3. In the case of loesses in the western Podolian Upland, the weathering wastes of the rocks of the crystalline basement and the deposits of the glacial origin, rich in crystalline rock material, might be the sources of the transparent heavy minerals (garnets and micas), dominating in the heavy mineral fractions. The deposits of the pre-Quaternary sedimentary cover, especially of the Mesozoic and Cenozoic age, consisting of organodetritic limestones, marls and detritic-quartz-free gaizes, outcropping in numerous steep edges of the valleys of the Dniestr River and its tributaries and the valley of the Bug River cutting the Volhynian Upland, were the source of carbonates and remnants of microfossils (foraminifers), abundantly occurring in many investigated loess logs. Their absence in certain logs evidences the influence of other local alimentation areas,

where in the basement other types of rocks occur, that yielded weathering wastes of different mineral composition. A very good example of such differentiation of the mineral composition of loesses may be found in the log at Charna (point 16 in Fig. 1), in which the exceptionally high contents of weathered glauconite were found (10 to 25% of the total transparent heavy minerals). This mineral could come from the weathering waste of the Tertiary rocks, e. g. the sandy deposits rich in glauconite. Absence of foraminifers in these loesses indicates that the region of accumulation in this case was outside the influence of the alimentation areas rich in weathering wastes of the Cretaceous rocks.

4. Existence of many local sources of fine-grained loess-forming material of differentiated mineral composition, resulting in very distinct variations of the mineral composition of loesses, evidences not only the genetic connection of loesses with the local sources of the dusty material, but also its short transport. The components of the mineral groups I an II, occurring in loesses, were included in subsequent sedimentary cycles, thus redeposited and accumulated many times not only due to the aeolian factor, but also in fluvial and periglacial conditions, however, the minerals of the groups III, IV and V survived their first and short transport from the weathering wastes of their original occurrence (e. g. crumbling sandstone deposits of the Krosno beds in Carpathian flysch, mud sediments of the San River valley, magmatic ands metamorphic rocks in the glacial deposits and components of the crystalline bedrocks).

5. Considering the transport directions one may conclude that generally, in the regional scale, the movement of many mineral components of the loess-forming dust occurred due to winds blowing from the west to the east (with deviations to N and S). However, other wind directions might have occurred, depending on the local, e. g. orographic conditions. The variable morphology of the mountainous and hilly areas of the Mid-Carpathian Foreland caused by their geological structure, caused the occurrence of "forced" wind directions, especially in the lower part of atmosphere, the influence of which on the transport of the local material was very important or even dominating. The sandy deposits at Zalishchyky (point 26 in Fig. 1) and the loesses at Charna (point 16 in Fig. 1) are the good example of the influence of the local bedrock on the mineral composition of loesses, confirming simultaneously the direction of transport of the loess-forming material from the west to the east. Mineral composition of these loesses (Fig. 24c) reflects quite exactly the mineral composition of the sandy deposits from Zalishchyky (Fig. 26b), occurring several tens of kilometres to the west.

6. The studies of the mineral composition of loesses in the investigated, vast and very differentiated morphologically area of Mid-Carpathian Foreland and western Podolian Upland allow the conclusion, that in certain regions the participation of the aeolian factor in accumulation of the dusty deposits was

dominating (e. g. the log of Jarosław – point 2 in Fig. 1, the log of Humniska – point 6 in Fig 1, for which the "aeolian vector" is very distinct, as shown in Figs 20c and 21b). In other regions, e. g. in the terrain between the San and Dniestr Rivers (the log of Siedliska – point 9 in Fig. 1) the supplementary participation of the aeolian factor was recognized jointly with the important deluvial, slope and fluvial processes.

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STRESZCZENIE

Przedstawiono uzyskane wyniki badań mineralogicznych i ich interpretację na tle budowy geologicznej i charakterystyki geomorfologicznej obszarów: Kotliny Sandomierskiej, Podkarpacia polskiego i ukraińskiego oraz zachodniej części Wyżyny Podolskiej, które stanowią znaczną część obszaru SE Polski i NW Ukrainy objętego projektem badań.

Analizę mineralogiczną lessów przedstawiono w oparciu o badania przezroczystych minerałów ciężkich oraz frakcji lekkiej. We frakcji lekkiej zwracano główną uwagę na obecność w niej szczątków, a także dobrze zachowanych mikroskamieniałości, głównie otwornic, a także minerałów o pokroju blaszkowym. Przedstawiana problematyka stanowi kontynuację analogicznych badań dotyczących górnego lessu młodszego Wyżyny Lubelskiej i Wyżyny Wołyńskiej (Chlebowski et al. 2003a), a charakterystykę mineralogiczną przedstawiono według wcześniej wypracowanej metodyki przy zastosowaniu dla celów interpretacyjnych wykresów radarowych (Chlebowski et al. 2002). Analogicznym badaniom poddano szereg próbek skał z bliskiego i dalszego otoczenia lessów, które uznano za prawdopodobne źródła materiału lessotwórczego. Stwierdzono, że dominujące w składzie przezroczystych minerałów ciężkich w lessach Podkarpacia są granaty i łyszczyki, które bezpośrednio nawiązują do składu mineralnego skał pobliskiego podłoża, tj. fliszu karpackiego. W przypadku lessów zachodniej części Wyżyny Podolskiej poza skałami fliszu karpackiego dodatkowymi obszarami alimentacyjnymi mogły być utwory wodnolodowcowe oraz zwietrzeliny skał krystalicznego podłoża, a także wulkanity Karpat rumuńskich, których obecność jest znaczona na mapie w rejonach na południe od Podola. Wpływ lokalnych skał podłoża na skład mineralny lessów potwierdzają również szczątki mikroskamieniałości (głównie otwornice) stwierdzone w lessach, a pochodzące ze zwietrzelin lokalnie występujących skał wieku kredowego, takich jak kreda pisząca, margle i gezy (Paruch-Kulczycka et al. 2003).

Stwierdzono duże zróżnicowanie składu mineralnego lessów na badanym obszarze, co jest związane z istnieniem wielu lokalnych źródeł (obszarów alimentacyjnych) dla drobnookruchowego materiału lessotwórczego. Badania składu mineralnego lessów, jego zróżnicowanie oraz związek genetyczny ze zwietrzelinami lokalnie występujących skał podłoża, pozwoliły określić kierunki transportu materiału pyłowego, który odbywał się przy udziale wiatrów głównie z kierunków zachodnich ku wschodowi (W–E) oraz wiatrów lokalnych o kierunkach SW–NE i NW–SE, a także wiatrów z kierunku południowo-wschodniego. Kierunki te dotyczą wiatrów w dolnych warstwach atmosfery, transportujących główne masy materiału pyłowego na niezbyt wielkie lub wręcz krótkie odległości, natomiast zapewne też pewną rolę odegrały wiatry z wyższych partii atmosfery, jednak rola ich była mniejsza.