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Lithostratigraphy of loesses and silty sediments in the Western Roztocze, southeastern Poland

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A regional stratigraphic pattern was prepared for the Pleistocene period from 530 to 10 ka BP. Development of loesses and "non-loess" silty sediments was presented against the background of palaeogeographic conditions characterized by processes of pedogenesis, erosion and denudation, weathering type and extents of the Scandinavian ice sheets. Loesses were accumulated mostly in pleniglacials of the specific glaciation periods under conditions of arid subarctic climate, while silty sediments, which were referred to as having aeolian-wash colluvial origin, formed in the earlier phase of glaciations, under conditions of a polar moist climate.

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Key words: Lublin Upland, Western Roztocze, Pleistocene, lithostratigraphy, loess, non-loess silty sediments.

INTRODUCTION

This paper results from a broader research conducted by the authors in various regions, simultaneously on loesses and on non-loess types of silty sediments. The goal of the research is to determine the age of the sediments, in addition to obtain new data on origin of the studied sediments and on sedimentary conditions. Our research in the Western Roztocze allowed to construct a regional stratigraphic pattern — common for loesses and silty sediments. Multi-layer non-loess silty covers were discovered there, in addition to stratigraphically diversified loess profiles. Comparative lithologic studies were conducted.

TL DATED GEOLOGICAL PROFILES

Loesses in the Roztocze form one of the four main loess regions in Poland (H. Maruszczak, 1961). Similarly to other ones, this region is more or less latitudinal and extends from Szczebrzeszyn in the east, through Kraśnik, and further to the west. It includes the Central and the Western Roztocze. Loesses form here relatively compact covers. In the western part of the region they were studied by J. Malinowski and J. E. Mojski (1960) in Sąsiadka and by J. Malinowski (1964) in drilling profiles (Fig. 1).

Silty sediments in the Roztocze have not been studied yet. A. Jahn (1956) mentioned them when distinguishing silty postglacial slope-wash sediments.

Conclusions presented in the present paper are based on the study of two representative profiles: a loess profile at Błażek (M. Łanczont *et al.*, 1998) and profiles of silty covers at Blinów (M. Łanczont, J. Wojtanowicz, 1998). Thermoluminescence analyses were conducted by J. Kusiak in the Thermoluminescence Laboratory of the Department of Physical Geography and Palaeogeography, Maria Curie-Skłodowska University in Lublin.

LOESS PROFILE AT BŁAŻEK

The Błażek profile is located in the western periphery of the Roztocze Region (Fig. 1). It coincides with a watershed (a divide of the 2nd order between the Wieprz and San Rivers), and is located at 295 m a.s.l. In geomorphologic

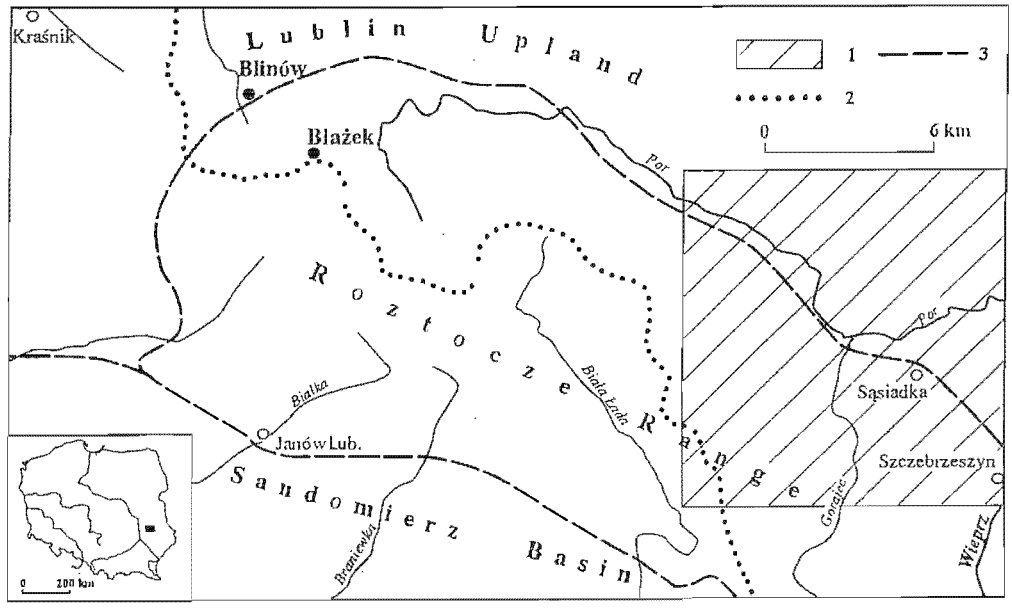

Fig. 1. Location of the study area

1 — study area of J. Malinowski (1964), 2 — watershed of the San–Wieprz Rivers, 3 — boundary of the Roztocze Region

sense, it is associated with a lower — from two distinguished in the Western Roztocze — plain of apical denudation. The area is characterized by a typical morphology for loesses with a dense network of denudation valleys and gorges.

The profile outcrops near a brickyard pit, located in the upper part of a slope in a depression which continues into a denudation valley of the Wieprz River basin and lies 60 m above the floor of the Por River valley. The profile was studied to a depth of 7.55 m in the outcrop, and lower to a depth of 13 m based on the hand augers cuttings. It is represented by two basic complexes of sediments. They are: (1) lithological complex loess series (layers a_1–k_2), and (2) sandy and loamy sediments of a slope-wash origin (layers l_1–m_2), occurring at the bottom of the profile. These sediments further overlie weathered deposits of the Tertiary detrital limestones (Fig. 2).

As far as age of the loess is considered, the Błażek profile basically refers to stratigraphic pattern, which is accepted for the loesses in the Roztocze (J. Malinowski, J. E. Mojski, 1960; J. Malinowski, 1964). Particularly a concept that the oldest loess in the Roztocze is associated with the Middle Polish (Saalian) Glaciation has been confirmed. The presence of several significant stratigraphic unconformities in the profile, which occur predominantly during transitions from warmer to colder periods of the upper stratigraphic rank, is a very characteristic feature. Processes of erosion and denudation played a significant role in these phases. This is undoubtedly the reason that younger loesses (of the Vistulian age) predominantly contribute to development of loess covers in the Roztocze; older ones in a big part have not been preserved. The presence of the Middle Polish Glaciation loesses can be contributed most probably to their apical location and a near-divide profile where erosional processes were relatively less active.

In the profile, three basic stratigraphic complexes of loesses representing various glaciations are distinguished: Odranian = Saalian I (layers h–k_2), Wartanian = Saalian II (layers f_1–f_5) and Vistulian = Weichselian (layers a_1–d). They are separated by two soil layers of a higher stratigraphic rank, from the Lublinian = Treenian Interglacial (layer g) and the Eemian Interglacial (layer e). The next fossil soil (layer m_1), which most probably may be associated with the Mazovian = Holsteinian Interglacial, underlies the loess cover. This soil is developed on the described slope-wash sediments, but its upper horizons are eroded and only lower parts of the illuvial horizon occur in the profile. Moreover, a rendzina soil (layer n) is present at the bottom of the Błażek profile, which formed on the carbonaceous bedrock. Both described above soils are distinguished as commonly occurring by J. Malinowski (1964), who considered the rendzina soil to be of the Early Pleistocene (Eopleistocene) age. Results of the study in the Błażek profile seem to confirm this hypothesis, among other things because of the fact, that greenish glauconitic sands overlying the rendzina soil originated from the washout of the local Tertiary material and may be classified as preglacial sediments.

A layer of loess from the Odranian (layers h–l_2) distinguishes by a relatively significant thickness and is topped by soil from the Lublinian Interglacial. Also this soil has been partially eroded in the upper horizons. A two-layer interstadial soil developed within a lower part of the loess representing the Odranian Glaciation. In the light of two determined TL datings, this loess could develop in the range of between 263 and 242 ka BP.

The beginning of accumulation of this loess corresponds with a time of ice sheet advance of the Odranian Glaciation, which maximum extent was very close to Błażek and is documented by varve-type clays with pebbles of the Scandinavian rocks in areas located at a distance of few kilometres

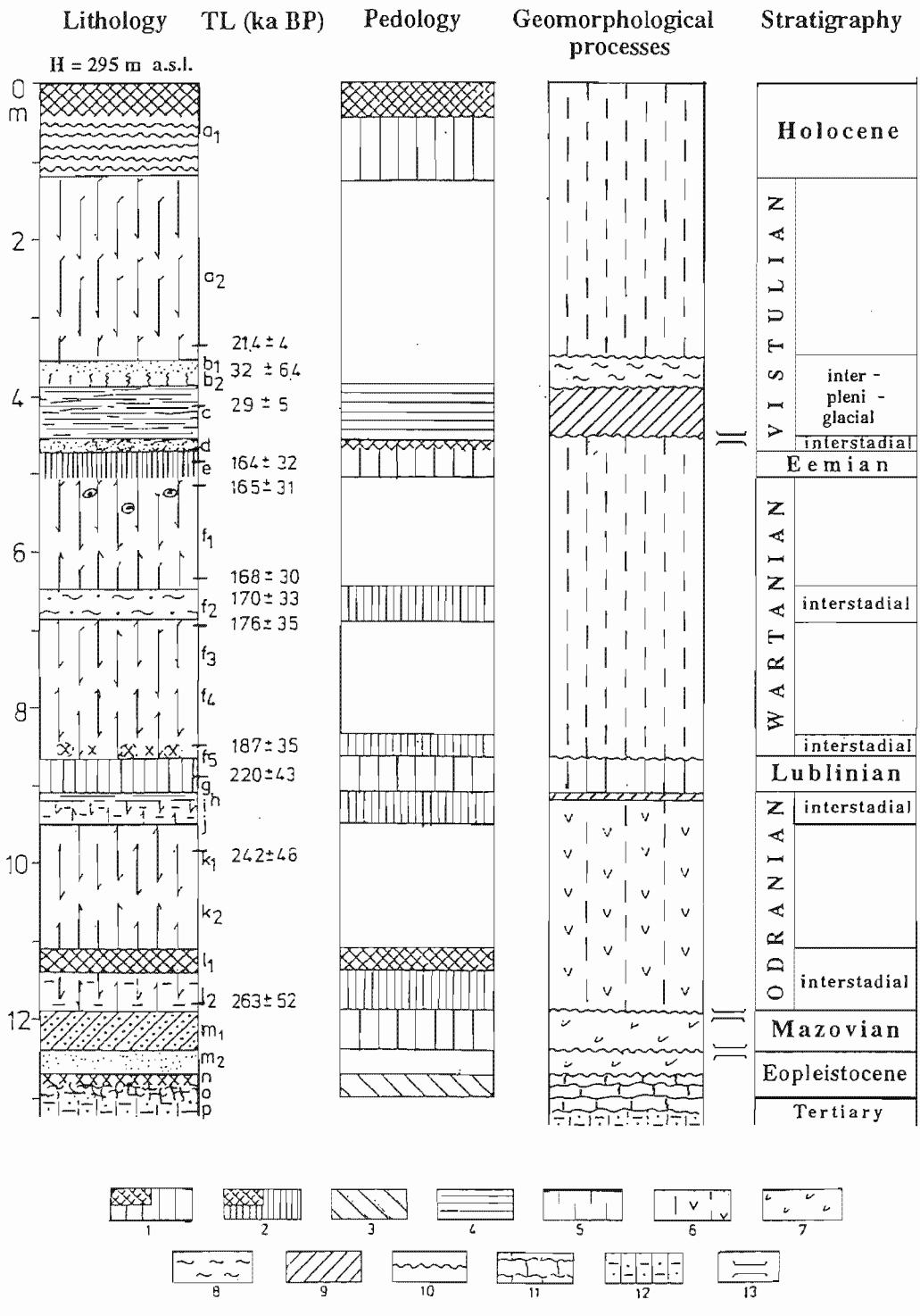

Fig. 2. Loess profile Błażek

1 — interglacial soils, 2 — interstadial soils, 3 — rendzina, 4 — soil sediment, 5 — aeolian accumulation, 6 — aeolian-slope-wash accumulation, 7 — mass wasting processes, 8 — washout, 9 — colluvial-alluvial soils, 10 — denudation surfaces, 11 — Tertiary rock regolith, 12 — detrital limestones (Tertiary), 13 — high rank hiatus (stratigraphic gaps) in the profile; explanations of letter symbols of specific layers in the text

to the west from the studied profile. Accumulation of these loesses has been continued in later glaciation substages with a distinguished interstadial phase (interstadial soil).

Relatively most thoroughly developed loesses representing the Wartanian Glaciation are developed at Błażek (thickness exceeding 4 m), and are differentiated onto three

Table 1

Indices of grain size distribution in loesses and silty covers of the Western Roztocze (according to R. L. Folk and W. C. Ward, 1957)

Loess						Silty (loess-like) covers						TL [ka]	Stratigraphy
Deposits	Mz [ϕ]	δ_I	Sk_I	K_G	$CaCO_3$ [%]	Deposits	Mz [ϕ]	δ_I	Sk_I	K_G	$CaCO_3$ [%]		
Loess on planation levels	5.69	1.99	0.35	1.52	6.93								Vistulian, upper part
Slope loess	5.51	1.80	0.37	1.45	8.38								
						silty-sandy	3.76	2.10	0.15	1.41	–	106	Early Vistulian
Slope loess	6.15	2.60	0.46	1.47	–							164–187	Wartanian
						silty-loamy	5.26	1.75	0.59	1.67	–	208	
Slope loess	6.68	2.85	0.47	1.79	–							242–263	Odranian
						silty	5.69	2.33	0.41	1.90			Liviecian
						silty-clayey	6.38	2.10	0.57	0.99	–	502	Sanian 2

Mz — mean grain diameter; δ_I — standard deviation; Sk_I — skewness, K_G — curtosis; carbonate content ($CaCO_3$) in percentage (mean values)

units of a lower stratigraphic order; there is lack of the upper part of the cover of these sediments. A layer of the Wartanian loesses is interlayered by two interstadial soils, which are dated: an older one at ca. 180 ka BP and a younger one at ca. 170 ka BP, respectively.

The Eemian soil, which formed on the Wartanian loesses, is preserved in a fragmented form. Parts of the illuvial horizon of this soil, intensively eroded on an inclined at 10–12° slope, have been preserved in the root fragments. Numerous traces of soil fauna activity were determined beneath, mainly in a form of crotovines, which are filled by a layered mineral material and/or a mineral-organic material, originated from presently non-existent upper genetic horizons of a forest soil.

Younger loesses are strongly stratigraphically reduced. There is, however, a lack of links from an older part of the Vistulian Glaciation, possibly these older sediments were removed and their material could be included in composition of slope-wash sediments (layer c), representing the middle pleniglacial of the last glaciation. These slope-wash sediments overlie a gley soil (of an uncertain stratigraphic position — a lower Plenivistulian?/early Vistulian?), which lies at a top of fragments of an illuvial horizon of the Eemian soil; in other locations of the outcrop, slope-wash sediments rest directly on roots of the Eemian soil.

A fact worth attention is that a fossil Eemian morphology, which can be detected on an extensive wall of the outcrop, is very concordant with a present morphology.

SILTY COVERS (LOESS-LIKE) AT BLINÓW

Silty sediments were studied in two locations described as Blinów 1 and 2, located at a border line between the Roztocze and the Lublin Upland (Fig. 1). From the point of view of our study, the profile Blinów 1, located at 250 m a.s.l. at the right slope of a dry valley which falls into the Bystrzyca River valley, is a representative one.

A series of silty and detrital sediments of a complex structure and variable thickness (maximum up to 4 m) occur within the slope near a road cut. This sequence is divided onto three basic links, which are sharply separated by clear denudation and erosional-denudation surfaces (Fig. 3) and additionally internally differentiated (the middle and upper covers, respectively) onto 2–3 sublevels of a variable thickness. These sediments fill a fossil depression, but presently a morphological inversion is present here, because they form a core of a convex part of the slope between two denudation valleys. The Quaternary sediments lie on a surface of the Cretaceous limestones with traces of activity of karst processes (pockets, karst crust).

Solifluctional-detrital cover composed of a limestone material (a) occurs at the bottom part of the profile and contains lenses of a sandy material and pebbles of quartzitic sandstone, which might be originated from destruction of the Eopleistocene (or older) gravels, described in upper topographic locations in the valley (A. Jahn, 1956).

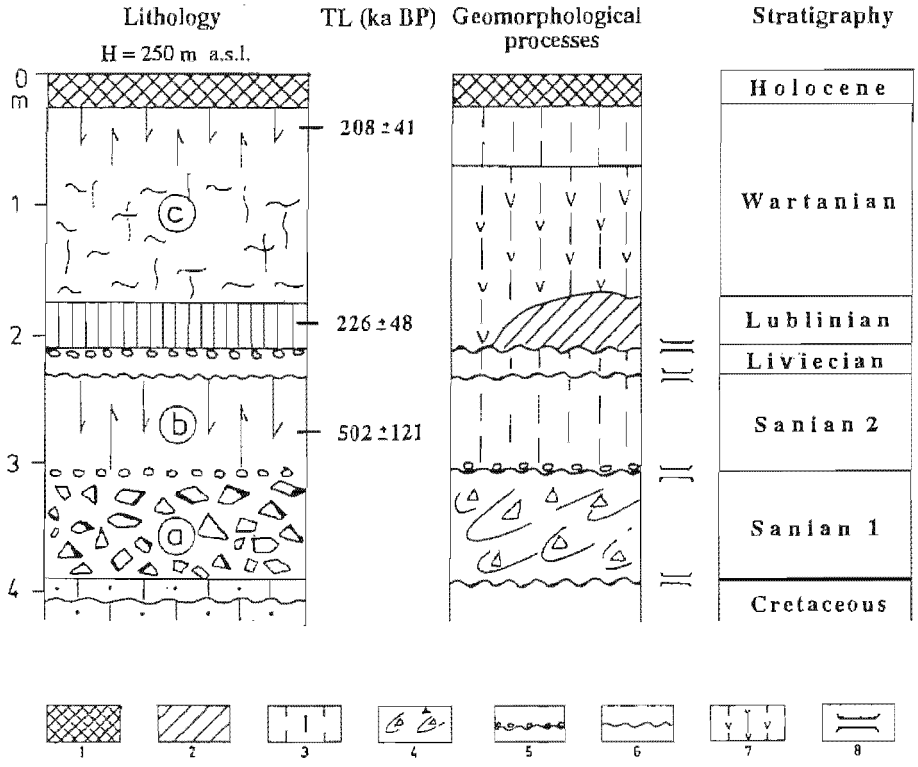

Fig. 3. Profile of silty sediments at Blinów

1 — soils, 2 — colluvial-alluvial soils, 3 — aeolian accumulation, 4 — erosional-denudation surfaces with a gravel pavement, 5 — denudation surfaces, 6 — detrital solifluction, 7 — structures of the ground ice, 8 — high rank hiatus (stratigraphic gaps) in the profile; explanations of letter symbols in the text

An erosional-denudation surface emphasized by a layer of loam and strongly weathered pavement with individual pebbles of the Scandinavian rocks, cuts off this detrital cover and is further overlain by few generations of silty covers. The first cover (**b**) is divided onto two parts separated by denudation surface, which is accentuated by a thin, discontinuous layer of a red slope loam. This cover is associated with the Mesopleistocene; so far it has no equivalent in the loess profiles of the Roztocze. Its lower link developed probably during an older part of the Sanian 2 = Elsterian 2 Glaciation (a before-maximum phase?), which was supported by TL dating at 502 ka BP. Traces of illuvial soil processes are marked clearly in the upper part of this link. We suggest that it is a lower part of the Mazovian Interglacial soil profile, upper horizons of which were destroyed as the result of later denudation processes. An upper part of the described silty cover is initially correlated with the Liviecian = Fuhne Glaciation. Indirectly it is indicated by characteristics resulting from analysis of features, age and sequence of layers in the profile.

A surface of unconformity of a high stratigraphic rank, being the next erosional-denudation surface with a pavement containing the Scandinavian material, occurs between the middle (**b**) and the upper (**c**) silty cover respectively; representing a time period from the Zbójnian = Dömnitz Interglacial through the Odranian Glaciation and to the Lublinian Interglacial. We suggest that remains of the illuvial horizon, occurring in a form of redeposited packages at the bottom of the upper silty cover **c** are associated with the last period, which indicates a pedogenesis under interglacial conditions. A sample from the illuvium was TL dated at 226 ka BP. Silty deposits, however, of this cover developed during the Wartanian Glaciation (TL age: 208 ka BP).

One more, this time the Vistulian (TL age: 106±21 ka BP) cover of the slope sandy or sandy-silty sediments, rhythmically interlayered with gleyey deposit, was determined in the closest neighbourhood of the Blinów 2 location.

LITHOLOGY

The studied loesses in the Western Roztocze indicate, in respect of grain size distribution, typical features of the zoned subaerial loesses, particularly the younger loess, i.e. of the Vistulian age, in which the content of fraction 0.05–0.02 mm reaches up to 56% (Fig. 4). Granulometric parameters slightly differ for younger and older layers, respectively (Table 1). The latter ones are, however, more fine-grained, poorer sorted and are characterized by more skew grain size distribution. Only the younger loess contains carbonates ($CaCO_3$ = 7–8%, max. 10%). Decalcified older loesses, of the Wartanian and the Odranian Glaciation, are more coherent.

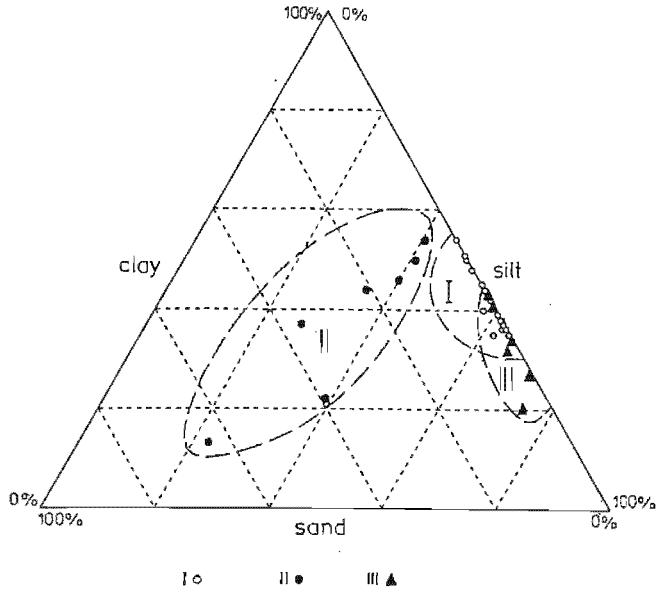

Fig. 4. Comparison between a mechanical composition of loesses (I), slope-wash interloess and underloess' sediments (II) in the Błażek profile and silty sediments (III) in the Blinów profile

Periglacial silty covers depart significantly in respect of lithological characteristics from loesses. These covers, except for one common feature — they are though carbonate-free, differ also among themselves. These differences to some extent are derived from a very differentiated age of the covers, but also their reason lies in diversified origin. It may be concluded from a granulometric analysis that younger covers of the Vistulian age contain more fine-grained and very fine-grained sand (about 50%), less silt (below 20%) and some clay (below 10%). In older covers these proportions are opposite and content of the described fractions is 10–20%, about 50%, and 15–20%, respectively. A higher content of clay fraction influences lithological features of the sediment, which is hard and coherent (Fig. 4). One could emphasize a generally poor and very poor sorting of the sediment. Skewness parameters of the grain size distribution are high for the older covers, which may result from presence of solifluction processes in their development, and are significantly lower for the covers of the Vistulian, which in turn may result from the fact that meltwaters (washout processes) affected their development.

STRATIGRAPHY

The conducted study allowed to construct a regional stratigraphic pattern, a certain type of ideogram of accumulation development of loesses and silty sediments. This pattern includes a period of the Pleistocene from 530 to 10 ka BP, which means a period of five last glaciation periods (Sanian 2, Liviecian, Odranian, Wartanian, and Vistulian) and four interglacial periods (Mazovian, Zbójnian, Lublinian, and Eemian). In the pattern, also other processes such as pedogenesis, erosion and denudation, a type of weathering which, after also considering the continental glacier cover, give jointly a picture of palaeogeographic conditions of the described period (Fig. 5).

A basic conclusion, which results from the study in the Western Roztocze and which is a matrix of the pattern, is the relationship between loesses and silty sediments. All seem to support an idea that these two types of deposits have not been formed simultaneously. Silty covers mainly formed in an early phase of glaciations and are older from loesses of the specific stage. They formed under conditions of a moist polar climate, in which frost weathering (cryogenic) occurred, but simultaneously soil processes of the gley type in the tundra environment developed and slope processes acted intensively, including solifluction, and a slope accumulation as their result. Silty sediments dated at that period may be characterized by an aeolian-slope-wash origin.

Loesses were accumulated during the pleniglacial in a subarctic arid climate, characterized by an intensive frost weathering and active aeolian activity. The both types of analyzed sediments are separated by a time interval; they do not, however, spatially interfinger.

This is contrary to the situation in the Carpathian Foreland, where such spatial interfingering of the slope covers (mainly solifluctional) and of the loess covers occurs (M. Łanczont, 1995). The reason of this state of affairs, which itself has a significant palaeogeographic meaning and is stratigraphically important, may result, among other things, from certain regional distinct conditions of accumulation in the Western Roztocze.

These conditions should be related to issues of silty material sources, where this material contributed to the development of loesses and silty covers in the Western Roztocze, character and a distance of transport, finally the relationship of sediments with morphology of the area. Periglacial covers are mainly located in lower parts of the fossil slopes, and silty material, undoubtedly washed out and blown out and transported in this way along short distances down the hill, contributed in their development. Loess covers, however, are found predominantly in upper topographic locations, and source areas, more abundant in silt, should be mainly anticipated in periglacial drift, deposited within depressions and river valleys, from where it was blown out under arid climatic conditions of the pleniglacial. Thus with respect to transport directions of a material forming these two types of sediments, one may suggest a hypothesis that they were generally opposing.

Conclusions presented above which refer to the development of loesses and silty sediments may be confronted with ideas associated with development of morphogenic processes in Poland, including loess accumulation, during the last glaciation (Vistulian Glaciation), which H. Maruszczak (1968) presented in two diagrams. Thus based on them, one may conclude that in an early glacial phase, accumulation of loessy silt had a small significance and occurred sporadically; however, the major role was played by river accumulation and a slightly smaller by a slope one. The major phase of loessy accumulation coincided with the Pleniglacial, and particularly

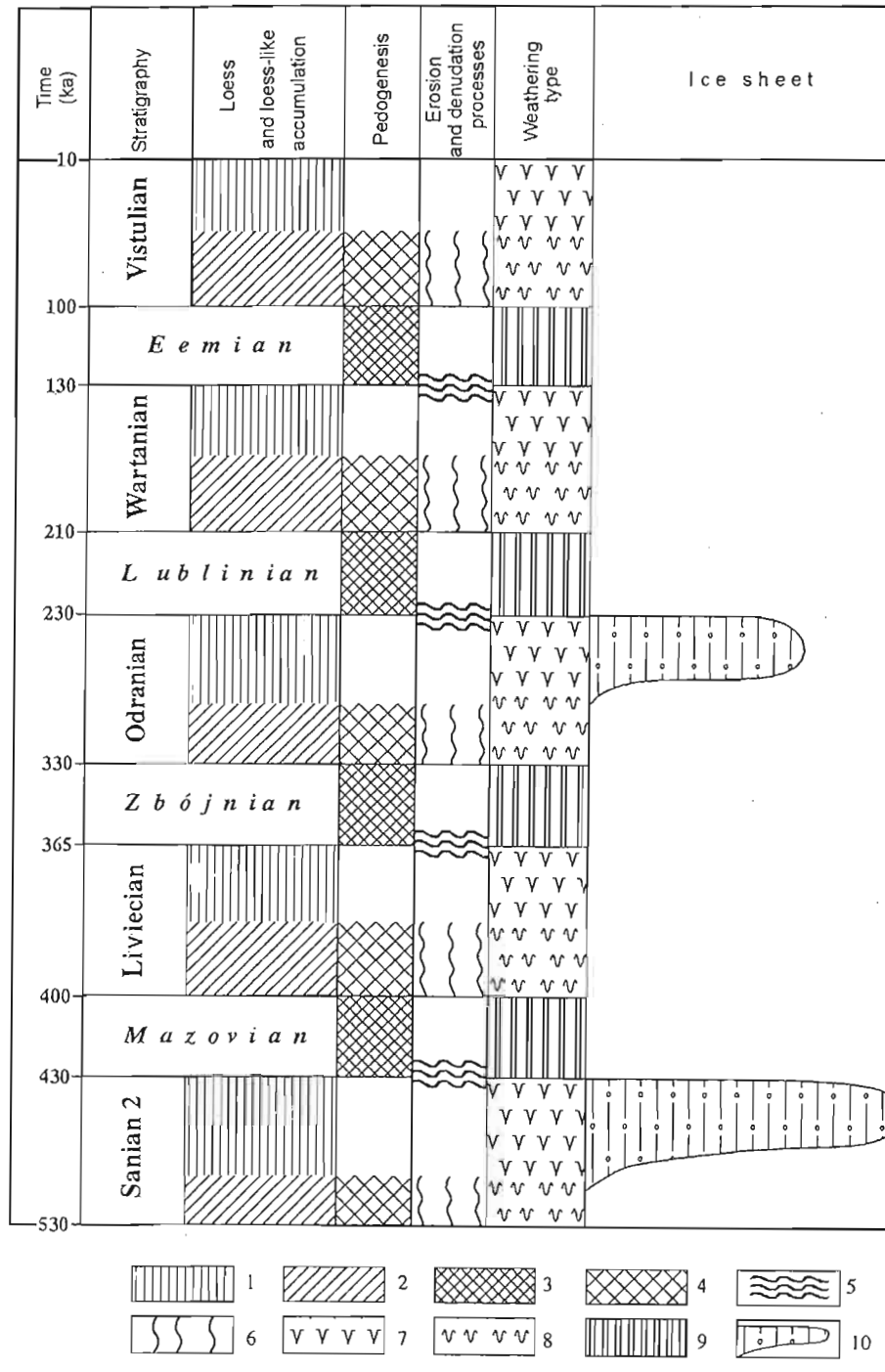

Fig. 5. Stratigraphy of loesses and silty sediments processes and related palaeogeographic conditions in the Western Roztocze

1 — loess accumulation, 2 — accumulation of slope-wash-aeolian silty sediments, 3 — interglacial soil processes, 4 — interstadial soil processes, 5 — erosion, 6 — denudation, 7 — frost weathering in subarctic climate (arid), 8 — frost weathering in polar climate (moist), 9 — chemical weathering in temperate forest climate, 10 — ice sheet

its upper part (Pleniglacial B). With respect to a period of time of the development of loesses, there is agreement between a scheme presented by the authors and a pattern of H. Maruszczak (1968).

Thus, there is a hope that a regional pattern of the Western Roztocze contains some more general regularities, which could be applied in other regions.

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LITOSTRATYGRAFIA LESSÓW I UTWORÓW PYLASTYCH ROZTOCZA ZACHODNIEGO

Streszczenie

Wnioski, przedstawione w artykule, oparte są na badaniach dwu reprezentatywnych profili: profilu lessowego Błażek oraz profilu pokryw pylastych w Blinowie (w dwu stanowiskach), położonych na zachodnich peryferiach Roztocza (fig. 1). Oba profile były szczegółowo opracowane oraz datowane metodą TL.

Profil lessowy w Błażku (fig. 2) reprezentuje, ze względu na swe położenie, fację lessu subaeralnego wierzchowinowego. Wyróżniono w nim trzy podstawowe kompleksy stratygraficzne lessów, odpowiadające zlodowaceniom: odry (solawy I) — warstwy h–l_2, warty (solawy II) — warstwy f_1–f_5 i wisły — warstwy a_1–d. Przedzielone są one dwoma glebami wyższej rangi stratygraficznej: interglacjałów lubelskiego (warstwa g) i eemskiego (warstwa e). W spągu profilu, pod lessami, występuje gleba (warstwa m_1), którą można by wiązać z interglacjałem mazowieckim *s.l.* (holsztyńskim *s.l.*).

Profil utworów pylastych w Blinowie (fig. 3) reprezentuje kilka generacji pokryw pylastych, które leżą na serii gruzowo-soliflukcyjnej. Pokrywy pylaste można wiązać kolejno ze zlodowaceniami: sanu 2 (elstery 2), liwca (Fuhne) i warty (solawy II). Przedzielone są one powierzchniami denudacyjnymi i zachowanymi fragmentarycznie glebami kopalnymi.

Przeprowadzono porównawczą charakterystykę litologiczną lessów i utworów pylastych, opartą na parametrach granulometrycznych (tab. 1, fig. 4). Z analizy tej wynika, że pod względem cech litologicznych pokrywy pylaste różnią się w sposób dość istotny od lessów.

Skonstruowano regionalny schemat stratygraficzny dla górnej części plejstocenu w przedziale czasu 530–10 ka BP (fig. 5), przedstawiając łącznie rozwój akumulacji lessu i utworów pylastych. Przeprowadzone badania wskazują, że oba typy utworów nie powstawały równocześnie. Pokrywy pylaste związane były głównie z fazą wczesną glacjałów i są starsze od lessów danego piętra. Powstawały one w warunkach klimatu polarnego wilgotnego, w którym zachodziło wietrzenie mrozowe (kriogeniczne), ale równocześnie rozwijały się procesy glebowe typu glejowego w środowisku tundrowym oraz intensywnie działały procesy stokowe, w tym soliflukcja, a w ich wyniku i akumulacja stokowa. Utworom pylastym datowanym na ten okres można przypisać genezę eoliczno-deluwialną. Lessy akumulowane były w pleniglacjale w klimacie subarktycznym suchym, o intensywnym wietrzeniu mrozowym i wzmożonej działalności eolicznej.

Rozważano także zagadnienia źródła materiału pylastego, który brał udział w tworzeniu lessów i pokryw pylastych na Roztoczu Zachodnim, charakter i długość transportu, wreszcie związek tych osadów z rzeźbą terenu. Peryglacjalne pokrywy pylaste lokują się głównie w dolnych partiach kopalnych stoków, a w ich formowaniu brał udział materiał pylasty spłukiwany, prawdopodobnie również przewiewany, i na tej drodze transportowany na krótkich odcinkach w dół stoku. Obszarów źródłowych dla pokryw lessowych bardziej obfitych w pył należałoby dopatrywać się głównie w nanosach peryglacjalnych, deponowanych w obrębie kotlin i w dolinach rzecznych, skąd był wywiewany w suchych warunkach klimatycznych pleniglacjału. W odniesieniu do kierunków transportu materiału tworzącego te dwa typy osadów można zatem postawić tezę, iż były one ogólnie przeciwstawne.