ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN—POLONIA
VOL. XLI, 11, 179—202 SECTIO B 1986

Institute of Geosciences Maria Curie-Skłodowska University,
Akademicka 19, 20-033 Lublin, Poland

Marian HARASIMIUK

Lithologic Properties as Indices of the Sedimentation Conditions of the Vistulian Loesses in the Eastern Part of the Nałęczów Plateau (SE Poland)

Litologiczne właściwości jako wskaźniki warunków sedymentacji lessów Vistulianu we wschodniej części Płaskowyżu Nałęczowskiego (Polska SE)

Литологические свойства как показатели условий накопления лессов в восточной части Наленчовской плоской возвышенности (ЮВ Польша)

ABSTRACT

Sedimentological and mineralogical studies were carried out on 188 samples from 6 drill-cores to 19 m thick loess cover in vicinity of Lublin — NW part of Lublin Upland. The results of analyses of granulation and the composition of heavy minerals allowed three stratigraphic complexes (from lower, middle and upper Vistulian) to be distinguished in the dynamics of sedimentation processes. The loesses studied are characterized by a bigger average grain diameter, better sorting and by a different mineral composition than loesses of the S and SE part of Lublin Upland.

INTRODUCTION

The loesses of the Nałęczów Plateau, which is distinguished from the other regions of the Lublin Upland owing to its loess cover (A. Jahn 1956, H. Maruszczak 1972), have arisen interest for a long time. One of the first geological papers containing a comparatively valuable information and a number of relevant observations about loesses from the Lublin environs was published by N. I. Krishtafovitch (1902). More detailed studies were started in the fifties. In those studies attention was drawn to the genesis of loess, stratigraphy and geotechnical features (A. Jahn 1950, 1956, A. Malicki 1950, W. Pożaryski 1953, J. Malinowski 1959). In the sixties and seventies the studies were largely concentrated on the western part of this region (H. Maruszczak 1969a, 1976, J. Morawski and J. Trembaczowski 1973, K. Konecka-Betley and H. Maruszczak 1976, M. Harasimiuk and A. Henkiel 1976), but they also concerned the loesses occurring in the Lublin area (H. Maruszczak 1969a, H. Maruszczak and J. Morawski 1976, H. Maruszczak and R. Racinowski 1968, 1976, R. Racinowski 1976). Very interesting materials have been recently presented by H. Maruszczak and M. Tkacz (1987) from the central part of the Plateau. From these materials it appears that not only loesses from the Vistulian occur here but, as was found earlier, also older ones (from Saalian II=Warta).

Despite the many published papers, the accumulation conditions of the Plateau loesses can still be regarded as insufficiently elucidated. This results from uneven distribution of the studied profiles and their location, chiefly on the slopes of valleys. To investigate these problems, studies of loesses were taken up by commission of the Geological Institute in the years 1978—1981, along with the preparation of Poland's Detailed Geological Map. Loesses are one of the main constituents of the litho-stratigraphic list of the Quaternary sediments. Six full-core drillholes were made through the Quaternary deposits represented mainly by thicker loesses. A geological and geomorphological works were carried the results of which jointly with a general analysis of lithology and stratigraphy of the Quaternary sediments have been published as the map (J. Butrym et al. 1980) and explanations (M. Harasimiuk and A. Henkiel 1982).

The test drillings were located in the NE part of the Nałęczów Plateau so as to obtain information on the loesses occurring within various morphological elements. Drillhole No 14 was made on the northern scarp of the loess patch, drillhole 12 on the interfluve sloping gently down the Ciemięga river valley, intersected by ravines and dry valleys, drillhole 15 on a wide elevation in the area of interfluve culmination, drillhole 10 on the bottom of a flat, dry valley and drillholes 7 and 8 on a terrace reaching 25 m above the contemporary bed of the Bystrzyca river (Fig. 1 and 2).

In the course of the drillings 95% of the core was obtained from loesses. Mean samples 0.5 m long were taken from the drillcores for analysis. In the case of changed macroscopic loess features samples were taken from appropriately smaller segments. For the all 188 samples were analysed grain size by the pipette method and carbonates content by Scheibler's method, for the 93 selected samples were analysed heavy minerals composition for the fraction 0.1—0.05 mm. From these analyses graphical measurements of the grain size composition were calculated according to R. L. F o l k and W. C. W a r d (1957) in the Department of Informatics of the Geological Institute. In detailed analyses of the material the author took into consideration the mean size at phi scale (Mz), standard deviation (σ) being the measure of sediment sorting and inclusive graphic skewness (Sk_I). The content of the basic loesses fraction (0.05—0.01 mm) and that of clay fraction (below 0.005 mm) were also analysed. The results are presented graphically (Fig. 3—7) and summarized in Table 1.

The author wishes to express his gratitude to prof. dr. J. E. Mojski for the discussions and valuable remarks while conducting the field studies and preliminary analysis of the materials, dr. J. Rzechowski for numerous methodological remarks and discussion, dr. K. Radlicz for

Table 1. Indices of granular composition in the examined loesses

Symbols of stratigraphic units	Profile No	Depth m	Mz	σ	Sk_I	Content of fraction in %	
						0.05 - - 0.01 mm	< 0.005 mm
LMg	7	0.0-14.6	5.16	1.31	0.45	45.38	12.45
	8	0.0-10.6	5.10	1.31	0.48	43.54	11.74
	15	0.0- 9.7	5.29	1.36	0.44	46.68	12.99
	11	0.0-10.6	5.14	1.32	0.48	44.64	11.90
	14	0.0-12.6	5.05	1.29	0.55	41.69	11.06
a v e r a g e			5.15	1.32	0.48	44.39	12.03
LMs	7	14.6-17.6	4.95	1.25	0.65	39.58	11.30
	8	10.6-15.0	5.07	1.34	0.50	42.00	12.12
	15	9.7-11.5	5.59	1.51	0.35	45.70	17.10
	11	10.6-13.4	5.45	1.44	0.41	46.52	14.76
	14	12.6-14.4	5.22	1.36	0.54	40.90	11.90
a v e r a g e			5.26	1.38	0.49	42.94	13.44
LMd	7	17.6-19.8	5.33	1.45	0.46	45.04	13.80
	8	15.0-18.0	5.68	1.62	0.30	46.64	18.64
	15	11.5-16.5	5.73	1.72	0.39	44.85	20.19
	11	13.4-18.1	5.58	1.56	0.45	42.90	17.71
	14	14.4-17.4	5.63	1.58	0.39	43.79	18.34
a v e r a g e			5.57	1.59	0.39	44.24	17.74

carrying out analyses of heavy minerals, prof. dr. A. Henkiel for his participation in supervising the test drillings and the overall cooperation in the preparation of the Lublin sheet of Poland's Detailed Geological Map and prof. dr. H. Maruszczak for his valuable remarks and pieces of advice in completing the manuscript of this paper.

GEOMORPHOLOGIC AND GEOLOGIC CONDITIONS OF THE OCCURRENCE OF LOESSES

The Nałęczów Plateau is a northwesternmost part of the Lublin Upland, which at the same time constitutes a fragment of the northern scarp zone of the south Polish Uplands. It stretches as a belt over a dozen

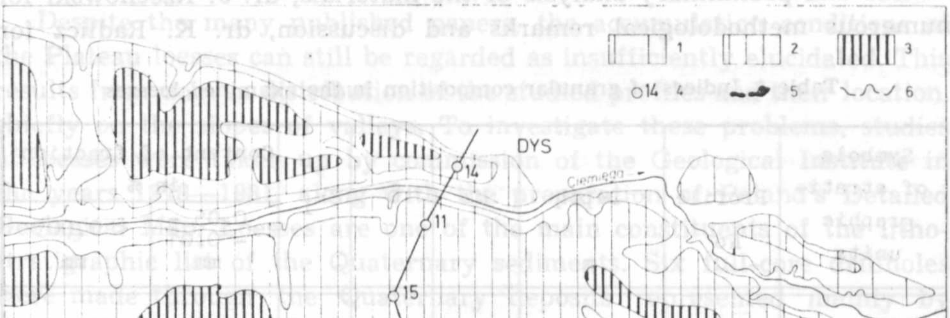


Fig. 1. Loess cover of eastern part of Nałęczów Plateau
1 to 3 — thickness of loess: 1) 0—10 m, 2) 10—20 m, 3) over 20 m; 4 — location of boreholes; 5 — covers of loess in SE Poland; 6 — boundary of the maximum extent of the Saalian I inland ice

kilometers wide between the valleys of the Vistula river in the west and the Bystrzyca river in the east. From the north and south it is limited by scarp, the distinction of which decreases eastwards. The scarps are partially controlled by geological structure (J. B u r a c z y ń s k i et al. 1983); however they were largely formed as a result of the spatially strongly differentiated loess accumulation (H. M a r u s z c z a k 1969b).

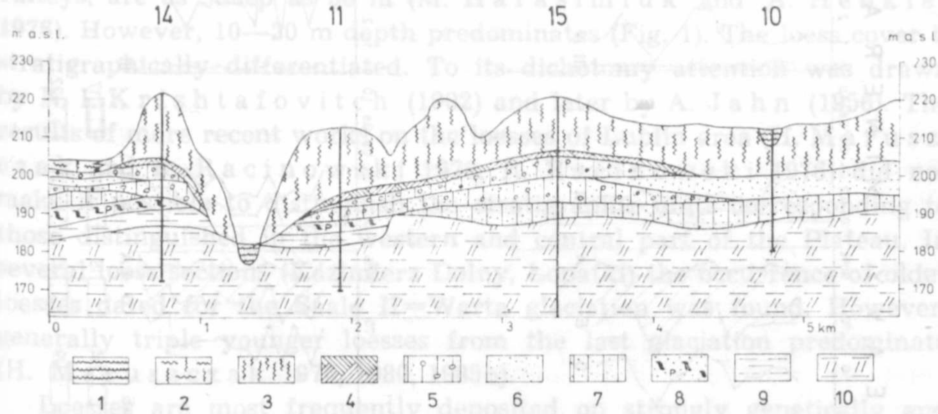
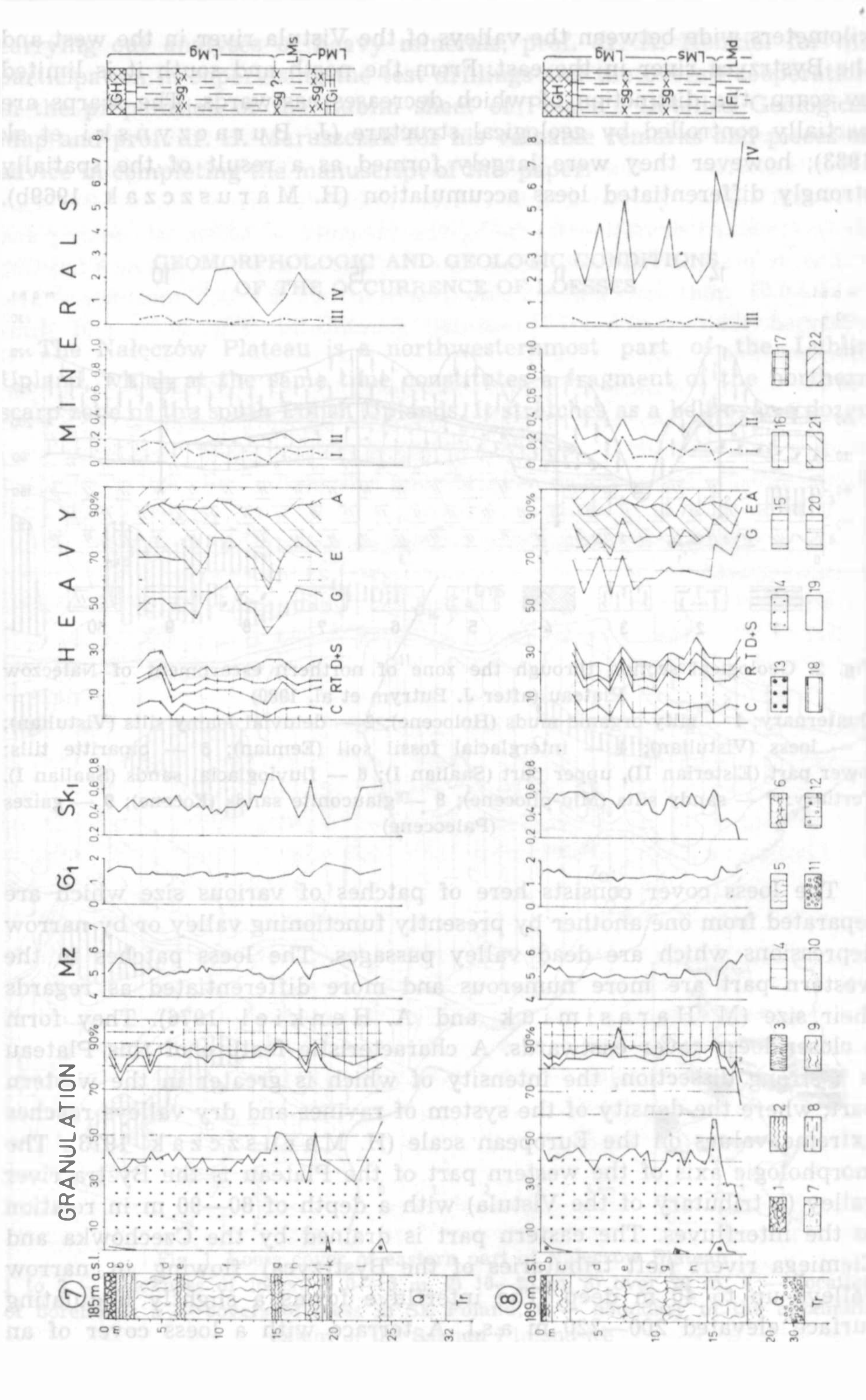


Fig. 2. Geological section through the zone of northern escarpment of Nałęczów Plateau (after J. Butrym et al. 1980)

Quaternary: 1 — silty-organic muds (Holocene); 2 — deluvial loamy silts (Vistulian); 3 — loess (Vistulian); 4 — interglacial fossil soil (Eemian); 5 — biparitte tills: lower part (Elsterian II), upper part (Saalian I); 6 — fluvioglacial sands (Saalian I). Tertiary: 7 — sandy silts (Mio-pliocene); 8 — glauconite sands (Eocene); 9 — gaizes (Paleocene)

The loess cover consists here of patches of various size which are separated from one another by presently functioning valley or by narrow depressions which are dead valley passages. The loess patches in the western part are more numerous and more differentiated as regards their size (M. H a r a s i m i u k and A. H e n k i e l 1976). They form a closer loess cover eastwards. A characteristic feature of this Plateau is a strong dissection, the intensity of which is greater in the western part, where the density of the system of ravines and dry valleys reaches extreme values on the European scale (H. M a r u s z c z a k 1973). The morphologic axis of the western part of the Plateau is the Bystra river valley (a tributary of the Vistula) with a depth of 80—90 m in relation to the interfluves. The eastern part is drained by the Czechówka and Ciemięga rivers (left tributaries of the Bystrzyca) flowing in narrow valleys up to 40 m deep. The interfluve forms a slightly undulating surface elevated 200—220 m a.s.l. A terrace with a loess cover of an


GRANULATION
Mz
σ_1
Sk_1
HEAVY MINERALS
185 m a.s.l.
189 m a.s.l.
Q
Tr
GH
LMg
LMs
LMd
Gl
Fl
C
R
T
D+S
G
E
A
I
II
III
IV

hight of about 180—185 m a.s.l. can be clearly distinguished along the Bystrzyca river valley.

The loess area of the Nałęczów Plateau the northernmost one in Poland, is distinctly isolated from others and it is wholly situated in the widely understood marginal zone of the maximal extent of the Saalian I=Odranian inland-ice.

Loesses in the western part of the region, in the zones adjoining the valleys, are as deep as 30 m (M. Harasimiuk and A. Henkiel 1976). However, 10—20 m depth predominates (Fig. 1). The loess cover is stratigraphically differentiated. To its dichotomy attention was drawn by N. I. Krishtafovitch (1902) and later by A. Jahn (1956). The results of more recent works on the loesses of Lublin area (H. Maruszczak and R. Racinowski 1976, R. Racinowski 1976) did not make it possible to distinguish the stratigraphic units corresponding to those distinguished in the western and central part of the Plateau. In several loess sections (Kazimierz Dolny, Łopatki) the occurrence of older loesses dated for the Saale II=Warta glaciation was found. However, generally triple younger loesses from the last glaciation predominate (H. Maruszczak 1976, 1980, 1985b).

Loesses are most frequently deposited on strongly genetically and lithologically differentiated sediments connected with the marginal zone of the maximal extent of the Odranian inland-ice. Tills predominate in this complex of sediments, a secondary role is played by fluvioglacial sediments and there are few areas of limnoglacial sediments. A generally well-developed interglacial fossil soil occurs relatively commonly on deposits of the Odra glaciation underlying the loesses; it is dated for Eem Interglacial (A. Jahn 1956, K. Konecka-Betley and H. Maruszczak 1976, J. Butrym et al. 1980).

Fig. 3. Loess profiles of 7 and 8 boreholes

Lithological schema: 1 — humus layer of recent soil; 2 — silty loams; 3 — silty organic muds; 4 — carbonate free loesses; 5 — carbonate loesses; 6 — loamy layers within loesses; 7 — clayey loesses; 8 — clays; 9 — sandy silts; 10 — sands; 11 — gravels; 12 — tills. Granulation: 13 to 17 — fraction contents: 13) over 0.1 mm, 14) 0.1—0.05 mm, 15) 0.05—0.01 mm, 16) 0.01—0.005 mm, 17) below 0.005 mm. Transparent heavy minerals content: 18 — group of resistant minerals (C=zircon, R=rutile, T=tourmaline, D+S=disthene+staurolite); 19 — G=garnet; 20 — E=epidotes, 21 — A=amphiboles; 22 — others, AND+TOP=andalusite+topaz. Indices of the composition of the transparent heavy minerals: I — A/G+A; II — O/S+N; III — C/G; IV — G/A (A=amphibole, C=zircon, G=garnet, O=resistants, S=medium resistants, N=non-resistants). Letter symbols of stratigraphic units of loesses: GH — recent soil, GJ — interglacial soil, Gi — interstadial soil, sg — soil sediments, Hd — Holocene deposits, Fl — fluvial or proluvial deposits, LM — younger loess, LMg — upper younger loess, LMs — middle younger loess, LMd — lower younger loess, Q — Quaternary, Tr — Tertiary

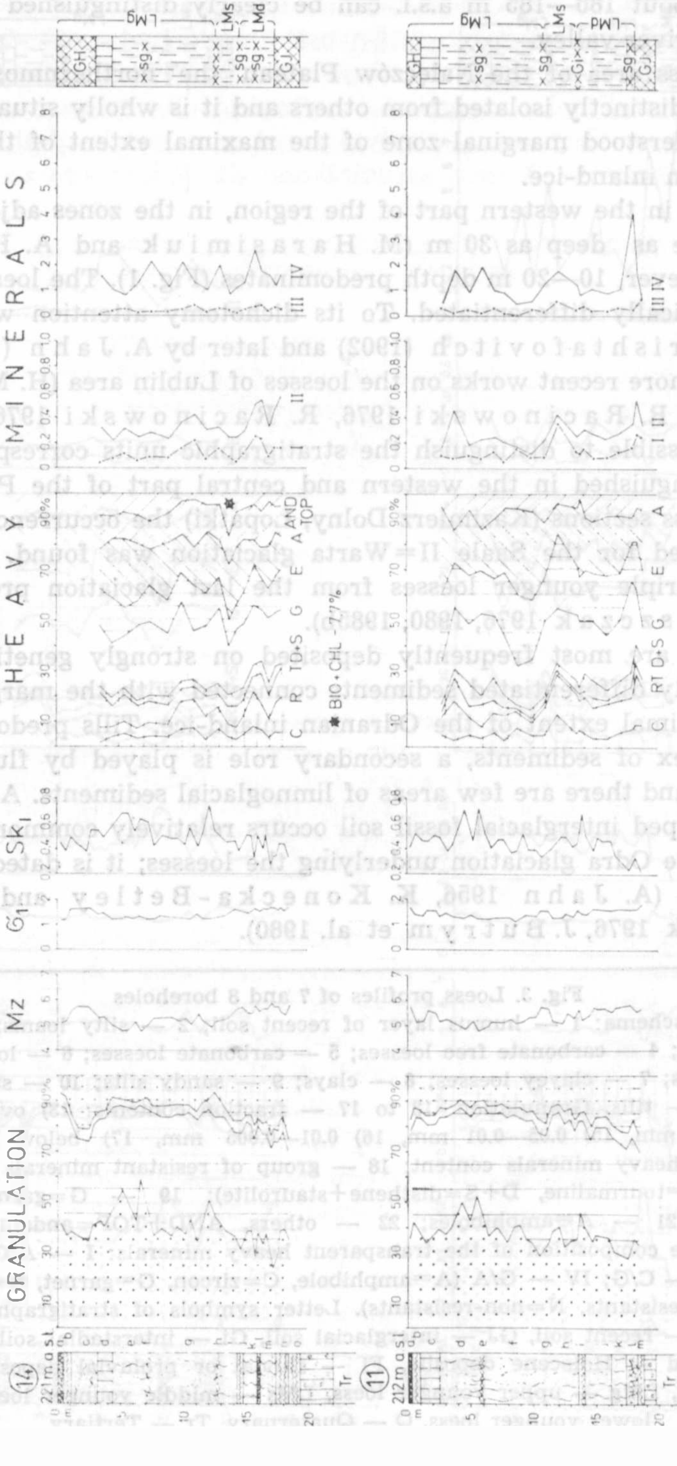


Fig. 4. Loess profiles of 11 and 14 boreholes. Explanations see Fig. 3

In the bed of Quaternary sediments there occur Neogene (Mio--Pliocene) and Eocene silts and sands, as well as gaize and mudstones of the Paleocene. In many places tertiary rocks constitute the bedrock of loesses (M. Harasimiuk and A. Henkiel 1976, 1982). From this point of view the loesses of the Plateau are of an exceptional rank among the loesses of the Lublin Upland, which are mostly deposited on Cretaceous rocks, more rarely on Paleocene ones.

LITHOLOGIC-MINERALOGIC CHARACTERISTIC OF LOESSES

Taking into account the occurrence of interglacial fossil soil in the drillholes 11, 14, 15 under loess deposits, and the absence of interloessial soil this rank, it has been assumed that the loesses studied wholly represent the last glaciation. The individual distinguished horizons can be fully correlated with the stratigraphical scheme of the Polish loesses (H. Maruszczak 1980, 1985b).

Lower younger loesses (LMd). In the drillholes 11, 14, 15 this complex of loesses reaches a thickness of 3—5 m. They are dark--yellowish and grey-yellowish structureless silts, or with irregular rust--coloured streaks, among which interbeddings characteristic for soil sediments (Fig. 4, drillhole 14, layers j, l). The LMd layers are surmounted by an interstadial gleyed soil with traces of browning, decalcified and about 0.6 m thick. In the deposits occurring in the Bystrzyca river valley, indistinct laminated grey slightly clayey silts with a soil of bog type in the top correspond to lower younger loesses (Fig. 3, drillhole 7, layers j, k).

The mean size (Mz) ranges from 5.58—5.73 for the interfluve sections and 5.23—5.68 for the loesses on the Bystrzyca terrace. These values are the arithmetical means of all samples representing the discussed complex in a given deposit. The individual layers show a relatively distinct differentiation, which is apparent particularly in the sections of the terrace area, from Mz=4.70 (drillhole 7) to Mz=6.08 (drillhole 8). The horizons of interstadial soils sediments connected with LMd are usually characterized by Mz indices increased by 0.15—0.20. An increase of Mz values is observed, that is of the average grain size, from the Bystrzyca valley towards the interfluve and in the direction from the northern scarp towards the interfluve. A similar direction of grain size changes for loesses of the Lublin area was found by H. Maruszczak (1969a) and H. Maruszczak and R. Racinowski (1976).

The values of the σ of the LMd layers ranges from 1.45 in drillhole 7 to 1.72 in drillhole 15. In the horizons of the initial soils, a distinct

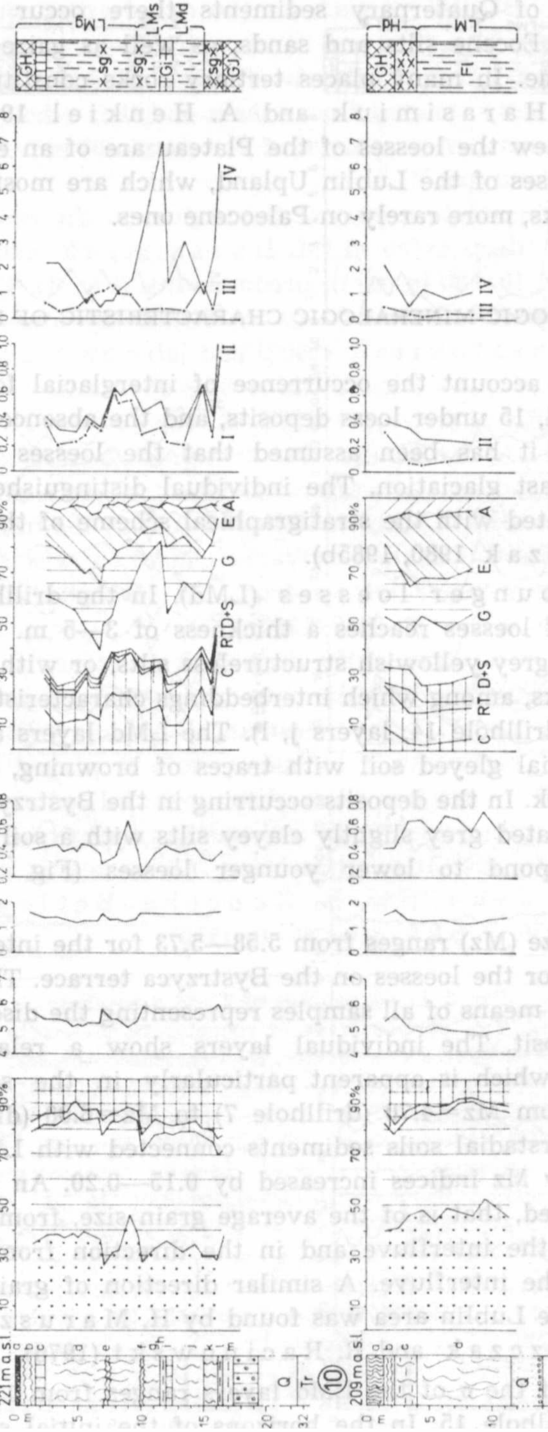


Fig. 5. Loess profiles of 10 and 15 boreholes. Explanations see Fig. 3

deterioration of the sorting degree can be found. A very week sorting (2.57) was found in the horizon with solifluction deformations in drillhole 15 (deluvial loesses). The best sorting occurred in drillhole 7, in laminated deposits with distinct predominance of fractions 0.1—0.05 mm (alluvial loesses).

All LMd samples analysed were characterized by little variable, very positive skewness (Table 1). Distinct differences should be stressed between the drillholes in the Bystrzyca terrace. Sk_I index for drillhole 7 situated nearer the slope of the valley is 0.46, and that of drillhole 8 only 0.30. The difference accounts for changes in the dynamics of silt precipitation from suspensions. In both drillholes this was an aqueous medium alluvial loesses. The differences resulted from facial changes within the flood plain. A small decrease of the Sk_I value in relation to unweathered loesses, on the average by 0.1 can be observed in soil horizons.

In LMd layers the content of the basic fraction in the terrace ranges from 43% (drilling 7) to 46% (drilling 8). In interfluve loesses it is smaller and less variable (43—44%). They are distinguished by the highest mean content of clay fraction — from 18 to 20%. The lowest content of this fraction was found in alluvial loesses in drilling-hole 7.

Lower younger loesses are characterized by the occurrence of several dozen deep decalcification horizons and the content of $CaCO_3$ did not generally exceed 4—6%. These are typical features for this complex on the regional scale (H. M a r u s z c z a k 1980, 1985a).

The composition of heavy minerals in LMd complex is spatially distinctly differentiated, which is marked particularly in the drillholes located in the terrace. Drillhole 8 (Fig. 3) is characterized by a very high content of garnets (up to 48%) and a low content of amphiboles and epidotes (6—12%). In drillhole 7 the content of garnets decreases to 30%, and that of amphiboles and epidotes increases twice as much. These changes can be determined as enrichment with minerals in drillhole 8 which are difficult to be blown or washed away, and as enrichment largely with amphiboles in drillhole 7 which are susceptible to eolian transport. This confirms the conclusions concerning from differentiation of grain size composition. It seems that the region of drillhole 8 is an area of week air currents near the edge of the flood plain and blowing away of the silty material after a flood, and the section of drillhole 7 represents the environment of the extra-channel zone with periodically stagnant waters and accumulation of dusts falling from the air.

The mineralogical composition of LMd in a meridional section from the N scarp to the Plateau inwards (Fig. 1 and 2) is characterized by distinctive tendencies. The content of garnets is not very variable (20—

30%) like that of amphiboles (20—25%), but the amount of rutiles and zircons increases from drillhole 14 inwards the Plateau. A distinctly increased content of rutiles and zircons in the region of drillholes 11 and

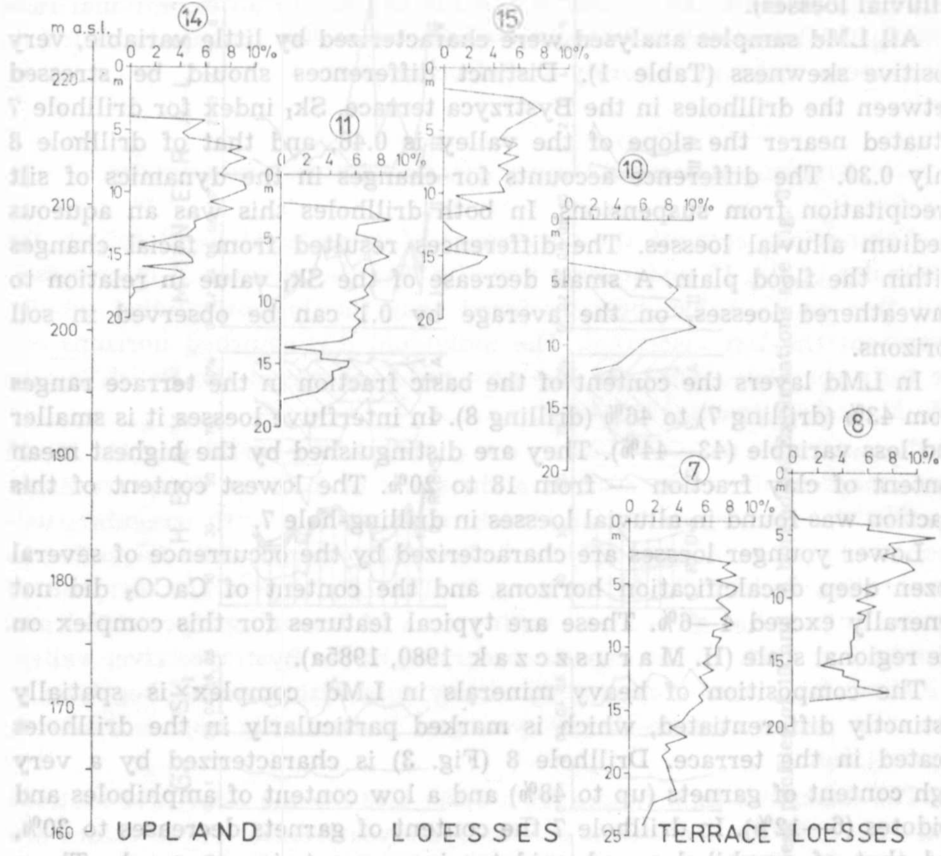


Fig. 6. Carbonates content in investigated loess profiles

15 may be directly connected with the occurrence of Neogene silts in the Quaternary bedrock of this region (Fig. 2), the main components of which among heavy minerals are just rutiles (48—60%), zircons (10—16%) and tourmalines (9—17%). A high content of andalusites and topazes in drillhole 14 (jointly to 17%) should be stressed, which distinguishes this drill from the others studied. Such a content of these minerals is constant in the whole section. The cause of this anomaly is not clear.

In the horizons of soil sediments and interstadial soil, surmounting LMd, the content of amphiboles decreases distinctly, which can be interpreted as a symptom of weathering.

M i d d l e y o u n g e r l o e s s e s (LMs) are best developed in drillhole 8 (Fig. 3, horizons g, h), where they reach a thickness of 4.4 m. They are yellowish silts with dark-yellow patches, not distinctly stratified. In the other drills they are weakly developed, and represented by slight clayey silts, streaky or patchy, grey-yellowish. From upper younger loesses they are separated by a not distinctly developed horizon with features of soil sediments rather than interstadial soil distinguished by J. Jersak (1973) in this stratigraphic position. This horizon is best developed in drillhole 15 (Fig. 5, horizon f) in the form of patchy clay silts with brown and glaucous patches.

Middle younger loesses differ from LMd practically at all indices. They are characterized by a larger Mz value, a better sorting and a higher positive skewness. Their content of the basic fractions is more variable and lower (Table 1), and they contain less clay fraction. They are spatially more differentiated. In the Bystrzyca terrace they are distinctly poorer in the basic fraction as well as in clay particles. The granulation indices from drillhole 14 are approximate to those of the loesses from the Bystrzyca valley. In drillhole 15 the mean size is the smallest (Mz — 5.59), the standard deviation ranges from 1.35 to 1.64, its average being the highest (1.51), which points to the worst sorting. The differences between drillholes 15 and 11 are rather small, which indicates homogeneity of the sedimentation conditions in the center of the loess area, and at the same time a faster stabilization of these conditions from the scarp of the loess cover to its interior.

The content of carbonates in the LMs complex is similar to that in LMd.

The composition of heavy minerals undergoes distinct changes. In drillhole 8 the content of garnets decreases by 15% and of amphiboles increases. Distinct changes in the proportions of these two components also occur in drillhole 7. As a result of these tendencies the mineral composition in both drillholes becomes similar, which points to unification of the sedimentation conditions within the terrace with the increasing role of the eolian factor. In drillhole 11 and 14 (Fig. 4) the mineral composition is similar, whereas in drill 15 (Fig. 5) a very distinct increase in the content of zircons (up to 18%) is observed. The joint content of resistant minerals (zircon+rutile+tourmaline+disthene+staurolite) reaches 35%. The content of garnets is also very high (up to 40%). However, the content of amphiboles and epidotes is low. In general the composition of heavy minerals of LMs in this drillhole is very similar to that of the underlying fossil soil.

Upper younger loesses (LMg) attain a maximal thickness of 14.6 m in the Bystrzyca valley (Fig. 3, drillhole 7), but in the other drillholes their thickness does not exceed 10 m. A weakly recognizable horizon of soil sediments occurs in all sections. Such a horizon is distinguished in many loess sections of the Lublin Upland (J. Jersak 1973, H. Maruszczak 1976, 1980, 1985, J. Buraczyński et al. 1978, L. Dolecki 1981). These loesses are carbonate represented by light-yellow structureless silts. Slightly clayey, indistinctly streaked, light-grey-yellowish silts occur only in drillhole 15 below the horizon of soil sediments.

LMg constitute on the average about 60% of all loess sections studied. From its layers 80 samples were studied, excluding those samples which came from the recent soil developed on this loess. The same tendency of indices to change is observed as between LMd and LMs. As a result the mean size increases, sorting improves and the mean value of Sk_I is approximately similar to that in LMs. The content of the basic fraction increases slightly, but that of clay particles decreases. If, however, the mean values are analysed for individual sections but not for the total LMg, there appear characteristic deviations from the general regularities. Thus, the value of Mz for drillholes 7 and 8 increases, i.e. the average grain size decreases. This results above all from the increase in the content of the basic fraction from 40% to 45% (Fig. 3, drillhole 7, Table 1), largely at the expense of the fraction 0.1—0.05 mm. The mean size is the largest in drillhole 14, in which the content of the basic and clay fractions is the lowest. In lower complexes of the loess cover of the NE part of the Plateau the largest mean size occurred within the terrace. The biggest vertical differentiation of the particular indices also occurs in drillhole 14.

Upper younger loesses contain 6—9% carbonates, and their maximal content was found in drillhole 8 (11%). There is characteristic tendency of the content of carbonates to increase upwards in this complex. The greatest variations occur in the drillholes located on the scarp of the loess area (Fig. 6).

In respect of the composition of heavy minerals, the LMg complex is dichotomous in most of the sections studied. In drillhole 8, the lower part up to the horizon of soil sediments contains as much as 37% of garnets and 17% of amphiboles. Over that horizon, however, the amount of garnets varies from 30 to 45%, in that the increase content of garnets is always accompanied by a decrease in the amount of amphiboles, which can be seen in the diagram of index G/A (Fig. 3). The horizon of soil sediments is characterized by an 8% increase of the content of resistant minerals at a double decrease of the content of amphiboles in relation to the underlying and overlying horizons. In drillhole 7 the amount of garnets increase from the floor of LMg to a depth of 9.5 m, whereas that of amphiboles simultaneously decreases. Above the depth of 9.5 m the content of these minerals is small variable, and the content of rutiles and zircons increases by a few percent. In the whole LMg section in drillhole 14, characteristic are small variations in the proportions between garnets and amphiboles. Index G/A varies from 1 to 2 (Fig. 4). In drillhole 11 the content of amphiboles decrease distinctly from 35% to 24% from the floor of LMg to a depth of 7 m, but that of garnets increases (from 15 to 25%). At the same time the content of the resistant minerals increases from 15 to 28%. Above that level G/A index varies from 1 to 2 (Fig. 4).

Very distinct are the differences in the composition of heavy minerals in drillhole 15. Soil sediments of the depth 7.0 m are a separating horizon. The differences concern zircons, rutiles, garnets and amphiboles. The horizon macroscopically determined as soil sediments cannot be considered from mineralogical point of view as a weathering one in the presence of the exceptional high contents of the amphiboles (26%). When this horizon was being deposited changes of the sedimentation conditions must have occured. The lower part of LMg in this drillhole is characterized by a very high content of resistant mineral (up to 40% of which that of zircons reache 23%), and by decreasing content of garnets and increase of amphiboles. In the upper part, above 7 m the amount of zircons decreases by 10%, and the relationship between the content of garnets and amphiboles is reverse than in the lower part.

Some attention should be given to drillhole 10 (Fig. 5). At a depth of 4 m dichotomous holocene sediments separated by a subfossil soil at a depth of 1.4—2.2 m were found. Above the soil there occur grey-brown anthropogenic silts, and below stratified yellow-brown loamy silts. At a depth from 4.0 m to 11.6 m, laminated, grey-yellowish carbonate silts are deposited. The values of Mz ranges from 4.81 to 6.07. The sorting is distinctly better than in typical loesses, and skewness is very positive (0.45—0.71). A low content of clay fraction (7—11%) is characteristic. The mineral composition varies little at a high content of amphiboles (about 25%). There should be stressed a considerable decrease in the content of amphiboles (to 9%) in the horizon of the subfossil holocene soil (Fig. 5). It seems that the silt deposits in this drillhole can be wholly interpreted as proluvia.

C o n t e m p o r a r y s o i l. Its thickness jointly with decalcification zone ranges from 2.4 m to 4.4 m (Figs 3—5). In relation to underlaying loesses the Mz index increases on the average by 0.4—0.5 (to 5.5—5.7), i.e. a distinct decrease of the mean grain diameter, worsening of the sorting index by about 0.3 and an increase of the content of clay fraction by 4 to 10% are observed. In humus horizon the content of fractions over 0.1 mm distinctly increases even to 4%, when in whole sections it does not exceed 1%.

The results of analyses allow drawing attention to some general features of the loesses of the area studied. They are distinguished above all by high content of a fine sand fraction, range on the average from 35 to 40% at a slightly higher content of the basic fraction (42—50%). The frequency of grains larger than 0.1 mm is very small. Attention to a higher content of fine sand fraction in loesses of the Lublin environs

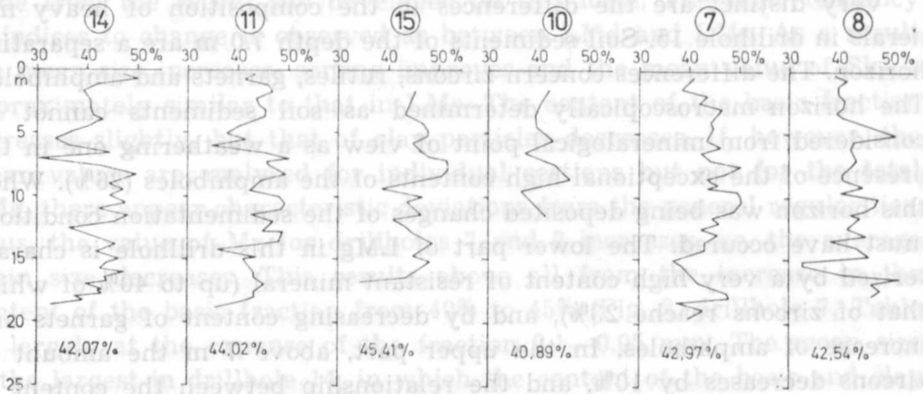


Fig. 7. Basic fraction (0.05—0.01 mm) content in loess profiles; 42.07% — mean for all profile

than in other regions was drawn earlier (H. Maruszczak 1969a, H. Maruszczak and R. Racinowski 1976, J. Nowak 1981). Loesses of the southern regions of the Lublin Upland are characterized by a distinctly smaller average grain and a worst sorting degree (J. Buraczyński et al. 1978, L. Dolecki 1981, 1987). In respect of the composition of heavy minerals some general regularities can be also observed. First to all the group: garnets-amphiboles-epidotes predominates. The content of garnets ranges on the average from 20 to 35%, and few samples show the content of this mineral below 15% and over 40%. The content of amphiboles is usually higher than 15%, but in many samples it exceeds 20%, and in few even 30%. The average frequency of epidotes ranges from 15 to 20%. H. Maruszczak and R. Racinowski (1976) and other authors found zircon to predominate in the Lublin loesses. The differences result largely from the fact that the mineral composition of other fractions was analysed (0.25—0.01 mm or 0.06—0.01 mm). The results of analyses of several samples from Lublin for fractions 0.1—0.06 mm, presented by R. Racinowski (1976) are comparable. The predominance of the mineral group: garnet-amphiboleepidote in the loesses of the Małopolska Upland and the borders of the Holly Cross Mts was found by B. Grabowska (1961) and R. Chlebowski and L. Lindner (1975), who analysed fraction 0.25—0.01 mm. However, in the southern part of the Lublin Upland the group of minerals: garnet-zircon-tourmaline-rutile predominate (J. Buraczyński et al. 1978).

The results of analyses of heavy minerals in full loess sections of the Nałęczów Plateau confirm the conclusions drawn by H. Maruszczak and R. Racinowski (1976) on the applicatibility of this kind of analysis for determination of not only the origin of loess material or the rate of its weathering but also for reconstruction of the dynamics of changes of the sedimentation conditions. The most suitable for this purpose are garnets and amphiboles as they are characterized by distinctly different susceptibility to eolic processes.

There should also be stressed distinctly recognizable relationships between the content of amphiboles in the sediment and index Sk_I. However, it is necessary to analyse the statistic relations of these relationships on a larger material coming from various regions, which is beyond the present paper.

CONDITIONS OF LOESSES SEDIMENTATION

Since the beginning of the seventies several papers have been published in which the authors attempted to reconstruct the conditions of loess accumulation in various loess areas in Poland (J. Cegła 1972, J. Jersak 1973, H. Maruszczak 1976, 1980). These problems have been recently reviewed by H. Maruszczak (1985a, 1985b). A very interesting regional analysis of the sedimentation processes on the basis of granulometric indices of the loesses of the Grzęda Horodelska Plateau was made by L. Dolecki (1987).

In all paleogeographic reconstructions on the basis of granulation analyses, the content of carbonates and the composition of heavy minerals, it is necessary to determine the duration of sedimentogenesis which is represented by a single sample. H. Maruszczak (1980, 1986) has determined the accumulation rate of lower and middle younger loesses at about 0.2 mm annually, and that of upper younger loesses on an average at 0.6 mm and extremely to 1 mm annually. Accordingly an examined sample 0.2—0.3 m thick for lower and middle loesses represents on the average a period of 1000 years, and an average sample of 0.5 m thick layer for upper younger loesses about 500 years. Thus, as a result of analyses a record of averaged features of the sedimentation conditions is obtained for relatively long periods of time.

The studied part of the Nałęczów Plateau was a slightly undulated plain by the end of Eem Interglacial, elevated at about 60 m above the wide bottom of the Bystrzyca valley. This plain was cut in 40—50 m by the Ciemięga and Czechówka rivers valleys broader than today. The zone of the northern Plateau scarp was mainly built of glacial sediments; the relative height of the scarp itself was only 5—10 m (M. Harasimiuk and A. Henkiel 1982).

Accumulation of LMd started in conditions of relatively moist climate, accompanied by very distinct processes of solifluction involving not only the slowly accumulating silt but the underlaying interglacial soil as well. These processes have been recorded by deposits of the type of soil sediments which are best developed in drillhole 15. This horizons has been covered by slightly clayey weakly carbonaceous loesses characterized by a weak sorting. The mineral composition and increased content of clay fraction seem to point to a small dynamics of winds. Therefore, loess deposits from the direct vicinity were the main source of silt material. In the Bystrzyca river valley the aggradation of the terrace started at that time, strongly accompanied by eolic processes (deflation and accumulation in different environmental conditions within the terrace). There is lack of data for reconstruction of the direction of winds for this period. Neither L. Dolecki (1987) has found any data for determination of the winds predominating in that period in the area of the Grzęda Horodelska Plateau. The accumulation period of LMd was finished by humidification and warming of the climate, which is marked by the decalcification level and the development of interstadial soil.

The effect of LMs sedimentation are deposits of not a big thickness (1.8—2.8 m) in the interfluve area; this has been also stressed by other authors (H. Maruszczak 1980, 1985a, L. Dolecki 1987). In that period the average grains size distinctly increased, which accounts for a greater dynamics of air currents. The direction of spatial changes of the graining indices seems to indicate the predominance of winds from sector E and NE, which is in agreement with the conclusions of H. Maruszczak and R. Racinowski (1976). In the zone of the northern scarp an increase in the dynamics of air currents is observed, but in the region of the slope of the Ciemięga river valley a weak reverse tendency can be noticed. H. Maruszczak (1969a), J. Cegła (1972) and also R. Chlebowski and L. Lindner (1975) pointed to the big role of local relief obstacles in the course of loess sedimentation. The eolian accumulation of the loess cover were locally disturbed by solifluction (drillhole 15 — the development of solifluction was favoured by the finest medium grain). At the same time the accumulation rate in the Bystrzyca valley distinctly increased (LMs thickness to 4.4 m). The initially differentiated sedimentation conditions became uniform, and the role of eolian accumulation decisively increased. The mineral composition as well as the granulation indices allow us to conclude that more distinct deflation were absent within the terrace in that period. Its surface was rather the recipient than tributary of the silt material.

In all drillholes studied LMs are separated from LMg by a very little recognizable horizon of the soil sediments type. Only in drillhole 8 weathering processes are marked more distinctly in this horizon, which is reflected in the composition of heavy minerals. A weak progression of soil processes in this period, correlated with Denekamp Interstadial, was stressed by H. Maruszczak (1980).

The thickness of LMg distinctly exceeds the mean values given for this period by H. Maruszczak (1980), J. Buraczyński et al. (1978), L. Dolecki (1987). Maximal thickness occurs in the Bystrzyca valley (14.6 m) and it is very big (12.6 m) in the zone of the northern scarp. This complex is dichotomous, to which attention has been recently drawn by many authors (J. Jersak 1973, H. Maruszczak 1976, 1980, 1985a, J. Buraczyński and J. Wojtanowicz 1975). Dichotomy is identifiable mainly in the composition of heavy minerals and it is less distinct in the content of the basic fraction and in the skewness index. This indicates two phases different in their dynamics conditions.

In the LMg layers there occured further increase of the average grain diameter and the sorting degree improved, decreasing distinctly the differences the particular drillholes. This can be connected with increased dynamics of air currents. A considerable increase of $CaCO_3$ content is associated with more severe, colder and drier climate. These conclusions fully correspond with the paleogeographic conditions as determined for this period by H. Maruszczak (1980, 1985a).

In the northern zone of the scarp (drillhole 14) dichotomy of LMg is not observed. However, periodical changes of air current dynamics recorded in the mineral composition can be distinguished. The specific location of this site has caused that even great changes of wind directions could not have been recorded here. It must have generally been winds perpendicular to the scarp zone, i.e. from the N and NE sector. The biggest average diameter of grains and the highest content of grains of fraction 0.1—0.05 mm point to direct material supply from the foreland of the scarp, similar regularities were observed by L. Dolecki (1987) in the N zone of the Grzęda Horodelska Plateau scarp.

During sedimentation of the lower LMg layers weaker air currents predominated within the terrace (increased Mz and σ indices), which blew away amphiboles more susceptible to deflation. As the amount of this component increases in drillhole 15 located west of the Bystrzyca river valley, east winds may have predominated. Stepwise changes in the upper LMg layers, largely in proportions between garnets and amphiboles point to a distinct variation of air current dynamics. It is most likely that the predominating direction at that time changed northwards, as a result of which the region of drillhole 7 appeared in the shadow of the Bystrzyca valley slope. This may be indicated by a distinctly smaller variation of the mineral composition.

CONCLUSIONS

1. Loesses of the NE part of the Nałęczów Plateau are generally characterized by a greater average diameter of grains, better sorting, a smaller content of the basic and clay fraction than loesses of the southern part of Lublin Upland. This differentiation is found in all stratigraphic horizons of younger loesses. At the same time a tendency of the average grain diameter to increase and a better sorting are observed in the studied loesses as in the whole region than in the floor layers towards the top. Also the content of carbonates increases in this direction. These phenomena result from general evolution of the climatic conditions from warmer, more humid in the first accumulation phases of the loess cover to colder drier ones in pleniglacial.

2. Spatial differentiation of the composition of heavy minerals and the directions of changes of the graining indices point to distinct associations with Quaternary and Tertiary sediments of the nearly surround. This confirms the earlier opinions on the short transport. Changes in the mineral composition and granulation — in space and time — lead to the conclusion that during sedimentation of the LMs complex winds from the E and NE sector predominated.

A distinct dichotomy of the LMg complex was found which can be largely observed in the composition of heavy minerals and to some extent in the content of the basic fraction. In the period of deposition of the lower LMg part a tendency to increase of air current dynamics is observed with predominating winds from N and NE. The upper part is characterized by a greater variation of the graining indices and the composition of heavy minerals, which can be connected with periodical oscillations of air current dynamics and the missing of a predominating transport direction.

3. The results of studies point to a considerable usefulness of the sedimentological and mineralogical method for paleogeographic reconstructions. For evaluation of the dynamics of air currents, especially helpful are Sk_I index and analysis of the relations between minerals

susceptible to deflation and eolian transport (amphiboles and micas) and less susceptible to deflation processes (garnets).

REFERENCES

B u r a c z y ń s k i J., D o l e c k i L., H a r a s i m i u k M., H e n k i e l A., M a r u s z c z a k H., W o j t a n o w i c z J. 1983, Geomorphological development of loess scarps in the Lublin Upland, south-eastern Poland. Studies in Quaternary Geomorphology, Cambridge, 125—133.

B u r a c z y ń s k i J., W o j t a n o w i c z J. 1975, Nowe profile lessowe Grzędy Sokalskiej (New loess profiles on the Sokal Range). Ann. Univ. M. Curie-Skłodowska, B, 28, Lublin, 1—35.

B u r a c z y ń s k i J., W o j t a n o w i c z J., R z ę c h o w s k i J. 1978, Studium sedymentologiczne i stratygrafia lessów w Ratyczowie na Grzędzie Sokalskiej (On sedimentation and stratigraphy of loesses at Ratyczów on the Grzęda Sokalska). Biul. Inst. Geol., 300, Warszawa, 235—302.

B u t r y m J., H a r a s i m i u k M., H e n k i e l A. 1980, Szczegółowa Mapa Geologiczna Polski 1 : 50 000, arkusz Lublin.

C e g ł a J. 1972, Sedymentacja lessów Polski (Loess sedimentation in Poland). Acta Univ. Vratisl., 168, 3—72.

C h l e b o w s k i R., L i n d n e r L. 1975, Wpływ podłoża na skład minerałów ciężkich głównych wysp lessowych NW części Wyżyny Małopolskiej (Relation between heavy mineral composition and source material of main "loess islands" in NW part of Małopolska Upland). Acta Geol. Pol., 25, 1, 163—178.

D o l e c k i L. 1981, Litologia i stratygrafia lessów Grzędy Horodelskiej (Lithology and stratigraphy of the loesses of Grzęda Horodelska). Ann. Univ. M. Curie-Skłodowska, B, 32/33, Lublin, 151—188.

D o l e c k i L. 1987, Differentiation of grain size of the Vistulian loesses on the Grzęda Horodelska Plateau (SE Poland). Ann. Univ. M. Curie-Skłodowska, B, 41, Lublin.

F o l k R. L., W a r d W. C. 1957, Brazos River bar: a study in the significance of grain size parameters. Jour. of Sedim. Petrol., 27, 1, 3—26.

G r a b o w s k a B. 1961, Analiza minerałów ciężkich na tle stratygrafii lessów okolic Ćmielowa (Heavy mineral analysis in the light of stratigraphy of loesses from the Ćmielów region). Biul. Geol. Uniw. Warsz., 1, 1, 50—67 and 176—177.

H a r a s i m i u k M., H e n k i e l A. 1976, Osobliwości pokrywy lessowej zachodniej części Płaskowyżu Nałęczowskiego (Peculiarities of the loess cover in the western part of the Nałęczów Plateau). Biul. Inst. Geol., 297, Warszawa, 177—184.

H a r a s i m i u k M., H e n k i e l A. 1982, Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1 : 50 000, arkusz Lublin. 1—83.

J a h n A. 1950, Less, jego pochodzenie i związek z klimatem epoki lodowej (Loess, its origin and connection with climate of the glacial epoch). Acta Geol. Pol., 1, 3, 257—310.

J a h n A. 1956, Wyżyna Lubelska — Rzeźba i czwartorzęd (Geomorphology and Quaternary history of Lublin Plateau). Prace Geogr. IG PAN, 7, Warszawa.

J e r s a k J. 1973, Litologia i stratygrafia lessu wyżyn południowej Polski (Lithology and stratigraphy of the Polish loess on the southern Polish Upland). Acta Geogr. Lodz., 32.

Konecka-Betley K., Maruszczak H. 1976, Analiza paleopedologiczna lessów z Kazimierza Dolnego nad Wisłą (Paleogeographic pedological studies of the loesses from Kazimierz Dolny on the Vistula river). Biul. Inst. Geol., 297, Warszawa, 185—206.

Krishtafovitch N. I. 1902, Gidro-geologicheskoe opisanye territorii goroda Lublina i yego okrestnostiey (Hydro-geologische Beschreibung des Territoriums der Stadt Lublin und ihre Umgegenden). Warszawa.

Malicki A. 1950, Geneza i rozmieszczenie lessów w środkowej i wschodniej Polsce (The origin and distribution of loess in Central and Eastern Poland). Ann. Univ. M. Curie-Skłodowska, B, 4, Lublin, 195—228.

Malinowski J. 1959, Wyniki badań geotechnicznych lessu między Kazimierzem Dolnym a Nałęczowem (Results of geotechnical investigations of loess between Kazimierz Dolny and Nałęczów — Lublin Upland). Kwart. Geol., 3, 2, 423—456.

Maruszczak H. 1969a, Genetic interpretation of lithological features of Polish loess. Geographia Pol., 17, 293—310.

Maruszczak H. 1969b, Une analyse paléogéographique de la répartition du loess polonais et de ses caractères lithologiques directifs. Biul. Perygl., 20, 133—152.

Maruszczak H. 1972, Wyżyny Lubelsko-Wołyńskie. Geomorfologia Polski, 1, Warszawa, 340—384.

Maruszczak H. 1973, Erozja wąwozowa we wschodniej części pasa wyżyn południowo-polskich (Gully erosion in the eastern part of Southern Uplands of Poland). Zeszyty Probl. Post. Nauk Roln., 151, Warszawa, 15—30.

Maruszczak H. 1976, Stratygrafia lessów Polski południowo-wschodniej (Loess stratigraphy of south-eastern Poland). Biul. Inst. Geol., 297, Warszawa, 135—175.

Maruszczak H. 1980, Stratigraphy and chronology of the Vistulian loesses in Poland. Quat. Studies in Poland, 2, 57—76.

Maruszczak H. 1985a, Main genetic features and relief of loess covers in southern Poland. Guide-book int. symp. "Problems stratigr. paleogeogr. of loesses", UMCS, Lublin, 9—37.

Maruszczak H. 1985b, Problems of stratigraphy and paleogeography of loesses in Poland. Guide-book int. symp. "Problems stratigr. paleogeogr. of loesses", UMCS, Lublin, 63—80.

Maruszczak H. 1986, Differentiation of the intensity of accumulation of the Vistulian loesses in Poland and Hungary. Biul. Perygl., 31, 213—222.

Maruszczak H., Morawski J. 1976, Zróżnicowanie składu minerałów ciężkich w podstawowych jednostkach litologiczno-stratygraficznych lessów polskich (Differentiation of the heavy minerals composition in the principal lithological-stratigraphic units of the Polish loesses). Biul. Inst. Geol., 297, Warszawa, 63—72.

Maruszczak H., Racinowski R. 1968, Peculiarites of the conditions of loess accumulation in Central Europe in the light of results of heavy mineral analyses. Geographia Pol., 14, 35—46.

Maruszczak H., Racinowski R. 1976, Dynamika akumulacji eolicznej lessu młodszego w okolicy Lublina w świetle badań uziarnienia i składu minerałów ciężkich (Dynamic of the aeolian accumulation of the younger loesses in the Lublin area in the light of grain size analysis and heavy minerals studies). Biul. Inst. Geol., 297, Warszawa, 211—225.

Maruszczak H., Tkacz M. 1987, The importance of the paleomagnetic investigation for the stratigraphic analysis of loesses on the example of the section at Łopatki (SE Poland). Ann. Univ. M. Curie-Skłodowska, B, 41, Lublin.

Morawski J., Trembaczowski J. 1973, Charakterystyka mineralogiczna lessów profilu Kwaskowa Góra w Kazimierzu nad Wisłą (Mineralogical characteristic of Kwaskowa Góra loess profile in Kazimierz upon Vistula). Ann. Univ. M. Curie-Skłodowska, B, 26, Lublin, 1—26.

Nowak J. 1981, Charakterystyka uziarnienia utworów pyłowych strefy krawędziowej północnej części Wyżyny Lubelskiej (Characterisation of granulation of silty formations of the marginal zone in the northern part of Lublin Upland). Ann. Univ. M. Curie-Skłodowska, B, 32/33, Lublin, 189—218.

Pożaryski W. 1953, Plejstocen w przełomie Wisły przez wyżyny południowe (The Pleistocene in the Vistula gap across the southern uplands). Prace Inst. Geol., 9, Warszawa.

Racinowski R. 1976, Uwagi o składzie minerałów ciężkich lessów lubelskich i przemyskich (Remarks on the heavy minerals composition of the Lublin and Przemyśl loesses). Biul. Inst. Geol., 297, Warszawa, 227—247.

STRESZCZENIE

We wschodniej części Płaskowyżu Nałęczowskiego wykonano 6 rdzeniowanych otworów wiertniczych przebijających cały czwartorzęd, którego głównym ogniwem są lessy o miąższości do 19 m. Wykonano 188 analiz uziarnienia lessów i zawartości $CaCO_3$ oraz 93 analizy składu minerałów ciężkich. Bogaty materiał analityczny pozwolił na rozdzielenie lessów w całości uznanych za vistuliańskie na trzy kompleksy stratygraficzne, które skorelowano ze schematem stratygrafii lessów polskich H. Maruszczaka (1980, 1985b).

Lessy wschodniej części Płaskowyżu Nałęczowskiego tworzą pokrywę rozciągającą się od teras Bystrzycy do poziomu wierzchowinowego. Różnią się one od lessów występujących w innych regionach Wyżyny Lubelskiej większą przeciętną średnicą ziarn, lepszym wysortowaniem, mniejszą zawartością frakcji podstawowej oraz ilasto-koloidalnej. Również w składzie minerałów ciężkich zaznaczają się wyraźne różnice. W lessach badanego obszaru dominuje zespół minerałów: granat—epidot—amfibol, podczas gdy w SE regionach Wyżyny Lubelskiej zespół: granat—cyrkon—rutyl.

Na podstawie danych analitycznych stwierdzono, że w miarę narastania pokrywy lessowej zmieniały się warunki depozycji pyłu. Akumulacja lessów młodszych dolnych (LMd) rozpoczęła się w warunkach dość wilgotnego, chłodnego klimatu, przy wyraźnym współudziale procesów soliflukcji. Skład mineralny i podwyższony udział frakcji ilastej wskazują na małą dynamikę wiatrów. W dolinie Bystrzycy na ówczesnej terasie zalewowej osadzały się, przy współudziale procesów eolicznych, pylaste aluwia facji powodziowych.

Lessy młodsze środkowe (LMs) cechuje mała miąższość. Ku górze średnia wielkość ziarn jest większa i poprawia się wysortowanie, co wskazuje na wzrost dynamiki wiatrów. Kierunek przestrzennych zmian wskaźników uziarnienia świadczy o roli wiatrów z sektora E i NE. Tempo narastania pokrywy lessowej na terasie Bystrzycy było dwukrotnie większe niż na obszarze wierzchowinowym.

Lessy młodsze górne (LMg) są dwudzielne. Różnice zaznaczają się głównie w składzie minerałów ciężkich. Nadal wzrasta przeciętna wielkość ziarn i poprawia się wysortowanie, co świadczy o dalszym wzroście dynamiki prądów. W czasie akumulacji dolnej części kompleksu LMg przeważały wiatry NE. W górnej części obserwuje się skokowe zmiany wskaźników uziarnienia i składu minerałów ciężkich, świadczące o zmienności dynamiki prądów oraz ich kierunków, z tendencją do wzrostu udziału wiatrów z sektora N.

РЕЗЮМЕ

В восточной части Наленчовской плоской возвышенности (СЗ часть Люблинской возвышенности) сделано 6 разведочных колонковых скважин пробивающих толщу четвертичных образований, среди которых главное звено составляют лессы мощностью до 19 м. Для 188 образцов лессов, избранных из колонок (кернов), определено гранулометрический состав и содержание карбонатов, а для 93 образцов состав тяжелых минералов. На основании результатов этих исследований все лессовые слои определено как вюрмские (Vistulian). Они разделяются на три стратиграфические горизонты (единицы) сопоставленные со схемой стратиграфического деления лессов в Польше по Х. Марущаку (H. Maruszczak 1980, 1985b).

Лессы исследованного района распространенные покровно, от террас реки Бистрицы до вершинных уровней. От лессов других районов Люблинской возвышенности отличаются они крупнейшим средним зерном, лучшей сортировкой, меньшим содержанием основной („лессовой") и глинистой фракцией зерна. Среди тяжелых минералов в исследованных лессах преобладает группа: гранат—эпидот—амфибол, в то время как в юго-восточных районах Люблинской возвышенности: гранат—циркон—рутил.

На основании аналитических данных констатировано, что с поступающим наслаиванием исследованного вюрмского, значит молодого лесса, изменялись условия накопления пыли. Образование лесса молодого нижнего (LMd) началось в условиях относительно влажного, холодного климата, при резко видных признаках развития солифлюкционных процессов. Минералогический состав и повышенное количество глинистых фракций свидетельствует о малой динамике эолового фактора. В долине реки Бистрицы в пределах тогдашней поймы накапливались, при участи эоловых процессов, поводковые фации алювия..

Лессы молодые средние (LMs) отличаются малой мощностью. К верху средний диаметр зерна увеличивается, а степень его сортировки повышается, что свидетельствует о возрастающей динамике эолового фактора. Пространственные направления изменений гранулометрических показателей указывают на возрастающую роль восточных и северовосточных ветров. Скорость накопления лесса на террасах в долине реки Бистрицы была два раза выше, чем на вершинном уровне.

Лессы молодые верхние (LMg) двучленные. Различия отражаются главным образом в составе тяжелых минералов. В дальнейшим наблюдается возрастание среднего диаметра зерен и повышение степени сортировки, что свидетельствует о возрастающей динамике эолового фактора. Во время накапливания нижних слоев LMg преобладали северовосточные ветры. Для верхних же слоев характерны скачкообразные изменения гранулометрических показателей и состава тяжелых минералов, что свидетельствует о изменениях динамики и направлений воздушных течений, с признаками возрастающей роли северных ветров.