MINERALOGIA POLONICA
Vol. 13, No 1 — 1982

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CLAY MINERALS OF LOESSES OF SE POLAND

UKD 549.623:552.52].08mieszanopakietowe:552.524+551.311.234.3.072(438-12)

Abstract. Minerals of mixed-layer smectite (beidellite)-illite type, illite and small amounts of kaolinite were found to occur in the finest fraction (below 2 μm) of loesses in SE Poland. The contents of these minerals vary with depth both in younger loesses (from the last glaciation) and in older ones (from the foregoing one). In deeper horizons there occur higher concentrations of mixed--layer minerals. Smectite/illite from older horizons displays higher degree of crystallinity than in younger ones. This indicates that recrystallization processes in loess profiles had to take place. The content of smectite/illite mixed-layer mineral in younger loesses amounts to 60—65% whereas in older ones and fossil soils increases up to 65—80%. Most probably, this difference can be partly explained by primary contents of this mineral in original sediments, from which the loesses in question were formed. It is supposed that diversified climatic conditions have influenced the rate of degradation of illite structure into that of mixed-layer smectite/illite type. Another factor could be the action of time i.e. the aging of primary sediment.

INTRODUCTION

There are very few data on clay minerals contained in Polish loesses. They are nearly exclusively qualitative in character and based on DTA study (Tokarski et al. 1961). More complex data on clay minerals in question, presented by Grabowska-Olszewska (1963), indicate that in loesses of the Sandomierz region, illite predominates, being accompanied by kaolinite and montmorillonite. Similar results were obtained for loesses of West Roztocze by Malinowski (1964). Uziak's (1961, 1964) investigations have shown that in soils formed from loesses in E Poland the most characteristic are mixed-layer illite-montmorillonite minerals and only locally montmorillonite predominates. Quantitative X-ray determinations, carried out in the Laboratory of Physical Geography in Amsterdam, have shown that the clay fraction of loesses from the Lublin region consists predominantly of illite (70—80%), accompanied by montmorillonite (5—15%) and trace amounts of kaolinite (Maruszczak, 1969).

In finer grained fractions of soils, covering loesses of the Trzebnickie Wzgórza Hills and Głubczyce Upland, there occur montmorillonite and mixed-layer mont-

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morillonite/illite minerals, accompanied by illite and subordinate amounts of kaolinite (Chodak 1973, 1976). The content of montmorillonite increases with depth.

Recent data of Chodak et al. (1979) on seven loess samples from SE Poland indicate that the kinds and amounts of clay minerals occurring in them are the same. Mixed-layer illite/smectite minerals are dominating in them. The authors suggest that smectites from older and younger loesses are slightly different. This is manifested by different temperature range of dehydroxylation endothermal DTA peaks.

Uziak's (1979) studies of loessial profiles in Pikulice near Przemyśl have shown the presence of three soil horizons, corresponding to Holocene, interstadial and interglacial (Eemsian) ages. No differences in clay mineral associations were observed in them. The only variations of mineral composition were found in fractions o different grain-size. So eg. in that 2—0.5 μm illite predominates whilst in the finer one (below 0.2 μm) mixed-layer illite/smectite mineral is the most abundant.

Rybicka and Ratajczak (1979) have determined quantitative mineral composition of loesses occurring in the slopes of Dłubnia river valley near Cracow. The most important clay mineral in them is smectite/illite, accompanied by small amounts of illite and kaolinite. The latter is more abundant in upper horizons.

In the above publications, there are presented the results of analyses of rather small amounts of samples, often coming from different profiles. On the other side, the studies carried out by soil scientists are concerning mainly the genetic horizons of soils and to much lesser extent the parent loessial rocks. Therefore, in the present study we have examined the selected loess profiles from their most important occurrences, showing lithological and stratigraphical differentiation. Four profiles were

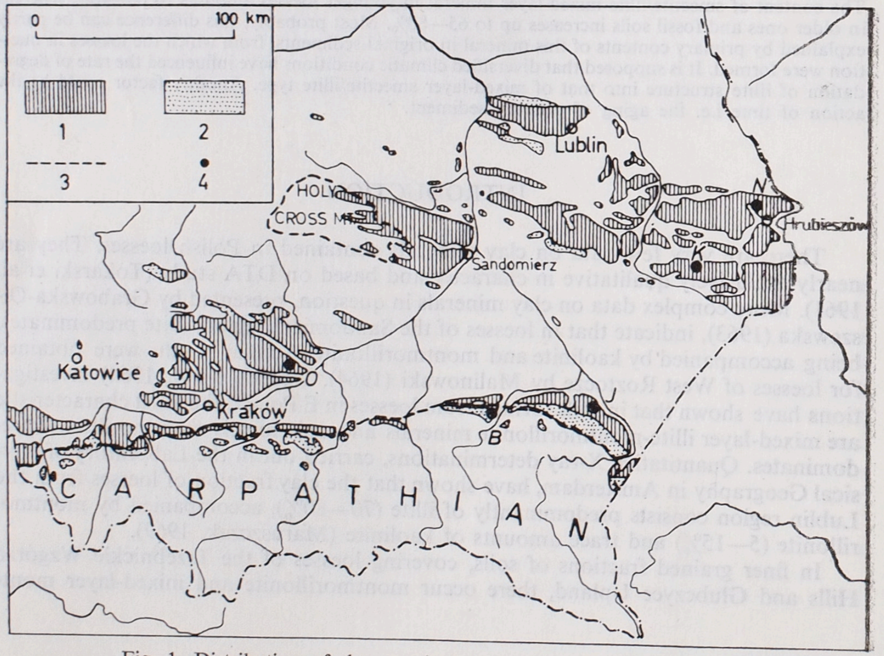

Fig. 1. Distribution of the examined loessial profiles in SE Poland
1 — proper loesses, more than 2—3 m thick, *2* — aleuritic-clayey periglacial deposits, locally with thin intercalations of eolian dusts, *3* — boundaries of mountain areas, *4* — more important loess profiles.

found to be the most representative and best characterized stratigraphically: 1) Nieledew, 2) Odonów Górny, 3) Komarów Górny, and 4) Jarosław (Fig. 1). In the first two outcrops, being of fundamental importance for the stratigraphy of Polish loesses, rather thin younger loesses (of the last glaciation) are underlain by well developed and stratigraphically diversified older loesses (from preceding glaciation). In the both remaining profiles, better developed and stratigraphically differentiated are the younger loesses. The older ones are represented only by top and, eventually, middle horizons. The samples for analyses were collected not only from loesses of different age but also from interglacial and interstadial soils, separating them. All the samples studied are from Maruszczak's collection.

Loessial profile in Nieledew, found and examined by Mojski, has been discussed in numerous papers (Mojski 1956, 1965; Jersak 1969, 1973; Maruszczak 1974, 1976, 1980b, c). The profile in Odonów has been discovered and examined by Jersak (1973, 1976), whilst that in Komarów Górny — by Maruszczak (1974). The first data on the profile in Jarosław were reported by Laskowska-Wysoczańska (1971) and its detailed stratigraphic interpretation presented by Maruszczak (1980c, 1976). Lithological and stratigraphical differentiation of these profiles are presented in Fig. 2. Geochronological interpretation, nomenclature and symbols of stratigraphic units and of fossil soils are in this figure after Maruszczak (1976, 1980 a, b).

There are very few data on detailed mineral composition and grain-size distribution of loesses occurring in SE Poland. The present authors have examined these important characteristics for typical loess deposit from Boguchwała near Rzeszów.

METHODS

Mineral composition of loess sample from Boguchwała, as well as of the finest clay fraction (below 2 μm), separated from those of the above mentioned four profiles (altogether 41 samples) has been determined using X-ray and DTA methods. X-ray analyses were carried out by means of X-ray Diffractometer DRON-1, using filtered CuK_α radiation. DTA studies were performed by applying Paulik-Paulik-Erdey Derivatograph. Moreover, grain-size distribution in loess sample from Boguchwała was determined using Sartorius sedimentation balance.

The contents of individual minerals (kaolinite, quartz, calcite and feldspars) were estimated by means of calibration curves, obtained by analyzing standard mixtures containing these minerals in various proportions and showing similar grain-size distribution and mineralogical character. Integral intensity of suitable reflections of these minerals (kaolinite — 0.714 nm, quartz — 0.426 nm, calcite — 0.301 nm, faldspar — ca. 0.32 nm) were measured and used to evaluate their contents. Weight losses in the range 360—650°C, resulting from TG curves, were accepted as the measure of total content of clay minerals in the samples examined. The loss corresponding to kaolinite was subtracted from the total one on the ground of the content of this mineral determined by X-ray method. So corrected weight losses were the basis for computation of total content three-layer clay minerals. It is well known that both the minerals — illite and smectite/illite — contain ca. 4.5 wt. % water bound as hydroxyl groups which are evolved in this temperature range.

On the ground of X-ray data, the ratio of integral intensity of lines ca 1.0 nm of illite and ca. 1.5 nm for smectite/illite was accepted as the measure of percentual ratio of these minerals in the samples examined (by assuming the intensities of their basal *001* reflections to be equal). This assumption results from similar chemical composition, structure and grain-size distribution of smectite/illite and illite occurring in the

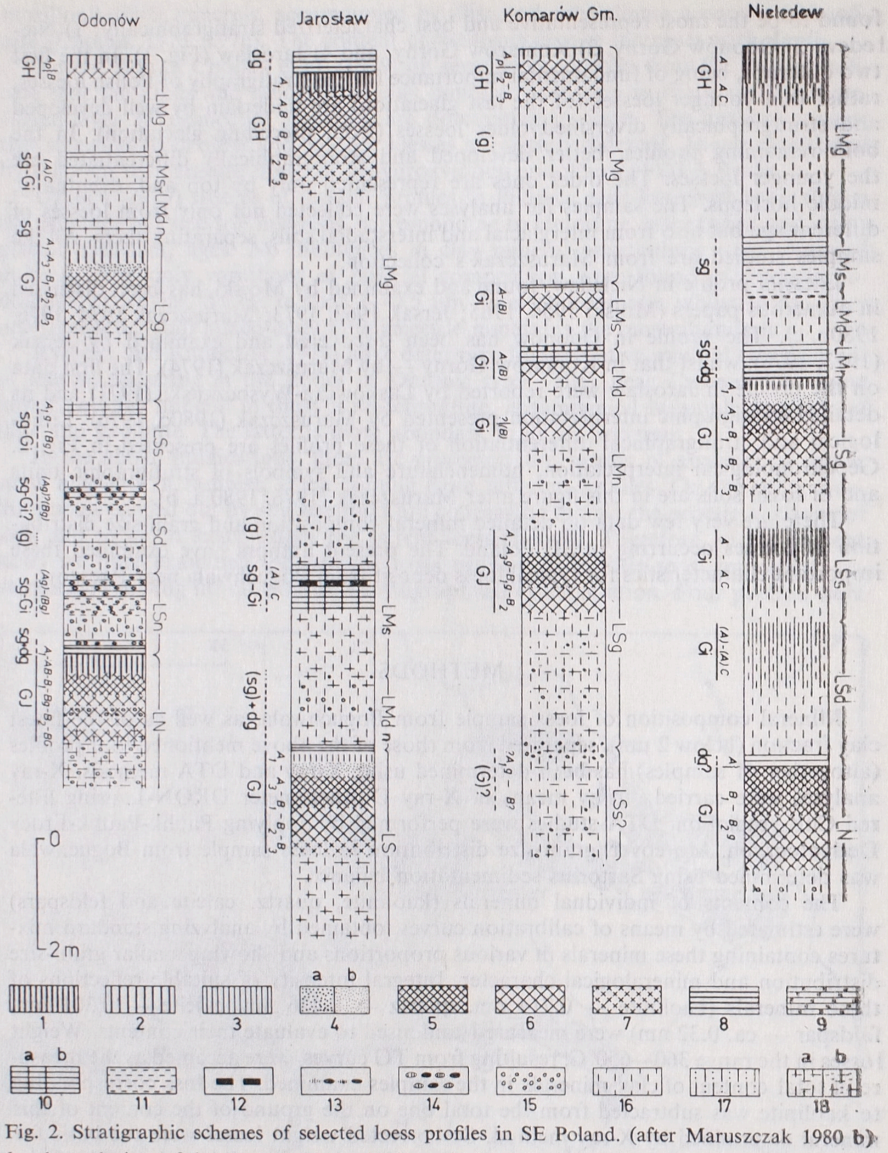

Fig. 2. Stratigraphic schemes of selected loess profiles in SE Poland. (after Maruszczak 1980 b)

1 — humus horizons of chernozem type, *2* — other humus horizons, distinctly marked, *3* — humus horizons poorly marked, *4* — lessivage horizons well (*a*) and poorly (*b*) marked, *5* — intensely coloured upper part of browned and illuvial horizons, *6* — middle, less intensely coloured part of browned and illuvial horizons, *7* — lower part of illuvial horizons with regular brown and yellow bands, *8* — dilluvia of chernozem horizons, *9* — other dilluvia of soil horizons (mainly humus), *10* — soil sediments showing symptoms of initial humus horizon — strongly (*a*) and poorly (*b*) marked, *11* — soil sediments showing symptoms of browning process, *12* — mineral-peat lenses in swamp soil, *13* — relics (?) of humus horizon with high concentrations of manganese compounds, *14* — spotty concentrations enriched in humus or in manganese and iron compounds, *15* — gleying symptoms, *16* — carbonate loess, *17* — arenaceous carbonate loess with intercalations of fine and dusty sands, *18* — carbonate-free loesses — typical (*a*) and arenaceous (*b*).

Symbols of stratigraphic units of loessial cover: *L* — loess, *M* — younger, *S* — older, *N* — the oldest, *g* — upper *s* — middle, *d* — lower, *n* — the lowest.

Symbols of soil units: *G* — soil showing well developed genetic horizons, *H* — contemporaneous (Holocene) soil, *J* — interstadial (fossil) soil, *sg* — soil sediments, *dg* — soil delluvia, (*g*) — traces of development of soil-forming processes.

examined fractions of loesses. On the ground of quantitative proportions of mixed-layer mineral and illite, and the total contents of these minerals, their percentual contents could be computed.

Finally, the content of carbonates was determined on the basis of weight losses in the range 650—750°C and checked by X-ray data. The weight losses in the range 200—360°C was the measure of organic matter content in the examined fractions of loesses. The eventual presence of chlorite was checked by X-ray study of samples heated at ca. 550°C.

The average error of such computation of quantitative mineral composition amounts to ca. 10 relative % for each mineral.

RESULTS

MINERAL COMPOSITION OF LOESS FROM BOGUCHWAŁA

The mineral composition and grain-size distribution of the rock in question is representative for loesses in SE Poland.

The analyzed sample was collected in a quarry of brickyard at the depth of approx. 8 m and examined in 1973. It represents the younger loesses and does not show any distinct stratigraphic differentiation.

Loess from Boguchwała is a fine-grained, light yellow rock, consisting predominantly of fine quartz grains. Besides, it contains small amounts of carbonate minerals, occurring in grains 30—40 μm in size. We also observe single dispersed mica flakes. The grains of the above minerals are cemented with clay substance, represented mainly by mixed-layer smectite/illite mineral and small kaolinite admixture.

On the ground of X-ray analysis, the mineral composition of this loess (whole rock) is as follows:

	wt. %
quartz	45
acid plagioclases	10
K-feldspar	10
mixed-layer smectite-illite	15
micas (sericite, illite)	10
kaolinite	5
carbonates (calcite, dolomite)	5

As follows from X-ray study, loessial rock of Boguchwała contains considerable amounts of feldspars. They are fine-grained and, consequently, hardly observable under polarizing microscope. Similarly, abundant feldspars were found by X-ray study to occur in loesses of the environs of Cracow (Rybicka, Ratajczak 1979).

As far as the grain-size distribution is concerned, loessial rock of Boguchwała is fine-grained in character — the fraction 60—4 μm constitutes ca. 80% of it (Table 1). It consists predominantly of quartz, accompanied by feldspars, carbonates and clay mineral aggregates. Subordinate 4 — 1 μm fraction (10% of the rock), consists predominantly of quartz and clay minerals, accompanied by very small admixture of carbonates and feldspars. The fraction below 1 μm is composed mainly of clay minerals with pelitic quartz admixture. The mineral composition of individual grain fractions is as follows:

Fraction above 60 μm — consists predominantly of sharp-edged quartz grains, accompanied by single calcite crystals and light mica flakes. Feldspars are fairly abundant, being represented mainly by plagioclases and subordinate potassium feldspars. Moreover, there occur clay mineral aggregates cemented with calcite.

Fraction 60—15 µm shows very similar mineral composition as the former one.

Fraction 15 — 4 µm contains more clay minerals that the coarser grained ones. They are represented predominantly by mixed-layer smectite/illite mineral, accompanied by dioctahedral mica of sericite type and some kaolinite. Potassium feldspar

Table 1

Mineral composition of individual loess fractions from Boguchwała

Fraction (grain-size limits in µm)	Content of fraction (in wt. %)	Content of minerals (in wt. %)						
		smectite/ /illite	kaoli-nite	mica (sericite, illite)	quartz	felds-pars	calcite	dolo-mite
above 60	10,2	10	1	10	55	17	4	3
60—15	65,2	5	2	5	50	30	2	6
15— 4	11,8	20	8	25	30	14	2	1
4— 1	3,5	30	10	27	25	6	2	1
1—0,5	1,9	53	10	25	10	2		
below 0,5	7,3	60	5	30	5	—	—	—

and plagioclases occur in equivalent amounts. Carbonates are represented by calcite and dolomite, the latter being more abundant.

Fraction 4— 1 µm is composed mainly of clay minerals: smectite/illite, illite, micas of sericite type and kaolinite. Feldspars and carbonates occur in very low amounts, whereby more resistant K-feldspar dominates over plagioclases.

Fraction 1 — 0.5 µm is carbonate-free. Feldspar content does not exceed 5% (mainly K-feldspars). Clay minerals dominate as in previous fraction.

The finest fraction (below 0.5 µm) consists nearly entirely of clay minerals, accompanied by ca. 5% quartz. No feldspars and carbonates were found to occur. Clay minerals of this fraction are represented predominantly by mixed-layer smectite/ /illite minerals. As follows from X-ray study of samples, saturated with $MgCl_2$, the ratio of smectite to illite layers amounts to 65/35. The content of illite is ca. 30%.

Mineral composition of fractions, separated from loessial rock of Boguchwała is presented in table 1, wheres the grain-size distribution and the partition of mineral components among these fractions are illustrated in Fig. 3.

MINERAL COMPOSITION OF CLAY FRACTION OF LOESSES

Detailed study of mineral composition of the clay fraction (below 2 µm) has shown that mineral associations in them are the same. However, we observe distinct differences in the ratio of two major mineral components — smectite/illite and illite. This is illustrated by the results of quantitative analyses of 41 samples (table 2). As follows from these data, the clay fraction of all the loesses examined is composed of mixed-layer smectite/illite mineral, illite and, probably also a little smectite, as well as kaolinite admixture. Swelling layers of smectite/illite in question are beidellitic in type, what is manifested by characteristic value of 001 reflection — ca. 1.47 nm on X-ray pattern. When saturated with K ions this structure collapses, changing into

illitic one. Consequently, in X-ray pattern, the *001* line is displaced to ca. 1.0 nm. The mineral in question displays swelling properties when treated with ethylene glycol. This is manifested by displacement of the *001* line to ca. 1.8 nm. We observe some differences in sharpness of the *001* line of mixed-layer smectite/illite occurring in the examined samples. This can be due to different degree of structural ordering (crystallinity) of this mineral. Another important component of the loesses examined is illite, identified by characteristic basal reflection ca. 1.0 nm. This line is broad and diffused, indicating considerable disintegration of this mineral and its weak structu-

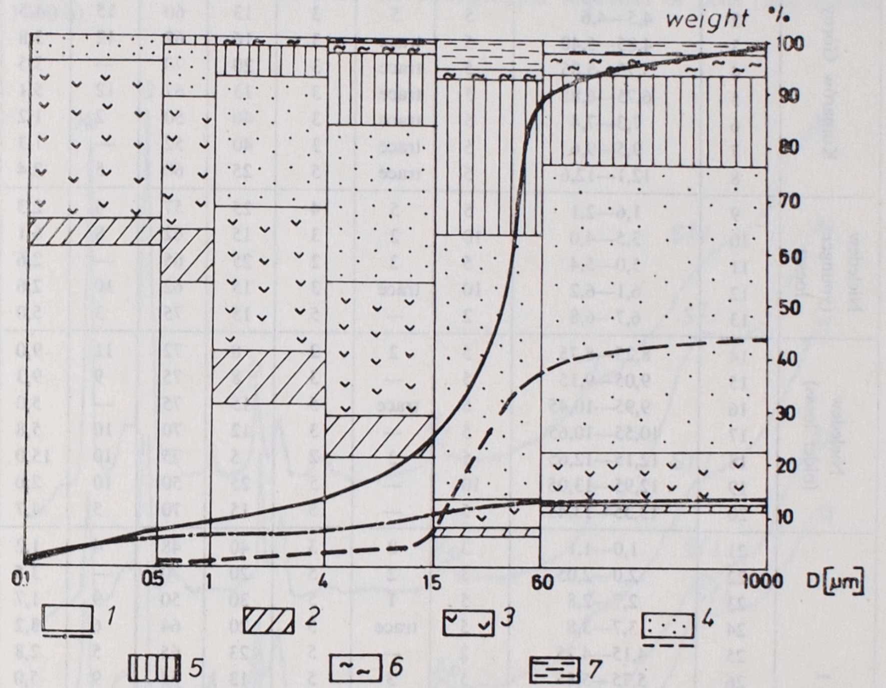

Fig. 3. Diagram showing mineral composition and grain-size distribution of loess from Boguchwała
1 — smectite/illite; *2* — kaolinite; *3* — mica; *4* — quartz; *5* — feldspars; *6* — calcite; *7* — dolomite

ral ordering. Besides, the examined fractions contain small amounts (up to 5%) of kaolinite (reflection ca. 0.714 nm). X-ray study of samples heated at approx. 550°C did not confirm the presence of chlorite.

DTA, *TG* and *DTG* curves of the samples examined are practically identical. They are characterized by the presence of intense endothermal peaks in the range 20—200°C (dehydration of swelling minerals) and 200—300°C (combustion of organic matter), followed by endothermal peak of simultaneous dehydroxylation of clay minerals: smectite/illite, illite and kaolinite (300—650°C). In some patterns there also appears a weak peak in the range 650—750°C, corresponding to calcite decomposition. At 820°C we observe a weak endothermal reaction of breakdown of smectite/ /illite and illite structures and at 880°C a weak exothermal peak also connected with the presence of these minerals.

Mineral composition of the finest fraction (below 2 µm) of loesses from the four essential profiles studied

Profile	Sample	Depth (m)	Content of minerals in wt. %						$\frac{S/I}{I}$
			quartz	calcite	kaolinite	illite	smectite/illite	other	
Komarów Górny	1	1,9—2,4	5	5	3	15	60	10	4,0
	2	4,5—4,6	5	5	3	13	60	15	4,5
	3	4,85—5,40	5	trace	3	16	62	12	3,8
	4	5,75—5,85	5	trace	3	20	70	—	3,5
	5	6,75—6,85	5	trace	3	13	67	12	5,1
	6	7,3—7,4	5	trace	3	40	50	2	1,2
	7	9,5—9,6	5	trace	3	40	52	—	1,3
	8	12,1—12,6	5	trace	5	25	60	5	2,4
Nieledew (younger loess)	9	1,6—2,1	5	5	4	25	57	4	2,3
	10	3,5—4,0	10	2	3	15	62	8	6,1
	11	5,0—5,4	5	3	2	25	65	—	2,6
	12	6,1—6,2	10	trace	3	15	62	10	2,6
	13	6,7—6,8	2	—	5	15	75	3	5,0
Nieledew (older loess)	14	8,25—8,75	5	2	2	8	72	11	9,0
	15	9,05—9,15	5	—	3	8	75	9	9,3
	16	9,95—10,45	5	trace	5	15	75	—	5,0
	17	10,55—10,65	5	—	3	12	70	10	5,8
	18	12,15—12,65	5	3	2	5	75	10	15,0
	19	12,95—13,05	10	—	5	25	50	10	2,0
	20	13,35—13,45	5	—	5	15	70	5	4,7
Odonów I	21	1,0—1,1	3	2	3	40	48	4	1,2
	22	2,0—2,05	3	2	5	20	70	—	3,5
	23	2,7—2,8	5	1	5	30	50	9	1,7
	24	3,7—3,8	5	trace	5	20	64	6	3,2
	25	4,15—4,25	2	—	5	23	65	5	2,8
	26	5,75—5,85	5	3	5	13	65	9	5,0
	27	6,5—6,6	5	trace	5	15	63	12	4,2
	28	7,5—7,6	5	1	3	30	60	—	2,0
	29	8,0—8,1	5	trace	5	16	70	4	4,3
	30	9,2—9,3	5	2	3	20	70	—	3,5
	31	9,6—9,7	5	2	3	10	80	—	8,0
	32	10,75—10,80	5	trace	4	7	70	—	10,0
	33	11,75—11,80	10	trace	4	15	60	14	4,0
	34	11,60—11,65	10	1	5	20	65	—	3,2
Jarosław 4B	35	1,2—1,3	5	—	5	25	62	3	2,5
	36	4,25—4,35	8	2	2	30	55	3	1,8
	37	9,4—9,5	10	trace	2	10	70	8	10
	38	10,85—10,95	10	trace	5	25	50	10	2,0
	39	12,9—13,0	10	—	5	15	70	—	4,7
	40	13,6—13,7	3	—	2	35	60	—	1,7
	41	15,7—16,2	3	—	2	25	60	10	2,4

Nieledew profile

This profile was completed on the basis of two adjacent outcrops in an abandoned brickyard. In Maruszczak's documentation (1980 c) they are registered as "Grabowiec 3". The upper part of this profile (Grabowiec 3E) embraces younger loesses with underlying younger interglacial soil (samples 12 and 13), whereas the lower one (Grabowiec 3A) — older loesses with underlaying older interglacial soil (samples 19 and 20). In Table 2 the depth of sampling sites in lower part of the profile is corrected to make more clear the stratigraphic sequence of beds (Maruszczak 1980 b).

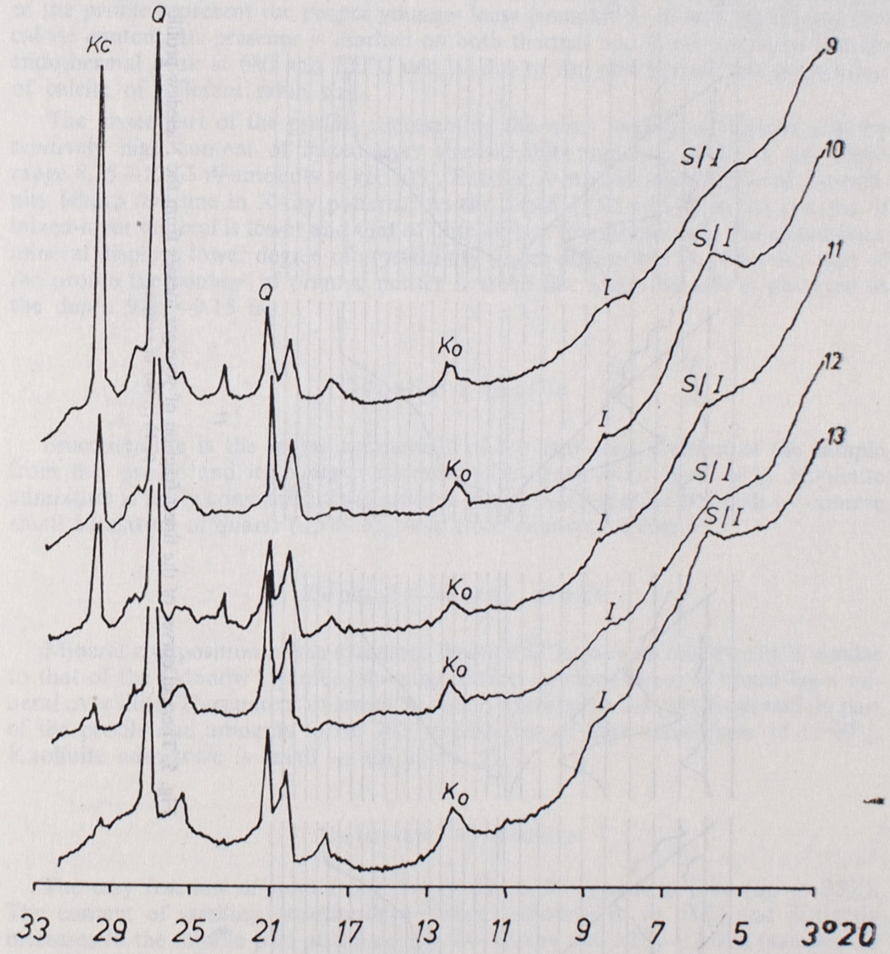

Fig. 4. X-ray diffractometer patterns of the finest fraction of samples from Nieledew profile (younger loess)

9, 10...No of samples. Basal reflections 001; S/I — smectite/illite; I — illite; Ko — kaolinite; Q — quartz

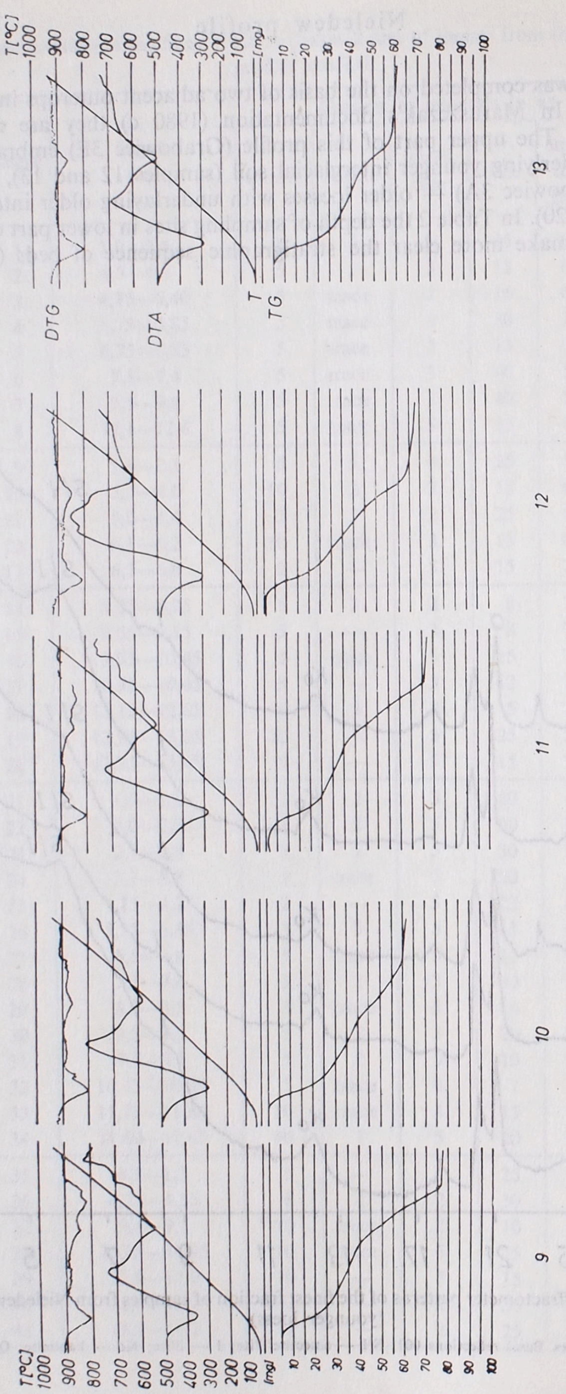

Fig. 5. Thermal curves of the finest fraction of younger loesses from the Nieledew profile
9, 10 ... No of samples

In the upper part of the profile the content of mixed-layer smectite/illite mineral decreases down to ca. 55%. Further downwards its content increases whilst that of illite diminishes. This is distinct already at the depth of 3.5—4.0 m below the top. Smectite/illite in deeper horizons is characterized by sharper X-ray *001* reflections, indicating higher degree of crystallinity of this mineral. Similarly well ordered mixed-layer mineral occurs in the illuvial horizon of interglacial soil at the bottom of younger loess horizon at the depth 6.7—6.8 m (sample 13), where its content amounts to 75%. Thermal and X-ray data for the fraction below 2 μm of this part of the profile are presented in Fig. 4 and 5.

The examined fractions of loesses contain negligible amounts of organic matter, probably sorbed on clay minerals. Its content increases with depth down to 6.1—6.2 m (sample 12) and, afterwards, distincly diminishes. The beds which in this part of the profile represent the proper younger loess (samples 9, 10 and 11) display low calcite content. Its presence is marked on both thermal and X-ray patterns. Double endothermal peak at 680 and 720°C can be due to the presence of two generations of calcite of different grain size.

The lower part of the profile, representing the older loesses, is characterized by relatively high content of mixed-layer smectite/illite mineral, which at the depth range 8.75—12.65 m amounts to ca. 70%. Besides, it exhibits high degree of crystallinity (sharp *001* line in X-ray pattern). At the depth 12.95—13.45 m the content of mixed-layer mineral is lower and that of illite higher. Simultaneously, the mixed-layer mineral displays lower degree of crystallinity (more diffuse *001* line). In this part of the profile the content of organic matter is small but some increase is observed at the depth 9.05—9.15 m.

Odonów I profile

Smectite/illite is the major component of the examined fraction of the sample from this profile and its content increases with depth from 50 to 80%. Kaolinite admixture is fairly constant and amounts to ca. 5%. Among other minerals we observe small admixture of quartz (up to 5%) and trace amounts of calcite.

Komarów Górny profile

Mineral composition of the examined fraction of loess from this locality is similar to that of the Odonów I profile, showing distinct predominance of mixed-layer mineral over illite. The content of smectite/illite is maximal in samples from middle part of the profile and amounts to ca. 70%, whilst that of illite varies from 15 to 40%. Kaolinite admixture is small — up to ca. 5%.

Jarosław 4B profile

The clay fraction of loess from this profile is fairly rich in illite (up to 35%). The content of swelling smectite/illite mineral amounts to ca. 60% and distinctly increases in the middle part at the depths 9.4—9.5 m and 12.9—13.0 m (samples 37 and 39). Besides, smectite/illite from this horizon displays higher degree of crystallinity (sharper *001* line — 1.47 nm). The content of organic matter is small. A little calcite appears at the depth 4.25—10.95 m.

MINERAL COMPOSITION OF THE FINEST FRACTION OF LOESSES (BELOW 0.2 µm)

In all the examined loess samples the clay fraction (below 2 µm) consists predominantly of smectite/illite and illite, accompanied by kaolinite, quartz and calcite. In order to examine more in detail the mineralogical character of the smectite/illite phase, the samples from the Odonów I and Nieledew profiles (containing its highest amounts) were mixed and from this mixture the fraction below 0.2 µm separated. Identification has been carried out using standard DTA and X-ray methods by applying the technique of examing the samples oriented by sedimentation and saturated with glycol. As follows from comparison of X-ray patterns, the major phase of separated fraction is represented by disordered, dioctahedral mixed-layer smectite/illite (Reynolds, Hower 1970). The content of smectite layers is variable, depending on the profile and depth, from which the samples were collected.

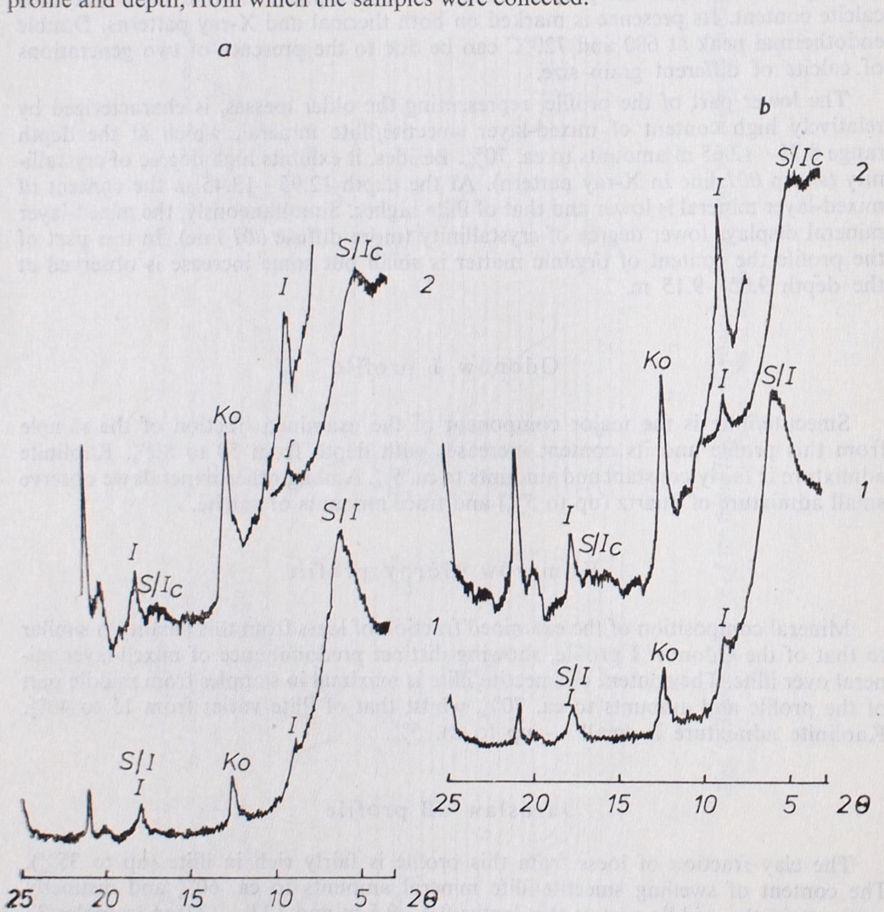

Fig. 6. X-ray diffractometer patterns of the finest fraction (below 0,2 µm) from the profiles: *a* — Nieledew (older loess), depth 9,95—10,65 m, *b* — Odonów I, depth 8,0—9,7 m
1 — non-treated sample; *2* — sample saturated with ethylene glycol; basal reflections 001: *S/I*-smectite/illite, *I*-illite, *Ko* — kaolinite, *Q* — quartz, *S/Ic* — of smectite/illite complex with ethylene glicol

The highest percentual content of smectite layers was found in the finest fraction of older loesses whereas the lowest — in the bottom part of the Odonów I profile. This content amounts to 50—70% whilst that of illitic layers — 30—50%. Smectite-poorer (40—50%) are the mixed-layer minerals of older loesses from the Nieledew profile. X-ray and thermal patterns of selected finest fractions are presented in Fig. 6 and 7.

The finest fraction consists nearly entirely of mixed-layer smectite/illite which is accompanied by illite (up to 10%) and kaolinite (several percents). X-ray and chemical data (Table 3) indicate that smectite/illite of mixed-layer structure consists of randomly interstratified smectite (beidellite) and illite layers. The content of swelling layers amounts to 40—60%, similarly as that of illitic ones. Consequently

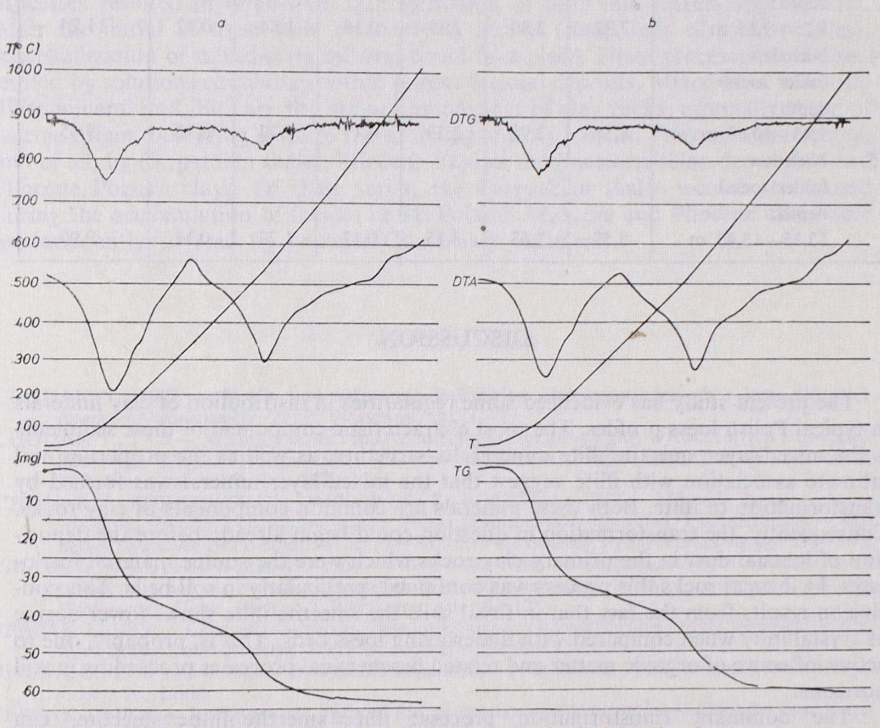

Fig. 7. Thermal curves for the samples detailed in Fig. 6.

the ratio of smectitic and illitic layers varies around the mean 1:1 value. Chemical composition of the finest fraction indicates that the mixed-layer mineral in question contains high amounts of Fe^{3+} in octahedral layer. Swelling layers easily fix potassium in interlayer spaces collapsing to ca. 1.0 nm.

Illitic layers in the lattice of mixed-layer mineral display high degree of degradation. As follows from K_2O content in the finest fractions (below 2 µm — table 3), illitic layers contain, on the average, 3.58 wt. % K_2O, whilst in typical illite the content of this element amounts to 5—7 wt. %.

Table 3

Contents of characteristic chemical components in the finest fraction (below 0,2 μm) in wt. %

Sample	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	Loss on ignition
1— Odonów I depth: 8,0—9,7 m	6,97	3,52	1,81	0,16	1,98	0,14	8,92
2— Odonów I depth: 10,75—10,80 m	6,80	2,05	1,57	0,16	1,57	0,14	8,70
3 — Nieledew (older loess) depth: 8,25—9,15 m	7,32	2,80	2,39	0,16	1,84	0,12	11,24
4 — Nieledew (older loess) depth: 9,95—10,65 m	8,57	2,91	2,39	0,17	1,73	0,12	9,45
5 — Nieledew (older loess) depth: 13,35—13,45 m	8,57	1,63	3,15	0,17	1,73	0,11	9,90

DISCUSSION

The present study has evidenced some regularities in distribution of clay minerals in typical Polish loess profiles. The most characteristic component of these sediments is the mixed-layer smectite/illite mineral. Its structure, as well as the properties and intimate association with illite suggest that the mixed-layer mineral was formed by transformation of illite. Both these minerals are common components of clay rocks. Consequently, the transformation in question could begin already before the deposition of loessial dust in the primary clay rocks which were the source material for losses. In loessial rocks this process was continued, particularly in soil beds. This conclusion results from the fact that in fossil soils the smectite/illite shows lower degree of crystallinity when compared with underlaying loess beds. This is, probably, due to active influence of organic matter and related biochemical processes proceeding in soil horizons.

The dominant transformation process: illit$\rightleftharpoons$smectite/illite$\rightleftharpoons$smectite, can proceed locally in opposite direction. Potassium ions, contained in pore waters (eg. from weathering feldspars), can be fixed by smectitic layers which subsequently collapse, transforming into sheets of illitic type. This is confirmed by saturation tests of clay fraction with potassium ions. It is supposed that in loessial deposits some equilibrium between these processes is established, causing relative stability of mixed-layer minerals, containing equal amounts of illitic and swelling smectitic layers.

The contents of mixed-layer and illite minerals in clay fractions are varying in loessial profiles. We may distinguish some horizons, in which the content of smectite/illite varies within 50—56%, whilst that of illite is higher than 15% and others, containing 65—80% of mixed-layer mineral and lower illite content (less than 15%). The former are characteristic predominantly for younger loesses (profiles: Komarów Górny, Jarosław 4B) whereas the latter — for older loesses and lower horizons of younger ones (Nieledew profile and lower part of the Odonów I one). Worth mentioning is high content of smectite/illite in interglacial and interstadial fossil soils (samples 29 and 31 of the Odonów I profile, 4 and 5 from Komarów Górny, sample 13 from Nieledew and samples 37 and 39 from Jarosław 4B profile).

The average percentual ratio of mixed-layer smectite/illite and illite $\left(\frac{S/I}{I}\right)$ for the profiles consisting predominantly of older loesses ranges from 3.3 to 7.2, whereas for those enriched in younger loesses — from 2.0 to 3.0. This difference can reflect variable content of mixed-layer mineral in parent clay rocks. However climatic conditions of deposition of loessial material could also significantly influence the rate of illite transformation. The time factor has also to be taken into account. Soil-forming processes resulted in large-scale transformation of illite into mixed-layer mineral. After the burial of these soils by overlying loesses (fossil soils of loess profiles), recrystallization of mixed-layer mineral could take place. These processes were accelerated by solutions circulating within porous loessial deposits. Mixed-layer smectite/ /illite mineral and illite are the major components of clay rocks, especially those of marine origin, occurring close to the sampling sites of loesses. They are represented, first of all, by Carpathian shales, Miocene clays of the Forecarpathian depression and Pliocene Poznań clays. Of these series, the Carpathian shales were best exposed during the accumulation of loesses in SE Poland. Miocene and Pliocene clays were predominantly covered by younger Quaternary sediments.

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MINERAŁY ILASTE LESSÓW SE POLSKI

Streszczenie

We frakcji < 2 μm lessów z południowo-wschodniej Polski stwierdzono obecność minerałów mieszanopakietowych typu smektyt (beidellit)-illit, illitu oraz niewielkie ilości kaolinitu. Zawartość tych minerałów zmienia się z głębokością zarówno w lessach młodszych (z ostatniego zlodowacenia) jak i starszych (z poprzedniego zlodowacenia). W głębszych poziomach występują większe ilości minerałów mieszanopakietowych. Smektyt/illit z głębszych poziomów wykazuje wyższy stopień krystaliczności niż z poziomów młodszych. Świadczy to o procesach rekrystalizacji jakie zachodziły w profilach lessowych. Zawartość mieszanopakietowego minerału smektyt/illit wynosi w młodszych lessach 60—65% podczas gdy w lessach starszych oraz glebach kopalnych wzrasta do 65—80%. Zróżnicowanie to może być po części związane z zawartością omawianego minerału w pierwotnych osadach, z których pochodził materiał lessowy. Autorzy przypuszczają, że zróżnicowane warunki klimatyczne miały wpływ na prędkość degradacji struktury illitu w kierunku minerału mieszanopakietowego smektyt/illit. Innym czynnikiem było postępujące z biegiem czasu starzenie się osadu.

OBJAŚNIENIE FIGUR

Fig. 1. Rozmieszczenie profili lessowych z terenu Polski południowo-wschodniej, z których pobrano próbki do badań

1 — lessy właściwe o miąższości przekraczającej 2—3 m, *2* — pylasto-gliniaste utwory peryglacjalne, miejscami z cienkimi płatami pyłów eolicznych, *3* — granice obszarów górskich, *4* — ważniejsze profile lessowe

Fig. 2. Schematy stratygraficzne wybranych profili lessowych z terenu Polski południowo-wschodniej (wg. Maruszczaka 1980, 1980b)

1 — poziomy humusowe typu czarnoziemnego; *2* — poziomy humusowe inne wyraźnie zaznaczone; *3* — poziomy humusowe słabo zaznaczone; *4* — poziomy przemywania (*a* — dobrze zaznaczone, *b* — słabo zaznaczone); *5* — część górna intensywniej zabarwiona poziomów brunatnienia oraz iluwialnych; *6* — część środkowa mniej intensywnie zabarwiona poziomów brunatnienia oraz iluwialnych; *7* — część dolna poziomów iluwialnych z nieregularnymi smugami brunatnawymi i żółtawymi; *8* — deluwia poziomów czarnoziemnych; *9* — inne deluwia poziomów glebowych (przeważnie próchniczych); *10* — sedymenty glebowe z oznakami inicjalnego poziomu humusowego zaznaczonymi (*a* — silniej, *b* — słabiej); *11* — sedymenty glebowe z oznakami rozwoju procesów brunatnienia; *12* — soczewki mineralno-torfowe w glebie bagiennej; *13* — relikty (?) poziomu humusowego z dużą koncentracją związków manganowych; *14* — plamiste skupienia ze zwiększoną zawartością próchnicy lub związków manganowo-żelazistych; *15* — oznaki oglejenia; *16* — less węglanowy; *17* — less węglanowy piaszczysty i z przewarstwieniami piasków drobnych oraz pylastych; *18* — lessy bezwęglanowe (odwapnione, *a* — typowe, *b* — piaszczyste)

Symbole literowe jednostek stratygraficznych pokrywy lessowej: *L* — less, *M* — młodszy, *S* — starszy, *N* — najstarszy *g* — górny, *s* — środkowy, *d* — dolny, *n* — najniższy.

Symbole literowe jednostek glebowych: *G* — gleba z dobrze wykształconymi poziomami genetycznymi, *H* — współczesna czyli holoceńska, *J* — kopalna interstadialna, *sg* — sedymenty glebowe, *dg* — deluwia glebowe, (g) — ślady rozwoju procesów glebotwórczych.

Fig. 3. Diagram składu mineralnego i krzywa uziarnienia lessu z Boguchwały

Fig. 4. Dyfraktogramy rentgenowskie próbek <2 μm z profilu Nieledew (less młodszy)

Fig. 5. Termogramy próbek <2 μm z profilu Nieledew (less młodszy)

Fig. 6. Dyfraktogramy rentgenowskie próbek frakcji poniżej 0,2 μm z profili: *a* — Nieledew (less starszy), głęb. 9,95—10,65 m, *b* — Odonów I, głęb. 8,0—9,7 m

Fig. 7. Termogramy próbek frakcji poniżej 0,2 μm z profili: *a* — Nieledew (less starszy), głęb. 8,0—9,7 m

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ГЛИНИСТЫЕ МИНЕРАЛЫ ЛЁССОВ ЮВ ПОЛЬШИ

Резюме

В фракции < 2 мкм лёссов из ЮВ Польши обнаружено присутствие смешанных пакетных минералов типа смектит (бейделлит) — иллит, иллита, а также небольшое количество каолинита. Содержание этих минералов изменяется с глубиной как в более молодых (из последнего), так и более древних лёссах (из предыдущего оледенения). В более глубоких горизонтах присутствует больше смешанно-пакетных минералов, Смектит/иллит из более глубовых горизонтов обнаруживает высшую степень упорядоченности чем в более молодых горизонтах. Это свидетельствует о процессах рекристаллизации, которые происходили в лёссовых разрезах. Содержание смешанно-пакетного минерала (смектит/иллит) в более молодых составляет 60—65%, тогда как в более древних лёссах, а также в ископаемых почвах, увеличивается до 65—80%. Это различие может быть отчасти связано с содержанием упомянутого минерала в первичных отложениях, из которых происходит лёссовый материал. Авторы полагают, что дифференцированные климатические условия оказали влияние на скорость деградации структуры иллита в направлении смешанно-пакетного минерала смектит/иллит. Другим фактором было прогрессирующее с временем старение садка.

ОБЪЯСНЕНИЯ К ФИГУРАМ

Фиг. 1. Размещение лёссовых разрезов на территории ЮВ Польши, из которых отобраны изучаемые образцы

1 — собственно лёссы мощности превышающей 2—3 м, *2* — пылевато-суглинковые перигляциальные образования, местами с маломощными участками золовой пыли, *3* — границы горных областей, *4* — важнейшие лёссовые разрезы

Фиг. 2. Схематические стратиграфические шкалы избранных лёссовых разрезов из территории юго-восточной Польши (по Х. Марущаку, 1980, 1980b)

1 — гумусовые горизонты черноземного типа, *2* — другие четко отмеченные гумусовые горизонты, *3* — слабообозначенные гумусовые горизонты, *4* — горизонты перемыва: *a* — хорошо обозначенные, *b* — слабообозначенные, *5* — верхняя более интенсивно окрашенная часть горизонтов побурения, а также иллювиальных горизонтов, *6* — средняя менее интенсивно окрашенная часть горизонтов побурения, а также иллювиальных горизонтов, *7* — нижняя часть иллювиальных горизонтов с нерегулярными буроватыми и желтоватыми полосами, *8* — делювий черноземных горизонтов, *9* — другой делювий почвенных (преимущественно перегнойных) горизонтов, *10* — почвенные отложения с признаками инициального гумусового горизонта: *a* — сильнее, *b* — слабее проявленными, *11* — почвенные отложения с признаками развития процесса окрашивания в бурый цвет, *12* — минерально-торфяные линзы в болотной почве, *13* — остатки (?) гумусового горизонта с большим содержанием соединений марганца, *14* — пятнистые скопления с повышенным содержанием перегноя или железисто-марганцевых соединений, *15* — признаки оглеения, *16* — карбонатный лёсс, *17* — песчанистый лёсс и лёсс с прослойками мелкозернистых, а также пылеватых песков, *18* — бескарбонатные (обеззоленные) лёссы: *a* — типичные, *b* — песчанистые

Буквенные индексы стратиграфических подразделений лёссового покрова: *L* — лёсс, *M* — более молодой лёсс, *S* — более древний лёсс, *N* — наиболее древний лёсс, *g* — верхний, *s* — средний, *d* — нижний, *n* — самый нижний

Буквенные символы почвенных единиц: *G* — почва с хорошо развитыми генетическими горизонтами, *H* — современная (голоценовая) почва, *I* — ископаемая межстадиальная почва, *sg* — почвенные отложения, *dg* — почвенный делювий, (*g*) — следы развития почвообразовательных процессов

Фиг. 3. Диаграмма минерального состава и гранулометрическая кривая лёсса из Богухвалы

Фиг. 4. Дифрактограммы образцов $<$ 2 мкм из разреза Неледэв (молодой лёсс)

Фиг. 5. Термограммы образцов $<$ 2 мкм из разреза Неледэв (молодой лёсс)

Фиг. 6. Дифрактограммы образцов фракции $<$ 0,2 мкм из разрезов: *a* — Неледэв (более древний лёсс), глуб. 9,95—10,65 м, *b* — Одонув I, глуб. 8,0—9,7 м

Фиг. 7. Термограммы образцов фракции $<$ 0,2 мкм из разрезов: *a* — Неледэв (более древний лёсс), глуб. 8,0—9,7 м