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Clay Minerals in Two Loess Profiles near Przemyśl (SE Poland)

Minerały ilaste w dwu profilach lessowych okolic Przemyśla (Polska SE)

Глинистые минералы в двух разрезах лёссов окрестностей г. Перемышля (ЮВ Польша)

ABSTRACT

In two loess profiles near Przemyśl the clay minerals are largely represented by mixed-layer smectite/illite, accompanied by illite and small amounts of kaolinite. The content of smectite/illite increases, whereas that of illite decreases in the horizons with strong symptoms of pedogenesis. This suggests that transformation of illite into mixed-layer smectite/illite proceeded during soil-forming processes.

Data on clay minerals of loesses of SE Poland were published by various authors (B. Grabowska-Olszewska 1963, J. Malinowski 1964, S. Uziak 1961, 1964, 1979, H. Maruszczak 1969, T. Chodak et al. 1979, E. Rybicka and T. Ratajczak 1979, L. Stoch et al. 1982). They found that the most important clay mineral in these loesses is mixed-layer smectite/illite, sometimes illite accompanied by kaolinite and sometimes also by chlorite or vermiculite.

In the present study, quantitative determination and characterization of clay minerals were attempted in two loess profiles near Przemyśl. These profiles are at Radymno and at Pikulice-Nehrybka. Their stratigraphic interpretation given by H. Maruszczak (1986, unpublished) is presented in Fig. 1.

Samples for mineralogical analyses were collected from the main

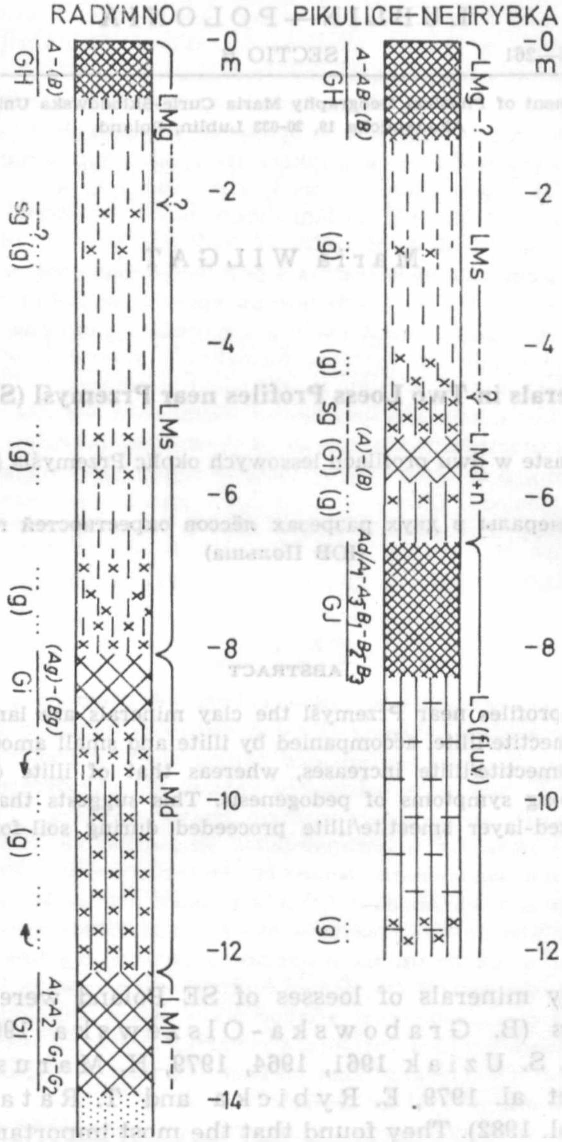

Fig. 1. Stratigraphic schemes of loess profiles (after H. Maruszczak 1986) Symbols of stratigraphic units: L — loess, M — younger, S — older, g — upper, s — middle, d — lower, n — the lowest. Symbols of soil units: G — soil showing well-developed genetic horizons, H — Holocene soil, i — interstadial soil, J — interglacial soil, sg — soil sediments, (g) — traces of development of soil-forming processes

stratigraphic horizons of loesses and from the fossil soil at Radymno (12 samples) and at Pikulice-Nehrybka (10 samples). The mineral composition of the clay fraction (<2 μm) separated from these samples was determined by the X-ray method. X-ray analyses were carried out with an X-ray diffractometer DRON-1.5, using filtered CuKα radiation. Clay minerals were identified by the technique of examining oriented samples saturated with ethylene glycol, with potassium, heated at 300°C and 400—500°C. The contents of quartz, feldspars, calcite, kaolinite and illite were determined by the method of external standard (L. S t o c h et al. 1983). The content of mixed-layer smectite/illite was estimated as the rest to 100% because of the difficulty in finding the suitable standard.

MINERAL COMPOSITION OF THE CLAY FRACTION

The mineral composition of the clay fraction (<2 μm) in both profiles studied is similar (Tab. 1). All samples contain several percent of quartz and feldspars. The samples from carbonate loess horizons also contain small amounts of calcite. Clay minerals are largely represented by smectite/illite, the content of which is 50—70%. The content of illite varies from 8 to 37%. Kaolinite admixture is small and relatively constant (3—5%). Trace amounts of chlorite were found in some horizons of the Radymno profile. With respect to the mineral composition of the clay fraction, the examined profiles are similar to others in SE Poland (L. S t o c h et al. 1982). However, they differ from Slovak loesses, in which illite is the major component of the clay fraction (J. K o š ť á l i k 1974).

Quantitative differences in the mineral composition of the clay fraction in the particular horizons of the examined profiles are small. However, one can observe some regularities, especially when the ratio of smectite/ /illite and illite content $\left(\frac{S/I}{I}\right)$ is calculated. For most samples this ratio ranges from 2 to 4, while for the horizons with distinct symptoms of pedogenesis it ranges from 5 to 8. Similarly differentiated results were obtained by L. S t o c h et al. (1982), when studying clay minerals in four loess profiles representative for SE Poland. These authors also found a higher content of swelling smectite/illite in older loesses.

Among the samples examined here only three in the Pikulice profile represent older loesses, but they do not contain an increased amount of smectite/illite. However, the content of this mineral is higher in the horizons with strong symptoms of pedogenesis. In the Radymno profile this occurs in two horizons of interstadial soil in the lowest younger

Table 1. Mineral composition of the clay fraction (<2 μm) in loess profiles

Sample	Depth /m/	Content of the clay fraction /wt.%/	Content of minerals in wt.%							S/I / I	Symbols of stratigraphic and soil units /acc. to H. Maruszczak 1986/
			Q	C	F	K	I	S/I	Ch		
Radymno											
1	0.15 - 0.25	21	8	-	5	3	25	59	-	2.4	GH/A
2	0.40 - 0.50	25	7	-	5	4	37	47	-	1.3	GH/B
3	0.90 - 1.30	27	8	2	3	3	19	65	trace	3.4	LMg
4	3.10 - 3.60	23	8	2	5	4	20	61	-	3.0	LMs
5	5.45 - 5.95	26	6	1	5	3	20	65	-	3.2	LMs/(g)
6	8.25 - 8.35	24	6	1	5	3	17	68	-	4.0	Gi/(Ag)
7	8.70 - 8.80	26	9	2	4	3	20	62	-	3.1	Gi/(Bg)
8	9.85 - 9.95	34	10	2	5	4	17	62	trace	3.6	LMd(g)
9	11.80 -11.90	53	10	-	3	5	9	72	-	8.0	LMd(g)
10	12.35 -12.40	51	18	-	4	5	8	65	-	8.1	Gi/A1
11	12.80 -12.90	78	10	-	1	5	11	73	trace	6.6	Gi/G1
12	13.95 -14.50	15	6	-	4	3	18	67	-	3.7	sands
Pikulice-Nehrybka											
1	0.80 - 1.50	14	13	5	6	4	16	56	-	3.5	GH/(B)
2	2.65 - 2.90	15	14	2	8	4	15	57	-	3.8	LMs/(g)
3	4.00 - 4.15	19	13	4	5	4	18	56	-	3.1	LMs/(g)
4	4.70 - 5.20	28	13	<0.5	5	5	11	66	-	6.0	LMd+n/(sg)
5	5.35 - 5.45	34	15	<0.5	5	5	10	65	-	6.5	LMd+n/Gi/(A)
6	6.95 - 7.05	21	15	-	5	3	11	66	-	6.0	GJ/A1
7	7.60 - 7.70	32	8	-	4	4	13	71	-	5.5	GJ/B1
8	8.40 - 8.90	21	10	-	5	4	24	76	-	3.5	LS
9	9.35 - 9.40	24	11	-	5	4	[illegible]	57	-	2.[illegible]	LS
10	11.55 -12.00	13	11	3	[illegible]	4	16	[illegible]	-	[illegible]	LS

Q - quartz; C - calcite; F - feldspars; K - kaolinite; I - illite; S/I - smectite/illite; Ch - chlorite

loess (samples No 10 and 11), and in the strongly gleyed horizon of lower younger loess (sample No 9) overlying this soil. Increased content of the clay fraction in these horizons indicates a strong activity of soil-forming processes. In the upper part of the Radymno profile the clay fraction constitutes 21—28 wt.%, while in the mentioned interstadial soil: 50—78 wt.%.*

Symptoms of gleyfication, which indicate the development of soil-forming processes, are also visible in the upper part of lower younger loess (8.25—8.80 m horizon described as interstadial soil) and in middle younger loess (5.45—5.95 m horizon). However, in these horizons the pedogenesis must have been weaker because both the content of the clay fraction and the content of smectite/illite are not increased when compared with unaltered loess horizons.

In the Pikulice-Nehrybka profile the content of swelling smectite/illite increases, whereas that of illite decrease in four horizons. There are two horizons of interglacial soil (Eemian Interglacial) developed on

* These results obtained by the weight method are higher about 10% than those by the aerometric method.

older loesses and two horizons with distinct symptoms of pedogenesis in the lowest and lower younger loess. These horizons are also enriched in the clay fraction.

In both profiles higher values of $\frac{S/I}{I}$ ratio calculated for the horizons with strong pedogenesis suggest that transformation of illite into mixed-layer smectite/illite took place during soil-forming processes.

Mineral composition of the clay fraction in the Pikulice profile was examined earlier by S. Uziak (1979), and no differences were observed in the particular horizons. However, a comparison of the data is difficult because S. Uziak presents the results of semi-quantitative analyes for the particular clay fractions (2—0.5 μm, 0.5—0.2 μm and <0.2 μm), while the results presented here are quantitative but only for the whole clay fraction (<2 μm). However, there is a distinct qualitative difference because S. Uziak discovered vermiculite in the Pikulice profile. He found considerable amounts (25—50%) of this mineral in 2—0.5 μm and in 0.5—0.2 μm fractions in which the content of smectite/illite is small. In fractions below 0.2 μm vermiculite is absent, whereas smectite/illite predominates.

Vermiculite was not found in the analysed samples of fractions below 2 μm, though its presence is possible. A high content of swelling smectite/illite with coexisting illite made the detection of vermiculite impossible despite the use of suitable X-ray tests (Fig. 2). Therefore, for more detailed studies of the mineral composition it seems reasonable to divide the clay fraction into several subordinate fractions. Mixed-layer smectite/illite is usually accumulated in the finest fraction, therefore in coarser ones the weak lines representing small amounts of vermiculite would not be covered by the wide line of smectite/illite.

CHARACTERISTICS OF SWELLING SMECTITE/ILLITE

In the examined profiles smectite/illite is the major component of the clay fraction, so it was possible to study more closely the character of this mineral. The shape of the 001 line of smectite/illite and the displacement of this line to about 17—18 Å when saturated with ethylene glycol confirm disordered interstratification of the smectite and illite layers. The content of the swelling layers in smectite/illite was approximately determined in several samples by the method of R. C. Reynolds and J. Hower (1970). It was found that the content of the swelling layers varried from 50 to 75%.

The content of smectite/illite is rather stable in the particular

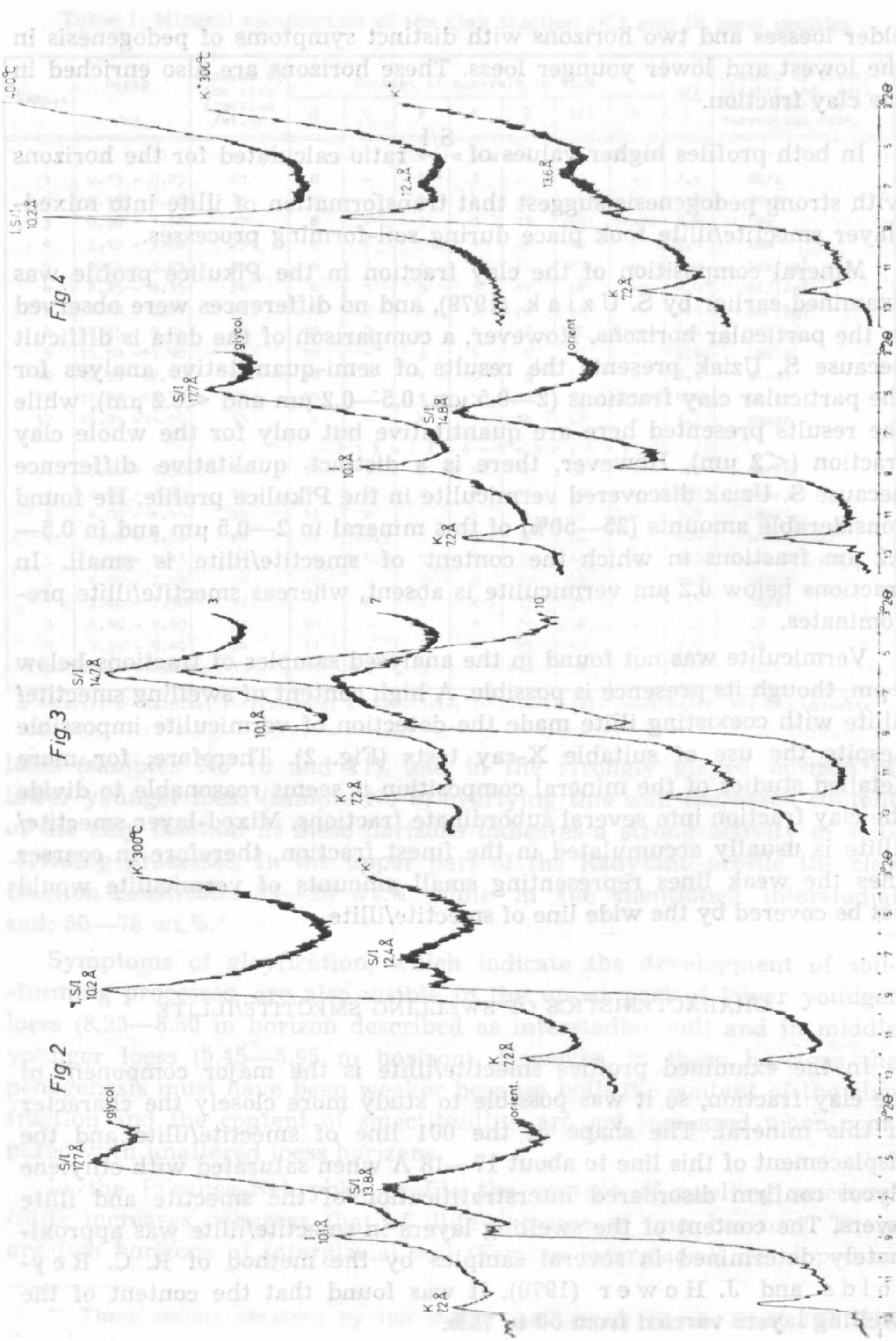
Fig. 2
Fig. 3
Fig. 4
glycol
orient.
K 7.2Å
S/I 17.7Å
S/I 13.8Å
10.1Å
I.S/I 10.2Å
S/I 12.4Å
K⁺ 300°C
S/I 14.7Å
S/I 14.8Å
13.6Å
12.4Å
K⁺ 300°C
3°2θ

horizons of both profiles. Thus the crystallinity of this mineral may be concluded from the shape (differences in sharpness) of the 001 line.

The degree of crystallinity of clay minerals is sometimes used as indicator of the state changes in the environment. According to Zheng Hong-han (1984), the clay fraction in China loesses consists predominantly of illite, which shows a lower degree of crystallinity in older loess and in the horizons subjected to pedogenesis.

In the Pikulice profile the highest degree of crystallinity is manifested by smectite/illite in older loesses and in the lowest and lower younger loess. However, the degree of crystallinity of this mineral is much lower in interglacial soil (Fig. 3). Similar results were obtained by L. Stoch et al. (1982) in studies of loess profiles in SE Poland. They found that smectite/illite showed a lower degree of crystallinity in fossil soils.

In the Radymno profile smectite/illite shows a lower degree of crystallinity than at Pikulice but at Radymno no connection with fossil soils can be seen. A higher degree of crystallinity of smectite/illite appears in the horizons with the highest content of this mineral, i.e. in samples No 9, 10 and 11.

When saturated with potassium, the 001 line of smectite/illite shifts to 12.4—12.8 Å. After heating at 300°C smectite/illite structure collapses, which is typical for smectites, and the 001 line shifts to 10 Å. However, some samples of the examined profiles exhibited different reactions. When saturated with potassium, the weak line appeared in the range 13.3—13.8 Å. After heating at 300°C this line shifted not to 10 Å, but only to 11.8—12.6 Å (Fig. 4). This indicates the presence of minerals thermally more stable than smectite in the absence of typical chlorite. These are probably mixed-layer smectite/chlorites, but their closer identification is impossible. In the Radymno profile these minerals appear in holocen soil, in the gleyed horizon of lower younger loess (sample No 9) and in interstadial soil (sample No 10). In the neighbouring samples No 8 and 11 trace amounts of chlorite were found. In the Pikulice profile mixed-layer minerals of this kind appear in the lowest, carbonate horizon of older loess and in all examined horizons of younger loess, including holocen soil. However, they are absent in weathered older loess and in interglacial soil. It is difficult to observe a regularity in the occurrence

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Fig. 2. X-ray diffraction patterns of the clay fraction (<2 μm) of sample No 9 from Pikulice-Nehrybka profile

Fig. 3. X-ray diffraction patterns of the clay fraction (<2 μm) of oriented samples No 3, 7, 10 from Pikulice-Nehrybka profile

Fig. 4. X-ray diffraction patterns of the clay fraction (<2 μm) of sample No 2 from Pikulice-Nehrybka profile

of these minerals in the examined profiles, because they appear both in carbonate and decalcified horizons. They are not correlated with soil horizons, either.

CONCLUSIONS

In both profiles examined clay mineral associations are the same. The clay fraction consists largely of mixed-layer smectite/illite, accompanied by illite and small amounts of kaolinite, sometimes also chlorite. Different mixed-layer minerals, probably smectite/chlorite type, appear in some horizons.

Quantitative differences in the mineral composition of the clay fraction in the particular horizon are small. However, higher values of the $\frac{SI}{I}$ ratio in the horizons with strong symptoms of pedogenesis suggest transformation of illite into mixed-layer smectite/illite during soil-forming processes.

Randomly interstratified smectite/illite is the predominating clay mineral with a variable content of swelling layers (50—75%). This mineral also shows a variable degree of crystallinity in the particular horizons.

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STRESZCZENIE

W dwu profilach lessowych okolic Przemyśla (profil Radymno i profil Pikulice-Nehrybka) stwierdzono występowanie stałego zespołu minerałów ilastych we frakcji poniżej 2 μm. Minerał mieszanopakietowy smektyt/illit stanowi od 50 do 70% tej frakcji, zaś zawartość illitu zmienia się w granicach 10—40%. Domieszka kaolinitu wynosi kilka procent, a czasami spotyka się śladowe ilości chlorytu. W niektórych poziomach stwierdzono występowanie minerałów mieszanopakietowych odporniejszych termicznie od minerału smektyt/illit. Prawdopodobnie są to minerały typu smektyt/chloryt.

Głównym minerałem frakcji ilastej jest mieszanopakietowy smektyt/illit o zawartości pakietów pęczniejących 50—75% i o różnym stopniu krystaliczności w poszczególnych poziomach. Ilość tego minerału zwiększa się w poziomach z wyraźnymi oznakami procesów glebotwórczych, natomiast ilość illitu maleje. Może to wskazywać na transformację illitu w kierunku minerału smektyt/illit podczas pedogenezy.

РЕЗЮМЕ

В двух разрезах лёссов окрестностей Перемышля (Радимно и Пикулице-Негрибка) обнаружено во фракции ниже 0,002 мм глинистые минералы близкие по качественному составу. Смешаннослойный минерал смектит/иллит составляет от 50 до 70% этой фракции, а доля иллита изменяется в пределах 10—40%. Примесь каолинита составляет несколько процентов, а хлорит встречается в ничтожных количествах. В некоторых горизонтах обнаружено смешаннослойный минерал термически более устойчивый чем смектит/иллит. Вероятно это минерал типа смектит/хлорит.

Главный минерал глинистой фракции составляет смешаннослойный смектит/ /иллит содержащий 50—75% набухающих пакетов о различной степени кристалличности в отдельных исследованных горизонтах. Количество этого минерала повышается в горизонтах с яркими признаками почвообразования, а количество иллита понижается. Это можно принимать как показатель трансформации иллита в смешаннослойный смектит/иллит во время почвообразования.

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