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IDENTIFICATION OF CLAY MINERALS IN SELECTED ALFISOLS WITH REGARD TO MIXED LAYER ILLITE/SMECTITE STRUCTURES

Abstract. The mineralogical composition of clay fraction (<2 μm) from Alfisols of the Ziemia Dobrzyńska region with special reference to illite/smectite minerals was investigated. The major component of clay fraction was illite with significant content of illite/smectite type minerals. The amount of smectite, chlorite and kaolinite was low. Illite/smectite minerals were characterized as ordered, ISII type structures with low content of smectite layers (<15%). Thus, analysed soil clay fraction may be classified to a highly illitic material.

Key-words: clay minerals, illite, illite-smectite.

INTRODUCTION

Alfisols (lessive soils) are one of the most abundant soils in Poland. They cover 30% of the country and are classified to moderate productive arable soils. Parent materials for these soils are mainly Quaternary glacial deposits (loam, sandy loam, silt). The secondary minerals formed from such materials will be the alteration products primarily of micas and feldspars which along with quartz are the dominant minerals. Among them clay minerals are the most important inasmuch as they constitute clay fraction (<2 μm) of soils, frequently form complexes with mineral and organic components and strongly influence the physical and chemical properties of soils (e.g. swelling, cation exchange capacity, buffer capacity, water retention properties). Clay minerals distribution in soil pedon and their composition also reflect the direction and rate of pedogenic processes.

The mineralogical composition of Alfisols (lessive soils) are rather poorly recognized. Particularly there are no reports on structure of mixed layer clay minerals in these soils. The present paper describes such minerals as well as

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other clay minerals that occur in Alfisols formed from glacial deposit of the Ziemia Dobrzyńska region.

MATERIALS AND METHODS

Three soil pedons representing the Ziemia Dobrzyńska region in Poland were sampled. Soil samples were taken from each morphological horizons, including parent material. Clay fraction (<2 μm) was collected through sedimentation after Na-resin (wofatyte) dispersion of soil samples. Clay particles (<2 μm) were saturated with Mg^{+2} or K^{+} for ethylene glycol solvation or heating (550°C), respectively.

Clay minerals were identified by X-ray diffraction analysis of oriented specimens. The X-ray diffraction patterns were recorded with a HZG-4 diffractometer, using Ni-filtered $Cu_{K\alpha}$ radiation, and a scanning speed of 1°2Θ/min. X-ray diffraction patterns were interpreted using guidelines set by Brindley (1980).

For the mixed layer clay minerals study, selected Mg-saturated, ethylene glycol solvated samples were X-rayed from 2 to 50° 2Θ. The type of interstratification and expendability of illite/smectite minerals were determined according to Środoń (1981, 1984).

In addition to peak positions for Mg-saturated, ethylene glycol solvated specimens, the following measurements were used:

➢ BB1 parameter — the joint breadth of 001 illite and adjacent illite/smectite reflections measured in °2Θ;

➢ BB2 parameter — the joint breadth of 004 illite and adjacent illite/smectite reflections;

➢ Ir — the intensity ratios — (peak heights ratios) of 001 and 003 reflections from the air dried and glycolated samples:

$$Ir = \frac{I_{001}/I_{003}\ \text{air dried}}{I_{001}/I_{003}\ \text{glycol saturated}}$$

The difference expressed in °Θ2 (defined as Δd 2) between the two main reflections in the region 42—48° 2Θ ($Cu_{K\alpha}$) was used as a measure of the content of smectite layers in mixed layer illite/smectite structures (Środoń 1984).

RESULTS AND DISCUSSION

Analysed soils were classified to Alfisols (FAO: Luvisols), where the dominant soil forming process is eluviation of fine soil particles from A and E horizon and enrichment of the Bt horizon (argillic horizon) — Soil Taxonomy (1975). The general characteristic of soil pedons is given in Table 1.

TABLE 1

General characteristics of investigated soils

Pedon	Horizon	Content of clay fraction <2 μm	pH (KCl)	$C_{org.}$ [wt.%]
1	A	10	6.21	0.82
	E_{et}	12	6.32	0.45
	B_t	20	6.30	0.13
	C	11	6.88	n.d.
2	A	9	6.19	0.54
	E_{et}	19	6.69	0.22
	B_t	21	6.97	0.12
	C	27	6.08	n.d.
3	A	6	5.78	0.73
	E_{et}	10	6.13	0.31
	B_t	22	6.37	0.06
	C	17	6.29	n.d.

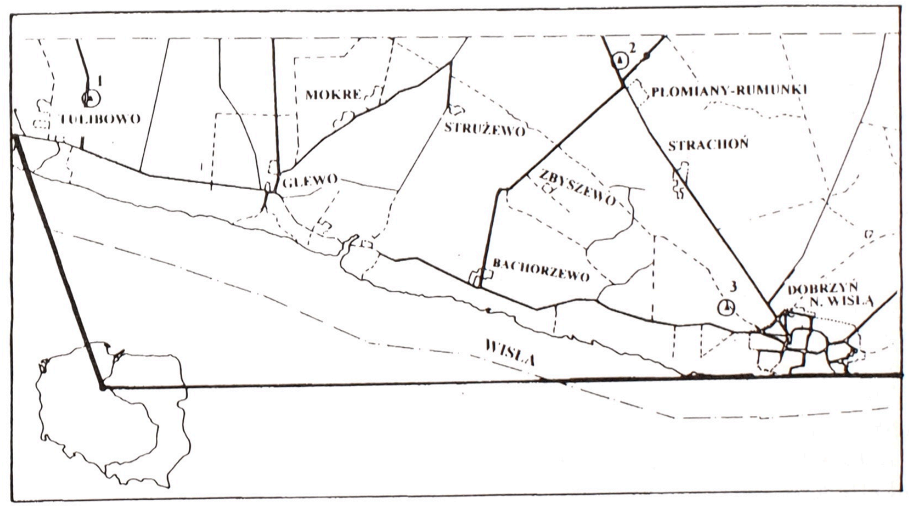

Fig. 1. Localization of the soil samples

Analysed soil clay fraction (<2 μm) gives similar XRD patterns, because of it only representative diffractograms are presented. All samples show reflections that correspond to illite (1.00; 0.500; 0.333 nm) (Brindley 1980). The relative intensity ratio of the third order to the first order illite peaks is in the range 0.76—1.70 which suggests that illite is mainly dioctaedral. After potassium saturation and heating to 550°C, the position of peaks does not change that confirms the structure of illite. According to Jackson (1965) dioctaedral micas are most common in soils.

TABLE 2

The relative abundance of clay minerals in Alfisols

Profile	Horizon	I	Sm	K	Ch	I/SM	I/CH	Ch/S
1	A	+ + + +*	+ +	+	+ + +	—	+ +	+ + +
	E_{et}	+ + + +	+ +	+	+ + +	+ + +	+ +	+ + +
	B_t	+ + + +	+ +	+	+ + +	+ +	+	+ + +
	C	+ + + +	+ +	+	+ + +	+ +	+	+ + +
2	A	+ + + +	+ + +	+	+ + +	—	+ +	+ + +
	E_{et}	+ + + +	+ +	+	+ + +	+ + +	+ +	+ +
	B_t	+ + + +	+ +	+ +	+ +	+	+	+ +
	C	+ + + +	+ + +	+	+ + +	+	+	+ + +
3	A	+ + + +	+ +	+ +	+ +	+ +	+ +	+ +
	E_{et}	+ + + +	+ +	+ +	+ +	+ +	+ +	+ +
	B_t	+ + + +	+ + +	+ +	+ +	+ +	+ +	+ +
	C	+ + + +	+ + +	+ + +	+ +	+ + +	+ +	+ +

I — illite, Sm — smectite, K — kaolinite, Ch — chlorite, I/Sm — illite/smectite, I/Ch — illite/chlorite, Ch/S — chlorite/smectite.

* Indicates relative abundance as judged from XRD peak intensities.

The glycol solvated and Mg-saturated samples show a strong 1.76 nm peak, typical of smectite structures. Smectite was found to be in slightly higher amounts in B_t horizons then in the A and E horizons, suggesting eluviation of fine (smectite-rich) clay fraction downwards in the profile during illimerization process (Allen, Fanning 1983). However, the amount of smectite in analysed soils is low.

Kaolinite is also present in small amounts (5—7%) in investigated soil samples — peak at 0.70 nm which disappears after heating at 550°C is characteristic of kaolinite minerals. Small amounts of chloritized layers are detected in pedons by the presence of 1.4 nm peak in the K — 550°C heated specimens. Chloritized layers may come from chlorite and mixed layer illite/chlorite and chlorite/smectite structures.

The plateau bridging the 1.0—1.40 nm maximum in Mg-saturated samples suggests interstratification of illite units with 1.40 nm minerals.

Detailed study of illite/smectite minerals were carried out for Mg-saturated and ethylene glycol solvated selected samples. These minerals give characteristic X-ray patterns (Fig. 2) with peak positions listed in Table 3. The 001 and 003 peaks of illite/smectite structures are intensive; peak 002 is diffused and broad. The 004 and 005 reflections are very weak and diffused; for three samples the position of 004 peak was not determined.

The degree of layer ordering in illite/smectite structures was evaluated by measuring the BB1 and BB2 parameter (Table 3). The calculated values for all examined samples were between 1.1 and 3.05° 2Θ and were lower then 4° 2Θ, which is characteristic of ISII type of interstratification (Środoń 1984). Thus, all analysed clay samples contain the same type of illite/smectite ordered minerals, with the same type of interstratification (ISII). As the mineralogical investigation showed the content of smectite layers in all illite/smectite structures is very small, less than 15%.

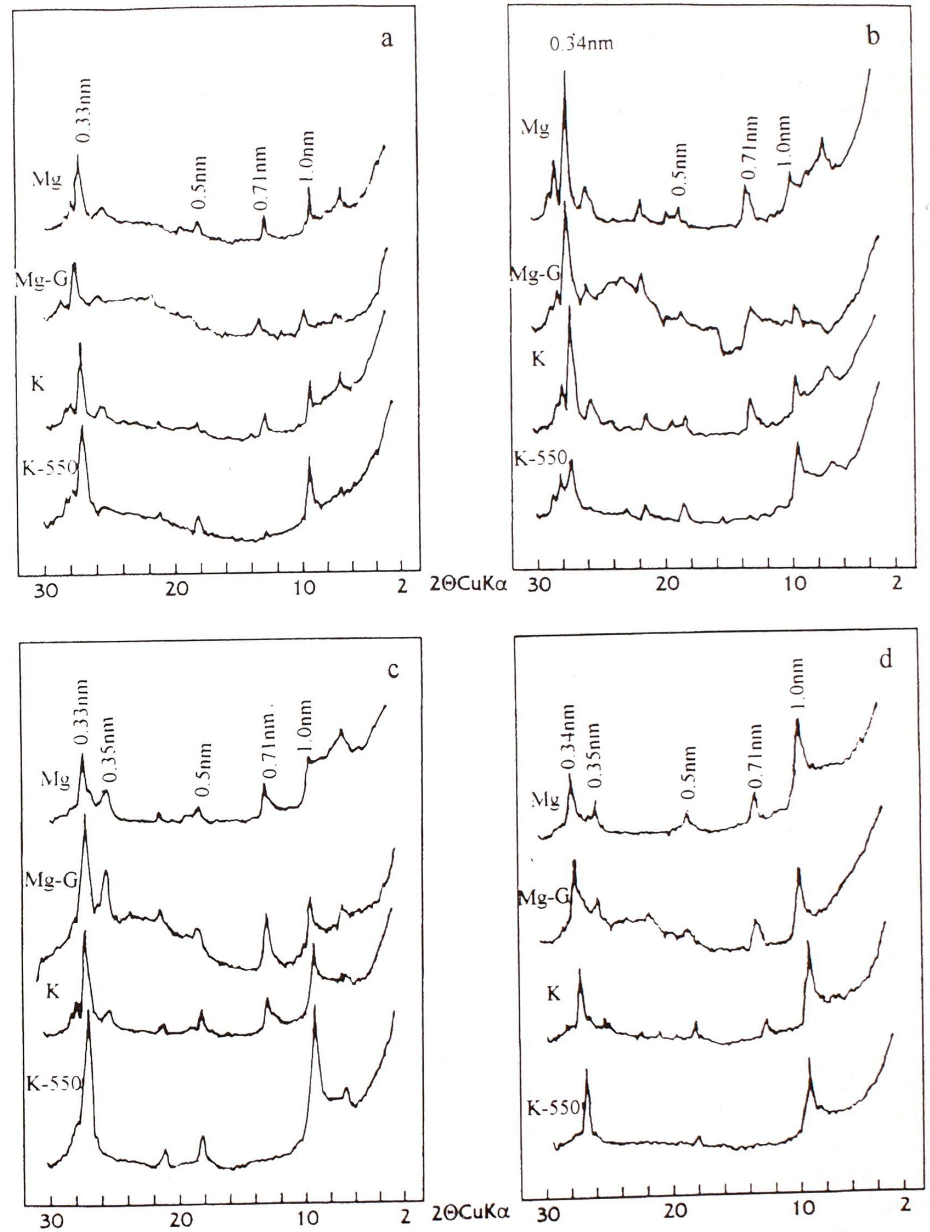

Fig. 2. X-ray diffractograms of clay fraction separated from pedon 3: a — A-horizon, b — E-horizon, c — B_t-horizon, d — C-horizon
Mg — Mg-saturated sample, Mg-G — Mg-saturated, glycol solvated sample, K — K-saturated sample, K-550 — K-saturated, heated at 550°C sample

TABLE 3

X-ray dofraction data for mixed-layer illite/smectite minerals

Pedon	Horizon	Reflections from glycolated preparations (° 2Θ CuKα radiation)					BB1*	BB2*	Ir*	% S**	Type illitic material
1	B_t	8.6	17.5	26.8	34.5	45.3	1.3	1.1	2.16	<15	ISII
	C	8.8	17.8	26.7	c***	45.5	2.3	2.8	1.75	<15	ISII
2	B_t	8.9	17.9	26.8	c***	44.8	1.9	c***	1.78	<15	ISII
	C	8.8	17.7	26.7	34.2	c***	1.7	3.05	1.50	<15	ISII
3	B_t	8.8	17.7	26.7	c***	45.0	c***	3.0	1.38	<15	ISII
	C	8.9	17.9	26.8	34.6	45.4	1.5	c***	1.05	<15	ISII

* Explanations in text.

** Content of smectite layers.

*** Coincidence with prism reflection (resulting from poor orientation).

The ISII type of interstratification and very low content of smectite layers (<15%) are typical of the highly illitic minerals (Reynolds, Hower 1970).

The mineralogical composition of soil clay fraction is the result of geological as well as pedogenic (soil forming) processes. The main component of analysed clay fraction is dioctaedral illite. The distribution of illite within soil pedons is rather uniform. The main reason for this similarity of composition is that investigated soils have been derived from the same glacial material. Other minerals present in minor amounts in soil clay fraction are: smectite, chlorite and kaolinite. The changes in distribution of soil minerals taking place during soil forming processes are represented by illuviation of smectite in Bt horizons. Relatively high mobility of smectite phase due to its fine size of crystallites in soil pedon is typical of lessive process.

Kaolinite is formed by intensive weathering of minerals (Allen, Fanning 1983) and is in relatively low amounts in analysed soils.

The presence of illite/smectite minerals in soils is the results of weathering of micas. It has been shown that the formation of swelling minerals from nonswelling minerals passes through a mixed-layer stage. For instance Droste and Tharin (1958) have shown that illite in glacial till gives rise to a mixed-layer illite/montmorillonite. According to Jackson (1965) removal of small amounts of the potassium from the interlayers of illite minerals are quite common in soils where weathering of illites progress through mixed-layer structures. However the degree of alteration is not high — the content of smectite layers is less then 15%. Similar structure of illite/smectite mixed-layer minerals and small amounts of smectite layers in altered minerals suggest that weathering process of illites towards smectites is not advanced in these soils; this also may confirm pedogenic uniformity of soil material.

CONCLUSIONS

1. Clay fraction of Alfisols from the Ziemia Dobrzyńska region consists mainly of illite type minerals; smectite, chlorite and kaolinite contents are very low.

2. Generally, the distribution of clay minerals within soil pedon is rather uniform. Soil pedogenic process (lessive) caused only the accumulation of smectite in the Bt horizon.

3. Among mixed layer structures the important component of clay fraction are mixed-layer illite/smectite ordered minerals, all with the same type of interstratification (ISII) and low content of smectite layers (<15%).

4. The mineralogical composition of clay fraction from Alfisols of the Ziemia Dobrzyńska region as well as the structure of mixed-layer illite/smectite minerals could be the evidence of uniformity and similar origin of investigated soils.

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IDENTYFIKACJA MINERAŁÓW ILASTYCH W WYBRANYCH GLEBACH PŁOWYCH ZE SZCZEGÓLNYM UWZGLĘDNIENIEM STRUKTUR MIESZANOPAKIETOWYCH ILLIT/SMEKTYT

Streszczenie

Zbadano skład mineralny frakcji ilastej (<2 μm) z gleb płowych z rejonu Ziemi Dobrzyńskiej, biorąc szczególnie pod uwagę minerały mieszanopakietowe

illit/smektyt. Głównym składnikiem frakcji ilastej jest illit ze znaczną zawartością struktur illit/smektyt. Zawartość smektytu, chlorytu i kaolinitu jest niewielka. Minerały typu illit/smektyt określono jako struktury uporządkowane typu ISII o niskiej zawartości pakietów smektytowych (<15%). Analizowana frakcja ilasta może więc być sklasyfikowana jako materiał o wybitnie illitowym charakterze.