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CHARACTERISTICS OF CLAY MINERALS IN BLACK EARTHS FROM KUJAWY REGION

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INTRODUCTION

Kujawy region is the area of good quality, high productive soils, formed from boulder loam of ground moraine. The dominated soil types in this region is typical black earth and black earth with cambic horizon. The investigation on genesis and physico-chemical properties of Kujawy black earths were carried on by Cieśla [1961, 1968] and his coworkers [Cieśla, Dąbkowska-Naskręt 1983; Cieśla, Kociałkowski 1973]. They concerned basic physical and chemical properties, as well as detailed study on heavy metal contents and chemical composition of clay fraction. Preliminary investigation on mineralogical composition of black earths were carried out, too.

The aim of the work was to characterize the mineralogical composition of clay fraction from the most commonly occurred soils in this region: typical black earth and black earth with cambic horizon, with the reference to soil transformation processes.

MATERIALS AND METHODS

Soil samples were collected from each horizon of black earths on Kujawy region. For the detailed mineralogical study, two soil pedons were selected: Płowce – where typical black earth occurs and Wybranowo – black earth with cambic horizon. These soils are formed from Quaternary glacial till of ground moraine.

The soil samples were air dried and sieved to remove coarse fragments (> 1 mm).

Clay fraction ($> 2 \mu\text{m}$) was separated following procedures described by Cieśla [1965]. Potassium and magnesium saturated samples were prepared for X-ray

diffraction analysis. The oriented specimens were prepared on glass slides and analyzed using CuK radiation and a HZG-4 X-ray diffractometer. The Mg saturated specimens were glycol solvated and reanalyzed by XRD.

Semiquantitative estimates were made using guidelines outlined in Brindley [1980].

The type of interstratification and expandability of illite-smectite minerals were determined according to Środoń [1984].

Some chemical and physical properties were determined according to commonly used methods: pH in H₂O and 1N KCl potentiometrically and the content of clay fraction according to Boycous and Cassagrande's method.

RESULTS AND DISCUSSION

The pH in H₂O increased with depth from 7.90 to 8.37 in Płowce pedon and from 7.72 to 7.85 in Wybranowo pedon. Organic carbon ranged from 0.62 to 1.86% and from 0.31 to 1.33%, respectively. The texture is loamy, with the clay content between 17 and 27% (Table 1).

Mineralogical analysis of the clay fraction indicated illite to be the dominant mineral (Table 2). Significant amounts of mixed-layer minerals (illite - smectite, chlorite-smectite) and chlorite was also detected. The main accessory minerals are smectite and kaolinite. The X-ray diffraction data obtained for analyzed samples are given in Figures 1–5.

Illite is rather uniformly distributed within soil pedons, however in the surface horizons a slightly higher amounts of this mineral was detected. The enrichment in illite minerals of top horizon may be caused by illitization process which occur due to the high content of potassium, added with potassium fertilizer.

TABLE 1. Physical and chemical properties of analyzed soils

Horizon	Depth [cm]	pH		C-org [%]	CaCO ₃ [%]	Content of < 2 μm fraction [%]
		H ₂ O	KCl			
Płowce						
Ap	10–15	7.90	7.38	1.86	0.8	17
A1	24–36	7.99	7.41	1.54	1.0	16
A/C	41–56	8.13	7.55	0.62	2.7	16
Cca	60–70	8.35	7.84	–	9.8	16
Ccag	90–100	8.37	7.86	–	12.4	23
Ccag	140–154	8.37	7.85	–	12.1	15
Wybranowo						
Ap	5–20	7.72	7.25	1.33	1.1	16
B1br	32–40	8.13	7.34	0.72	5.0	18
B2br	45–65	8.17	7.55	0.31	12.8	26
Cca	66–80	8.31	7.85	–	12.8	27
Ccag	80–90	8.21	7.51	–	14.3	26
Ccag	130–145	8.19	7.62	–	13.9	19

TABLE 2. The relative abundance of clay minerals in clay fraction of black earths from Kujawy region

Horizon	Depth [cm]	Illite	Smectite	Chlorite	Mixed-layer minerals ¹	Kaolinite
Płowce						
Ap	10–15	+++	+	++	++	tr
A1	24–36	+++	tr ²	++	++	tr
A/C	41–56	++	+	++	++	tr
Cca	60–70	++	+	++	++	tr
Ccag	90–100	++	+	++	++	tr
Ccag	140–154	++	+	++	++	tr
Wybranowo						
Ap	5–20	+++	tr	++	++	tr
B1br	32–40	++	+	++	++	tr
B2br	45–65	+++	tr	++	++	tr
Cca	66–80	++	+	++	++	tr
Ccag	80–90	++	+	++	++	tr
Ccag	130–145	++	+	++	++	tr

¹Mixed layer minerals: illite/smectite, illite/chlorite, chlorite/smectite;
tr. – trace

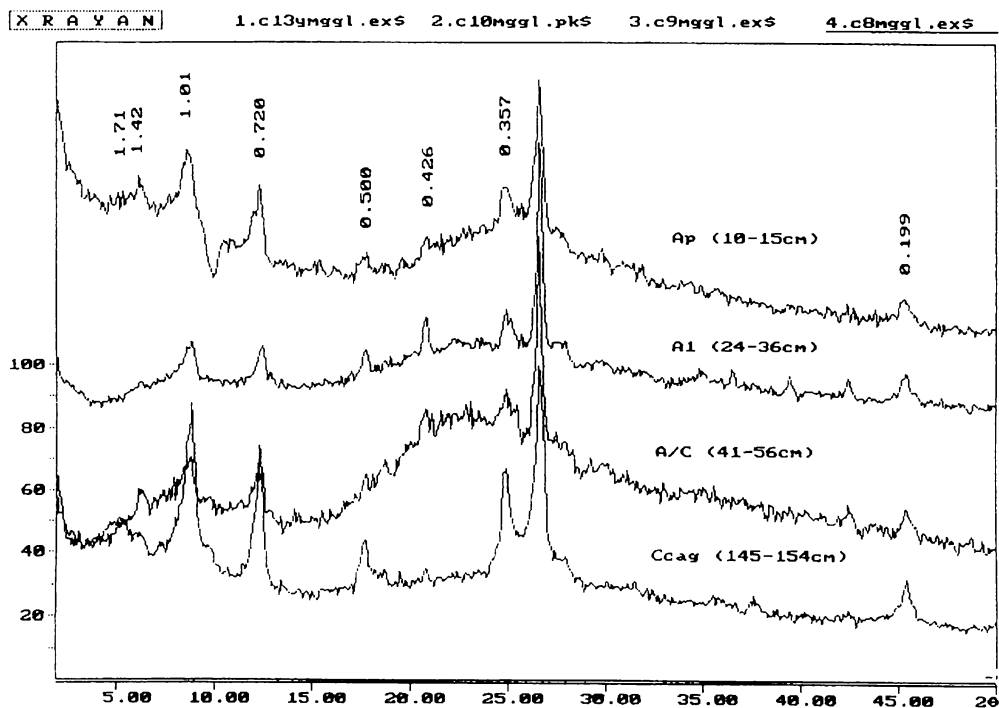


FIGURE 1. X-ray diffractograms of Mg^{+2} saturated, ethylene glycol solvated samples from all horizons of Płowce pedon

TABLE 3. X-ray diffraction data of mixed-layer illite-smectite minerals in investigated samples

Horizon	Depth [cm]	S ¹ [%]	Type ²	Selected reflections ³ [nm]
Płowce				
Ap	10–15	55	R	0.545; 0.278; 0.207
A1	24–36	–	–	
A/C	41–56	28	IS	0.526; 0.257
	41–56	33	IS	0.534; 0.204; 0.191
Cca	60–70	25	IS	0.524; 0.261; 0.203
	60–70	35	IS	0.921; 0.536
Ccag	90–100	47	R	0.905; 0.543; 0.272; 0.205
Ccag	140–154	58	R	0.549; 0.276
Wybranowo				
Ap	5–20	55	R	0.545; 0.279; 0.206
B1br	32–40	23	IS	0.523; 0.269; 0.202
	32–40	55	R	0.545; 0.270
B2br	45–65	15	ISII	0.513; 0.257; 0.201
	45–65	28	IS	0.525; 0.262; 0.202
	45–65	47	R	0.542; 0.279; 0.206
Cca	66–80	18	ISII	0.515; 0.260; 0.201
	66–80	24	IS	0.524; 0.262; 0.203
	66–80	30	IS	0.937; 0.264; 0.204
Ccag	80–90	32	IS	0.533; 0.266; 0.203
Ccag	130–145	60	R	0.897; 0.547; 0.276

¹content of smectite layers (%).

²type of interstratification: R – random, ISI – regular (20–50% smectite layers),

ISII – partially regular (15–25% smectite layers),

³reflections from glycolated preparations

Analyzed soils contain significant amounts of mixed-layer minerals, among them illite-smectite type structures dominate. The formation of mixed-layer minerals from micas has been explained by Jackson et al. [1948] as being due to the removal of potassium from silicate layers. It has been shown that the formation of swelling minerals from nonswelling minerals passes through a mixed-layer stage [Droste, Tharin, 1958]. In analyzed soils mica has partially weathered to illite-smectite. Illite-smectite minerals differed quite markedly in the content of smectite layers and the type of ordering. The content of smectite layers in mixed-layer illite-smectite type silicates is shown in Table 3.

Clay fraction separated from the surface soil and a parent material contain randomly ordered illite-smectite. The surface samples gave an asymmetrical reflection at 16,23–16,24 2 θ and a peak at 32,07–32,10 2 θ , characteristic for illite-smectite minerals. These reflections were detected in diffractograms A1 horizon of typical brown earth from Płowce (Fig. 1)

The highest content of smectite layers in illite-smectite structures were present in the deeper soil parent material (Ccag) up to 60% – Table 3, Figure 2. Thus, in these samples the process of removal of potassium from silicate layers is the most

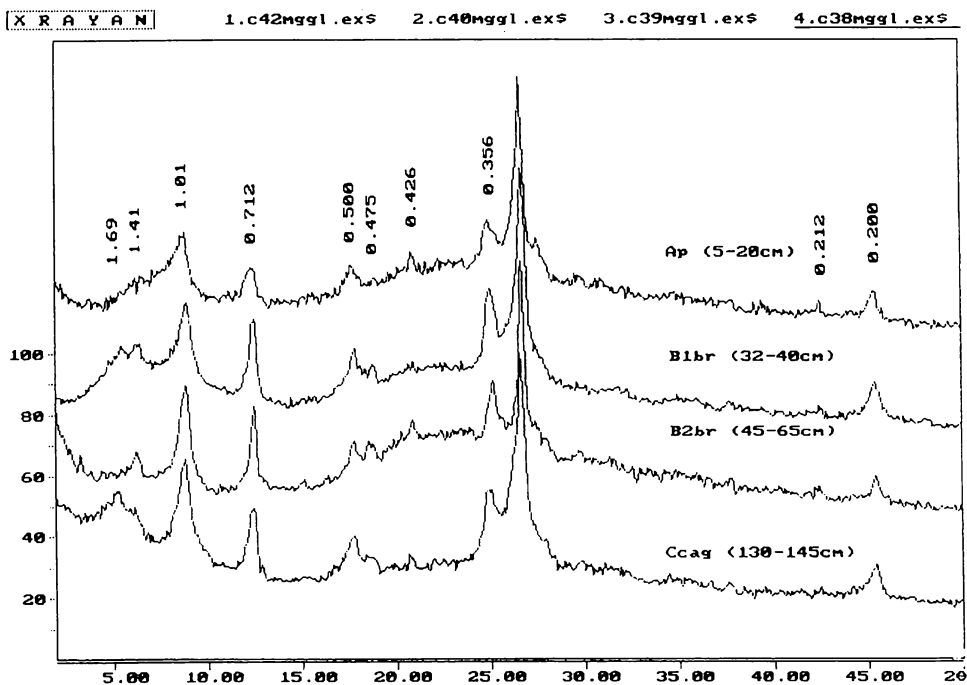


FIGURE 2. X-ray diffractograms of Mg^{+2} saturated, ethylene glycol solvated samples from all soil horizons of Wybranowo pedon

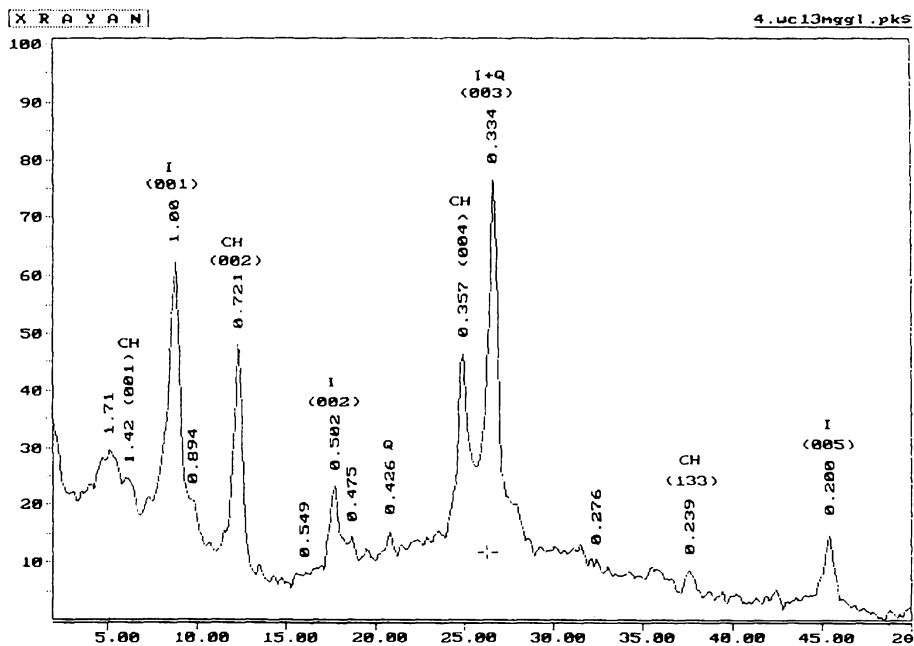


FIGURE 3. Characterization of X-ray reflections of Mg^{+2} saturated, ethylene glycol solvated sample from C_{cag} horizon (140–154 cm) of Płowce pedon

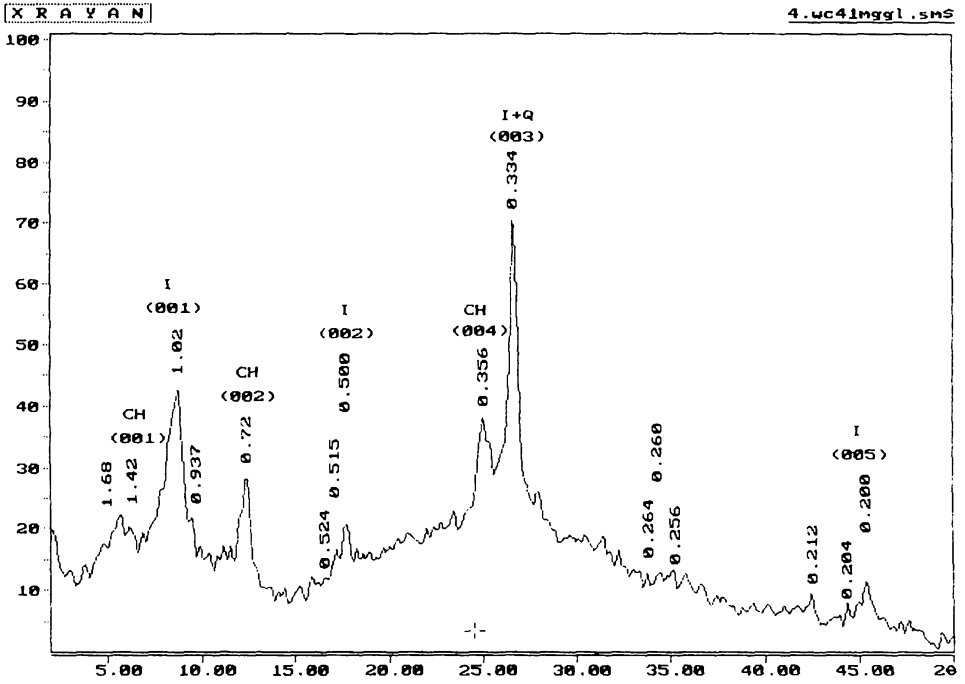


FIGURE 4. X-ray diffractogram of Mg^{+2} saturated, ethylene glycol solvated sample from C_{Cag} horizon (66–80 cm) of Wybranowo pedon

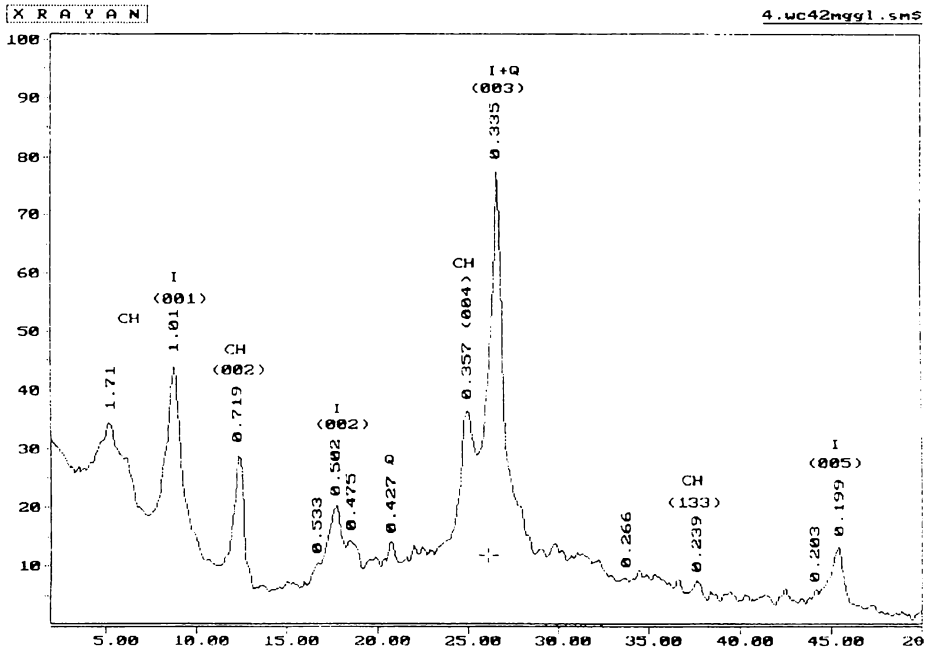


FIGURE 5. X-ray diffractogram of Mg^{+2} saturated, ethylene glycol solvated sample from C_{Cag} horizon (80–90 cm) of Wybranowo pedon

advanced, compared to other horizon of this pedon. The interstratification of illite-smectites in Ccag horizon is random.

The main effect of weathering on the clay fraction of the brown earths of temperate regions is partial removal of interlayered potassium from micas to form interstratified mica-montmorillonite [Catt 1986]. Appearance of the 1.4 nm reflections indicates that the mica has partially weathered to illite-smectite.

The interstratification of illite-smectite minerals in Bbr horizon, A/C horizon and a top of parent material is regular (IS or ISII) – Figure 4.

The frequent broadening of X-ray diffraction peaks in near-surface horizons of investigated soils also suggests a decrease in the particle size of some clay components or increased structural disorder within clay particles.

On the base of results, there were no differences observed in clay mineralogy of typical black earths and black earths with cambic horizon. The only difference noticed in clay mineralogy is a slightly higher content of illite in cambic horizon, compared to other soil horizons in Wybranowo pedon.

CONCLUSIONS

1. On the base of X-ray diffraction analysis of clay fraction separated from black earths, it was stated the dominant mineral is illite. Significant amounts of mixed-layer minerals (illite-smectite, chlorite-smectite) and chlorite was detected. The main accessory minerals are smectite and kaolinite.
2. The clay fraction from analyzed soils contains a mixture of illite-smectite minerals. The contents of smectite layers in these minerals differs from 15 to 60%.
3. There was no differences observed in mineralogical composition of clay fraction from typical black earth and black earth with cambic horizon.

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CHARAKTERYSTYKA MINERAŁÓW ILASTYCH W CZARNYCH ZIEMACH KUJAWSKICH

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STRESZCZENIE

Region Kujaw obejmuje swoim zasięgiem obszar zasobnych i żyznych czarnych ziem, charakteryzujących się wysoką produktywnością rolniczą.

Wieloletnie badania nad genezą i właściwościami fizykochemicznymi czarnych ziem kujawskich prowadzone były przez Cieślę i in. [Cieśla 1961, Cieśla 1968; Cieśla, Kociołkowski 1973; Cieśla, Dąbkowska-Naskręt 1983].

Celem niniejszej pracy jest charakterystyka składu mineralogicznego frakcji ilastej dwóch podtypów czarnych ziem: właściwej i zbrunatniałej. Analiza składu mineralogicznego metodą rentgenograficzną wykazała, że dominującym minerałem we frakcji ilastej jest illit. Stwierdzono też znaczące ilości minerałów mieszanopakietowych oraz chlorytu. Spośród minerałów mieszanopakietowych dominowały struktury typu illit-smektyt. Minerale te charakteryzowały się zróżnicowaną zawartością pakietów smektytowych.

Nie stwierdzono różnic między składem mineralogicznym frakcji ilastej czarnej ziemi właściwej i czarnej ziemi zbrunatniałej.

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