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Clay minerals from Weichselian glaciolimnic sediments of the Sępopolska Plain (NE Poland)

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Abstract: Glaciolimnic deposits sampled from three sedimentation reservoirs located on the Sępopolska Plain (north-eastern Poland) were investigated. The material under study was deposited in the recession phase of the Pomeranian phase of Vistula (Weichselian) glaciation. The clay fraction was separated by centrifugation after preparation according to Jackson. Mineralogical investigations were done by X-ray diffraction. The analysed deposits had a similar complex composition of clay minerals. The main components were illites mixed with the illite/smectite mineral with percentages < 10 % S. Another part were minerals of the illite/smectite type which had differentiated content of smectite layers (mainly 80–90 % S). There were also chlorite minerals, probably as mixed layer minerals of the chlorite/vermiculite type or HIV with a negligible amount of chlorite layers. The results indicated that all the deposits were of the same age as well as similar deposited material and the samples are different from typical Pomeranian till and typical limnic material of the same age. Small differences observed among the deposits of specific sedimentation reservoirs were probably the result of later processes.

Key words: Late Pleistocene, north-eastern Poland, glaciolimnic sediments, clay minerals.

Introduction

Young glacial areas of northern Europe with diversified surface features are covered with different materials, such as till, limnic and fluvioglacial materials (Björck & Möller 1987; Ringberg & Erlström 1999; Krzywicki 2002; Ber 2006). Apart from diversification due to the deposition process those materials underwent transformations during the post-deposition period, which of course affected their properties. It can be seen both in their morphological, granulometric and petrographic properties, as well as in the mineralogical composition of their clay fraction. As has been proved by numerous researchers, clay minerals contained in that clay fraction of limnic, glacial and glaciolimnic materials can be an index for the origin of those materials; as well as processes in which they transformed during the post-deposition period (Stankowska 1979; Peuraniemi et al. 1997; Ringberg & Erlström 1999; Kalinenko 2001; Dlugosz 2002).

The objective of this study was to determine and compare composition of clay minerals from glaciolimnic materials of various sedimentation reservoirs. Another aim was to compare the set of clay minerals of a glaciolimnic deposit with a limnic and glacial deposit of the same age.

Material and methods

The study site is located on the Sępopolska Plain (north-eastern part of Poland), a southern part of the Staropruska Lowland. It is a basin 40–50 m high in the central part and 80–100 m near the edges (Kondracki 2000). The major part of this area is covered with very diversified glacial till deposited over the Pomeranian phase of the Vistula (Weichselian) glaciation period (Ber 2006) and also fluvioglacial and limnic created during the continental ice-sheet recession of the Pomeranian and Holocene phases. On a large area of the Sępopolska Plain, the top part of the glacial till becomes glacial clay because of outer-layer variety that was deposited in water through small short-lived water ponds. These ponds existed on the continental ice-sheet forefield as a result of lack of possibilities of glacial water runoff (Slowinski 1975). The thickness of these deposits usually reaches several meters.

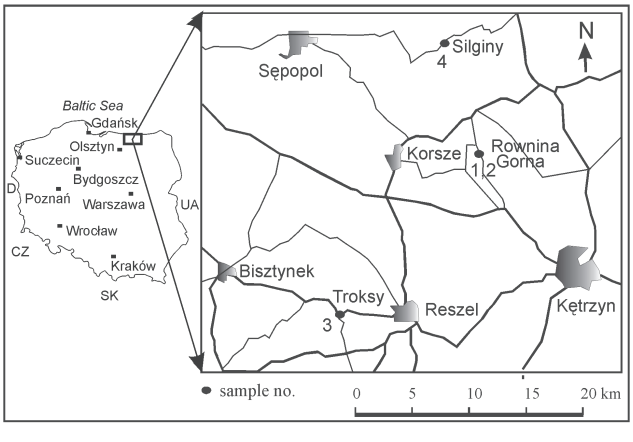

Fig. 1. Localization of the investigated samples.

Table 1: Texture and pH of the investigated samples.

Sample number	Particle-size fraction (mm)							Texture*	pH	
	2–1	1–0.5	0.5–0.25	0.25–0.1	0.1–0.05	0.05–0.002	< 0.002		H_2O	KCl
1	0.0	7.0	14	3	6	32	38	CL	7.2	6.1
2	0.0	4.0	2	2	7	51	34	SCL	7.0	6.2
3	0.0	1.0	5	3	15	48	31	CL	7.5	6.9
4	0.0	0.0	0	1	2	19	78	C	6.8	6.1

* — texture according to USDA classification.

Four samples of glacial clay were collected for mineralogical analyses. The sampling sites were located near the following villages: Rownina Gorna — 54°10′48.3″ N, 21°14′9.10″ E (samples 1 and 2), Troksy — 54°03′16.4″ N, 21°04′22.0″ E (sample 3) and Silginy — 54°15′51.0″ N, 21°12′22.0″ E (sample 4) (Fig. 1). The samples represented 3 separate basins where the deposition took place. The sampling was done at the depth of about 1 m where no influence of pedogenic processes were observed. As for their texture, we analysed it according to the USDA classification. The samples represented different textures and were finally classified as: samples 1 and 3 — clay loam, sample 2 — silt clay loam, sample 4 — clay. The full particle size data of the analysed samples are given in Table 1. The pH of the samples varied little, and did not exceed the range 6.1–7.0 (Table 1). All the samples were gleyed. This process was found strongest in the case of sample 4.

The clay fraction (<2 μm) for mineralogical investigations was separated by the Beckman centrifuge after dispersion with Na-ionite (Amberlite 120) (Gonet & Ciesla 1988). Prior separation of the samples was done according to Jackson's method (Jackson 1975) that was used to get rid of peptizing components ($CaCO_3$, organic matter and free iron oxide). The mineralogical composition of the clay fraction was assessed by X-ray diffraction using the HZG — 4 instrument with a CuKα lamp and nickel filter. For this analysis, samples of specific fractions were saturated with Mg^{2+} ions (Mg), then solvated with ethylene glycol (Mg+EG), and K^+ ions. Next, the samples were heated to 300 and 550 °C. These were oriented preparations obtained from a water suspension by sedimentation. The results were used for qualitative analysis, as well as the mixed layer minerals illite/smectite structure as described by Srodon (1980, 1981, 1984). The fitting of the experimental data was done using ORIGIN 7.0 software, which similarly to Lanson's DECOMPXR software, is based on the Gauss and Lorentz functions (Lanson & Velde 1992). The programme reconstructed single peaks by fitting the envelope curve of overlapping peaks.

Results

The mineralogical analysis of the clay fraction (<2 μm) from the glaciolimnic materials under study, showed very complex compositions with a great deal of similarity. The main minerals were illite minerals which were mixtures of illites and illites/smectites with a low content of smectite layers (up to 20 %). It was demonstrated as the calculated Ir index (Ir = the intensity ratios of 001 and 003 reflections from the air-dried and glycolated samples) (Srodon 1984). This was demonstrated as reflexes 1.00, 0.500 and 0.334 nm in preparates saturated with magnesium ions (Mg^{2+}). They

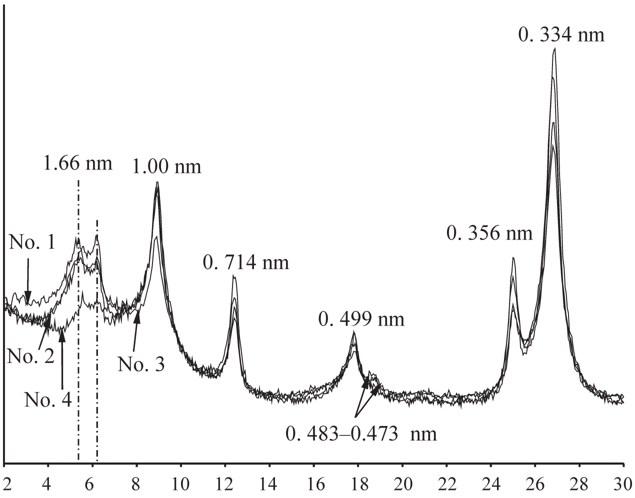

Fig. 2. X-ray diffractograms of the clay fraction of the analysed samples saturated with Mg^{2+} and solvated with ethylene glycol (EG).

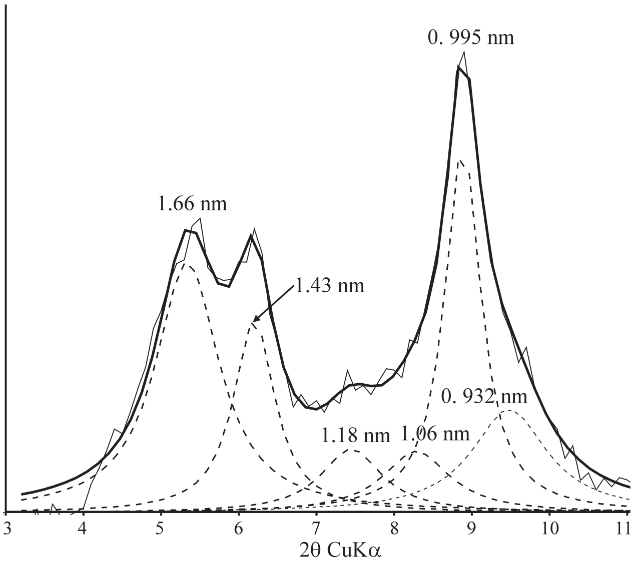

Fig. 3. X-ray diffractogram of the clay fraction of sample No. 3 (from Troksy) saturated with Mg^{2+} and solvated with ethylene glycol (EG) in the range 3–11° 2θ CuKα. Bold line represents the fitted envelope curve, broken line — reconstructed picks, while fine full line represents experimental data.

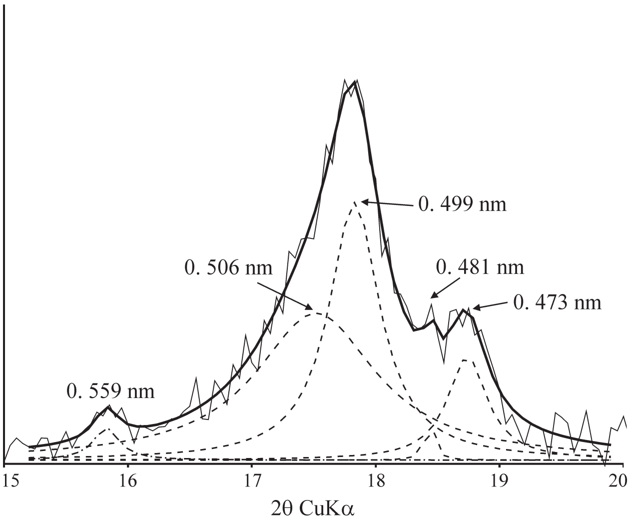

Fig. 4. X-ray diffractogram of the clay fraction of sample No. 2 (from Rownina Gorna) saturated with Mg^{2+} and solvated with ethylene glycol (EG) in the range 15–20° 2θ CuKα. Description as in Fig. 3.

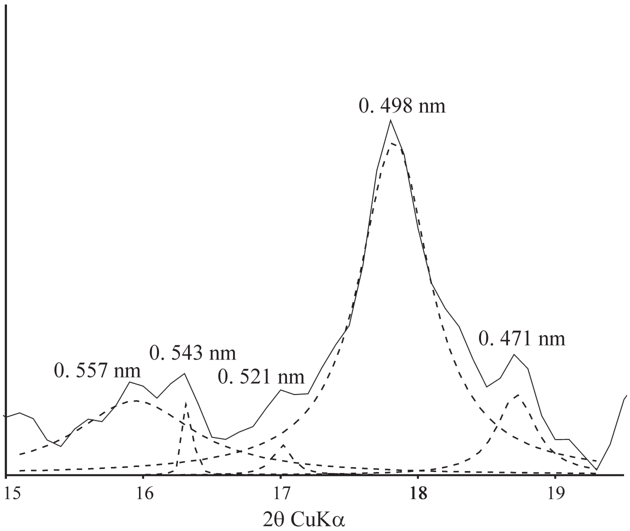

Fig. 5. X-ray diffractogram of the clay fraction of sample No. 3 (from Troksy) saturated with Mg^{2+} and solvated with ethylene glycol (EG) in the range 15–20° 2θ CuKα. Description as in Fig. 3.

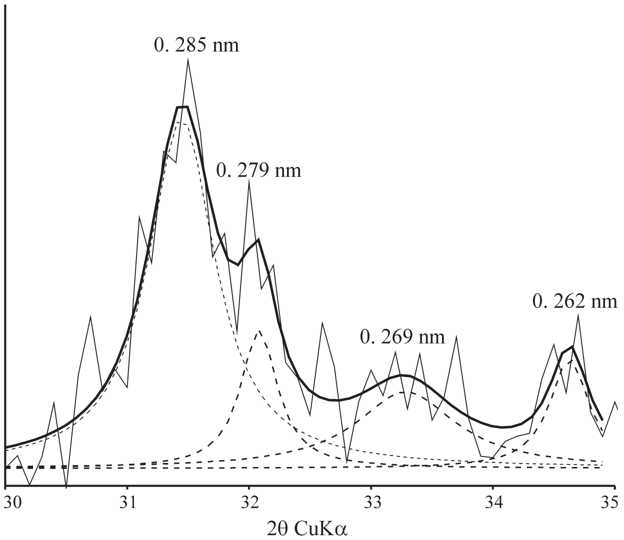

Fig. 6. X-ray diffractogram of the clay fraction of sample No. 2 (from Rownina Gorna) saturated with Mg^{2+} and solvated with ethylene glycol (EG) in the range 30–35° 2θ CuKα. Description as in Fig. 3.

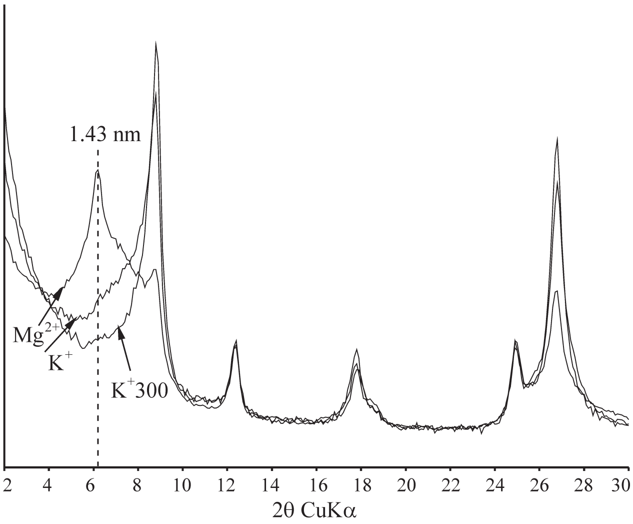

Fig. 7. X-ray diffractograms of the clay fraction of the sample No. 3 (from Troksy).

were shifted from 1.00 to 0.998 nm (001) and from 0.500 to 0.498–0.499 nm (002) in magnesium preparations solvated with ethylene glycol (Mg^{2+}+EG) (Fig. 2). Another component also found in the samples was highly concentrated swelling minerals, such as smectites characterized by thinner layers or mixed-layer minerals of the illite/smectite type containing 80–90 % of smectite layers. Swelling minerals occurred in the clay fraction separated from all the analysed samples. Their presence was recorded as reflexes 1.66–1.67 nm (Figs. 2, 3), 0.932 nm (Fig. 3), 0.559 (Figs. 4 and 5) and 0.279–0.281 nm (Figs. 6 and 7) in the Mg^{2+}+EG preparations. In addition, reflexes indicating the existence of minerals from the illite/smectite type of 80–90 % S in some of the investigated clay fractions reflexes 0.521 nm (Fig. 5) and 0.262 nm (Fig. 6) were recorded probably coming from illite/smectite minerals of 20–25 % S (samples 1 and 3) as well as reflexes 0.506 nm (Fig. 5) and 0.245 (Fig. 6) suggesting the occurrence in samples 1 and 2 of minerals of the illite/smectite type of 15 % S.

The third main component of the clay fraction for the samples under study was minerals containing vermiculite layers with a small amount of chlorite minerals. A very small reflex 1.43 nm in the K^+ and K^+300 (Figs. 7, 8) preparations indicated a negligible amount of pure chlorites. The occurrence of mixed-layer minerals containing chlorite layers was demonstrated as reflexes recorded within the range 0.473–0.483 nm in the Mg^{2+}+EG preparations (Figs. 2 and 4). Probably these were mixed-layer minerals of the chlorite/vermiculite type with a high but diversified amount of vermiculite or hydroxy-interlayered vermiculite (HIV) layers. The latter conclusion was based on the observation that the shift of the reflex from the 001 band identifying that compounds in the K^+ and K^+300 preparations did not come to 1.00 nm in full, allowing a broad reflex in the range 1.4–1.1 nm (Figs. 7 and 8) (Barnhisel & Bertsch 1989; Pai et al. 2004). An additional observation supporting this conclusion was a lack of the reflex at 0.7 nm in the K^+550 preparation. The broadening of the reflex in those preparations was also caused by the presence of minerals of the illite/smectite type in the clay fraction because minerals of this kind undergo natural collapsation (Jackson 1963). There was no chance for the occurrence of the chlorite/smectite type because in the Mg^{2+}+EG preparations there were no reflexes of the 0.714–0.852 nm range that corresponded to the 002 band minerals of this type. Kaolinites were present in all the samples as accessoric minerals, what was shown as a reflex at d = 0.234–0.238 nm and the lack of the reflex at 0.7 nm in the K^+550 preparation (Fig. 9).

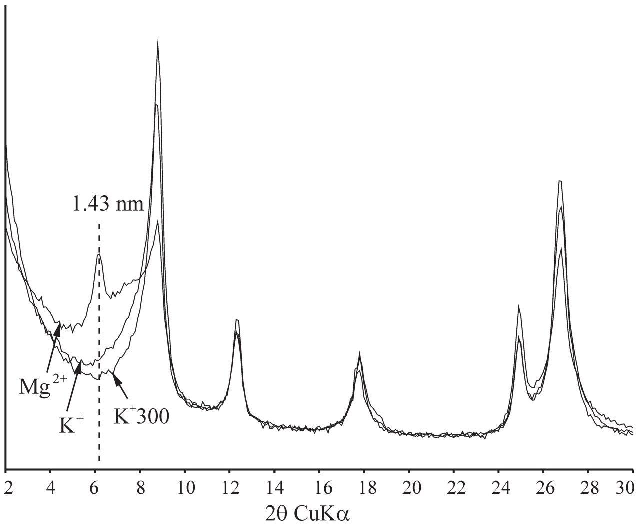

Fig. 8. X-ray diffractograms of the clay fraction of sample No. 4 (from Silginy).

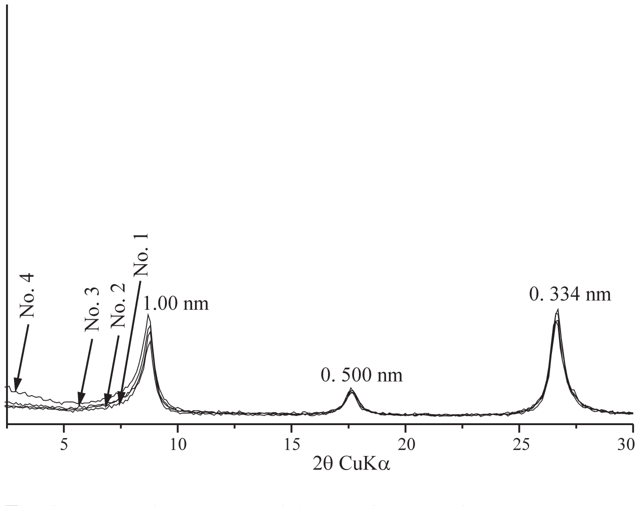

Fig. 9. X-ray difractograms of the clay fraction of analysed samples saturated with K^+ and heated to 550 °C.

Discussion

Despite the origin of separate sedimentation basins, the mineral composition of the clay fraction from the glaciolimnic material under study showed a high similarity. The main components identified were mixed layer minerals of diversified structure as well as illites mixed with well-ordered minerals (IS) of the illite/smectite type (less than 10 % S). Minerals of the illite/smectite type from various contents of smectite layers (ranging 80–90 % S) as well as chlorite/vermiculite from the vermiculite layers, superiority dominated in the group of mixed-layer minerals. In addition, the presence of partly-ordered minerals (IS/ISII) from the illite/smectite type (20–25 % S) was observed in the material sampled at Rownina Gorna and Troksy, as well as well-ordered of the IS type (about 15 % S) in the deposit of Rownina Gorna. Only the clay fraction from Silginy did not contain minerals of the illite/smectite type with a low content of smectite mixed layers. The latter composition was very clearly different from the mineral composition of the glacial material (till) from the Pomeranian phase of the Drawskie Lake District. This lake region is known for showing a high content of illite minerals in the clay fraction without vermiculite minerals, accompanied by a very small percentage of smectite layers (Dlugosz 2002). Glaciolimnic material from south-eastern Sweden deposited in the late Weichselian glaciation period investigated by Ringberg & Elström (1999) also contained a clay fraction composed of a high percentage of illite without traces of vermiculite layers, whereas, material of the glacial till from northern Finland analysed by Peuraniemi et al. (1997) and by Soveri & Hyyppä (1966) (glacial clay of southern till from Finland) demonstrated a high content of vermiculite of chlorite layers. However, the comparison of the percentage from smectite layers in the studied material showed that it was similar to glacial deposits of the Poznan and Leszno phase of the Weichselian glaciation period (Stankowska 1979; Dlugosz 2002). The results indicated that the main minerals in the composition of the clay fraction of the deposits under study are the residues of the parental materials of that sediment. The lack of effects of post-sedimentary processes was confirmed by a poor acidity of the investigated material, which does not promote the development of vermiculite layers. These minerals are formed over the process of the leaching of alkaline ions at much lower pH (4–5) (Vincente et al. 1977; Katarhansis 1988; Matsue & Wada 1989). Another reason that these minerals did not occur in glaciolimnic sediments was a lack of oxidoreductive conditions, necessary for their creation because these conditions provide the Fe^{3+} ions composing them (Vincente et al. 1977; Douglas 1989). That is why mixed-layer minerals containing vermiculite layers found in the clay fraction of the glaciolimnic deposits under study could be chlorited vermiculites developed during weathering of biotite in the sequence biotite → vermiculite → chlorited vermiculite (Barnhisel & Bertschel 1989) or minerals of the chlorite/vermiculite type could be an intermediate product in the transformation of detrite chlorites to smectites (Senkayi et al. 1981). However, mixed-layer minerals of the illite/smectite type can already be the product of diagenesis of glaciolimnic material. During this process illites occurring in the sediment underwent depotassication, which could be promoted by the reaction of pH 6–7 assayed in that sediment (Ismail 1970; Crawford et al. 1983).

Conclusions

The results showed a high uniformity of the clay fraction in the glaciolimnic material from the deposit basins under study. The composition of the clay fraction of those deposits indicated that it was formed mainly from the glacial material (till) of the Poznan phase of the Weichselian glaciation. The remaining part was constituted of the very fine limnic material of the Pomeranian phase. A small variability among the samples of specific basins was caused by the processes forming smectites during the post-sedimentation period. However, the assessed composition of the clay minerals suggested an origin of the investigated materials different from typical Pomeranian glacial till as well as typical limnic material from the same age. However, it should be clearly stated that our conclusion for these differences needs further study on the mineralogical composition of the clay fraction of minerals, both from this type and typical glacial till and limnic clay from the Staropruska Lowland.

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