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Chapter III

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Soils of the Drawskie Lake District Formed from Glacial Till

GEOMORPHOLOGICAL CHARACTERISTICS

The Drawskie Lake District is one of the most beautiful regions in Poland with many touristic and recreational values. In the area there are a lot of lakes and forests; whereas, arable lands occur in minority and most of them are persistence grasslands [KONDRACKI 2001]. The District is a mesoregion belonging to the Central European Lowland, the South Baltic Lake District sub-region and the West Pomeranian Lake District macroregion. The region with an area of 1861 km^2 northerly borders the Lobez Plateau; easterly the Gwda Valley, the Bytowskie Lake District and the Polonowska Plateau; in the west the Ińskie Lake District; while in the south it joins with the Wałecka Plain, the Wałeckie Lake District and the Drawska Plain [[KONDRACKI 2002]. This area relief is very differentiated. It is indicated by significant denivelations. The highest differentiation is shown by the plateau areas which appear at 170-190 m above sea level (asl) and in some other places it exceeds 200 m asl, for example: Wola Mountain – 219,3 m asl: Kukółka Mountain – 206.2 m asl; Spyczna Mountain – 203.2 m asl [KŁYSZ 1990]. Whereas, the most even region is the area of the Drawa outwash plain and Złocieniec ice marginal basins [KŁYSZ 1990]. Its main elements are glacial and fluvioglacial forms formed during the Pomeranian phase of the main Vistulian glaciations stage (about 16 kBa), [KOZARSKI 1995]. There is especially high controversy among geomorphologists about the south Lake District border since it is connected with the marginal Pomeranian zone. In 1901 Keilhalck marked the border on the marginal moraines running from Drawsko Pomorskie north in the direction of Połczyn Zdrój across Ostrowice and Ciemienko [KŁYSZ 2001]. This opinion, according to KŁYSZ [2001], was later accepted by other researchers, Galon, Bartkowski, Kozarski and Karczewski among others. A different opinion about the Pomeranian phase range on the area was introduced in 1978 by MAKSIAK and MRÓZ [1978], who transferred its border south of Czaplinek. According to the mentioned above authors the range was marked by the moraine hills running from Kalisz Pomorski by Zabinek and Broczyno in the direction of Liszkowo [MAKSIAK, MRÓZ 1978; MAKSIAK et al. 1978]. It was confirmed by other studies carried out by KŁYSZ [1990, 1995, 1996, 2001] focused on lithographic-morphological research of the area. On the grounds of the research the author stated that the indication of maximum range of the Pomeranian phase continental glacier on the studied area is the sequence of frontal, bouffant moraines, running along the axis above given, while marginal forms considered formerly as the maximum of transgression are frontal ablacial moraines as a prove for the lively ice edge stabilization during deglaciation [KŁYSZ 2001], (Fig. 1).

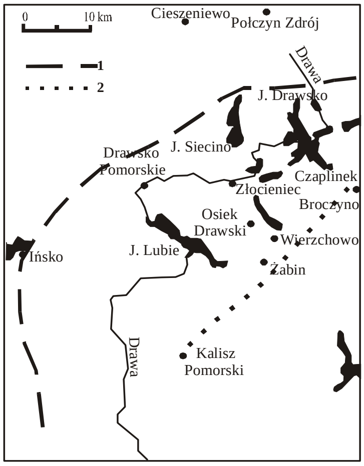

Fig. 1. The range of marginal Pomeranian phase at the Drawskie Lake District
(KŁYSZ 2001), 1 - the range appointed by Keilhalck in 1901
2 - the range appointed by Maksiak and Mróz

The continental glacier transgression on the Drawskie Lake District had a lob character and the area relief according to GALON [1972] was formed under two glacial lobs (Rega and Parsęta). The deglaciation occurring on the Drawskie Lake District had differentiated and complex course. On some areas it was frontal disintegration, which was proved by the occurrence of the ground moraine, outwash plain and limnic sediments, while there was areal decay on the others, indicated by the kames, kameic terrace and dead–ice moraine [KŁYSZ 1990]. The dead-ice blocks appearance during the areal deglaciation was gradual and lasted thousands of years [DOBRACKA, LEWANDOWSKI 2002]. In connection with so complex geological structure, varied relief [LEWANDOWSKI et al. 2006a) and related differentiated parent material of the Drawskie Lake District soil cover is also very diversified. According to the soil map in a 1:100 000 scale on the Drawskie Lake District area Eutric Cambisols or Distric Cambisols soils dominate, which occur on the area covered by the till formation. On the basis of these compositions

Luvisols were developed as well, while on the outwash plains and kames areas Podzols and Brunic Arenosols are predominant [PECIO, KERN 1979, 1979a]. Sandy soils are afforested, while loamy soils are used agriculturally.

SOME CHARACTERISTIC PROPERTIES OF GLACIAL TILL

Very few studies have concentrated on physico-chemical parameters as well as mineralogical composition of clay fractions of tills of the studied region and soils formed of them. The first research on these parameters was conducted within the confines of the research project 819/P06/97/12 “The influence of lessive processes on mineralogical composition of the clay fraction in Luvisols formed of glacial till of different origin.” At present the research is being continued within the confines of the research project 0531/B/PO1/2008/34 “Differentiation of clay minerals composition and their transformations in soils formed from acid glacial till of the Drawskie Lake District. “ realized by the authors. The project includes particle-size research, basic physico-chemical parameters (organic carbon, $CaCO_3$, actual and exchange acidity, soil exchange capacity, exchangeable cations), mineralogical research of clay fraction (<0.002 mm) and fine clay fraction (<0.0002 mm) and they include the quality analysis of clay minerals and the analysis of mixed layers minerals structure.

The objective of the research are soils formed from the Pomeranian stage glacial till localized in the south part of the Drawskie Lake District between Złocieniec and Czaplinek (Fig. 2). The choice of soil profiles was conducted on the base of a detailed geological map of Poland in the scale 1:50000 (sheet Czaplinek), [LEWANDOWSKI et al. 2006a). The present paper is an attempt of characterization of Pomeranian glacial till as the parent material and soils formed from it. Moreover, the aim of the work is the initial verification of classification of these soils on the basis of modern standards. The Pomeranian glacial till thickness found by KŁYSZ [1990, 2001] and DOBRACKA [2008] among others was very differentiated and ranged from 0.5 – 20 m. It was also confirmed by drills and profiles carried out by the authors of this publication where the minimal thickness of the sediment accounts for 1.2 m, while the maximum was higher than 2.5 m (the maximum profile depth). In most cases it was the carbonate-free till, which was shown by DŁUGOSZ [2002], KŁYSZ [1990, 2001], POPIELSKI [2005], DOBRACKA, [2008] and LEWANDOWSKI et al. [2008] in the top part, i.e. down to the depth of 5 m.

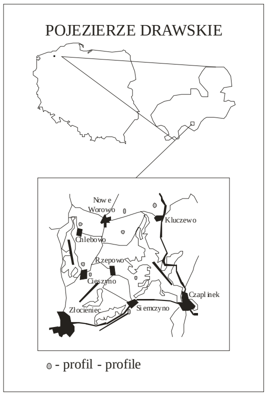

Fig. 2. The area of the investigation with soil profiles localization

The exception was the till from the Cieszyno profile where the $CaCO_3$ content ranged from 9.0–9.5%. A somewhat higher calcium carbonate content (11%) was reported by DOBRACKA [2008] in the neighbourhood of the Drawsko Pomorskie in the floor part of Pomeranian till. Also GORALSKA [1953] found that $CaCO_3$ concentration in the till from the same area was 15-17%. Similarly, the tills of the Pomeranian stage from West Pomerania contained calcium carbonate [KOĆMIT et al., 2008]. It confirmed that the lack of carbonates in those tills is not original and is the result of leaching process which took place in the post-depositional period. The decalcification which was the effect of that process could cause an increase of weathering intensity. It could be shown by a high and varied free iron content (3.2-8.8 $g \cdot kg^{-1}$), which was similar to the amount occurring in the elder tills, e.g. the Warta [DŁUGOSZ 2002, KUŻNICKI et al. 1979] and Poznań type [DĄBROWSKA et al. 1999]. Another result of that process is lower contribution (5.6–17.1%) of limestone fragments in the petrographic composition of the gravel fraction of younger tills [KŁYSZ 1995, 2001]. The colour of the tills determined under moist conditions ranged from yellow-grey to olive-brown (10YR 5/4–10YR 4/4). However, morphologically the tills showed a high mosaic pattern which was caused by spotted gley. The spots of gley had different sizes and intensification, which undoubtedly affected the formation of the colour. Numerous oxidized iron lens occurred also within parent material. The colour mosaic pattern of the till from the area under study was confirmed by the author of geological maps of the region [DOBRACKA 2008, POPIELSKI 2005, LEWANDOWSKI et al. 2006]. In some profiles, vertical, strong gleing inserts of strongly sandy loam long for 60 – 80 m were observed. It could be the ice-wedges, the presence of which in the top part of the till was confirmed by POPIELSKI [2005] who investigated tills from the neighbourhood of Barwice.

In regard to the texture the tills of the area under study were numbered to sandy loam and loam (according to USDA 1999). In the same way they were classified by geomorphologists who studied the area [KŁYSZ 1990, 2001, LEWANDOWSKI et al. 2006, 2008, DOBRACKA 2008]. Similarly, the clay index for the tills obtained by the authors ranging from 0.18-0.21 is similar to the one given by KŁYSZ [2001]. The quantity index of the investigated tills of the Pomeranian glaciation is much lower than elder tills of the Warta and Poznan type. The analysis of the tills texture under study showed that sandy fractions had the highest participation (mean percentage 56.7%), (Fig. 3).

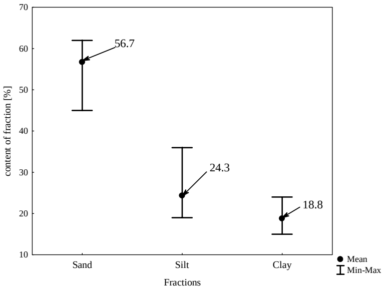

Fig. 3. The range and the mean of fractions in Pomeranian till of area under study

The fine sand dominated among the sandy fractions (0.25 – 0.1 mm). The clay fraction is the most important till fraction as for the influence on physico-chemical properties. The till from the Drawskie Lake Districtict region contained from 15 to 24% of clay fraction with an average value of 18.8% (Fig. 3). This kind of texture is characteristic for the second till type, which according to Racinowski [1969] is characterized by two main fractions. The contents obtained are similar to those given for glacial tills of the Pomeranian phase from West Pomerania [KOĆMIT et al. 2008] and Poznań phase investigated by DŁUGOSZ [2002], DZIERŻKA and OLSZEWSKA [1996], GAJEWSKI et al. [2007] and JAWORSKA et al. [2008].

Significant differentiation in the clay fraction content reflected a wide range of cation exchange capacity (CEC) of the studied district which ranged from 9.2 to 21.6 cmol(+)· kg^{-1}. The values of the CEC are close to the one determined for the Poznań phase till of the Inowrocław Plain [KOBIERSKI, DĄBKOWSKA-NASKRĘT 2005, KOBIERSKI, et al. 2005]. Those values were smaller (4.96–8.96 cmol(+)·kg^{-1}) than CEC found in the till of the Pomeranian phase localized in the Baranowo and Studnica catena (Masurian Lakes), [ORZECHOWSKI et al. 2004, SOWIŃSKI et al. 2004]. Tills of the investigated area were characterized by a high differentiation of exchangeable acidity, which in pH units ranged from 3.76–7.42, with mean geometrical value of 5.0 (Fig. 4).

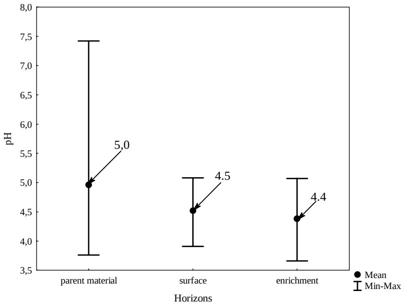

Fig. 4. The range and the geometrical mean of exchangeable acidity in genetic horizons in studied soils

The confirmation of the acidic character of the larger part of the till from the Drawskie Lake District was a high value of hydrolytic acidity reaching even the level of 4.5 cmol(+)$^{\cdot}$kg^{-1} and a high contribution of hydrogen ions in exchangeable complex reaching up to 43.9% [DŁUGOSZ 2002]. Therefore the high acidity of the discussed tills is the result of the leaching process which most likely took place in the periglacial period. The evidence that it is the process of the leaching and not the acidic character of the original material is the occurrence of an alkaline reaction in some profiles (e.g.Cieszyno) and the existence of this kind of reaction in the floor part of Pomeranian till in the vicinity of the Drawskie Lake District [DOBRACKA 2008]. Despite the acid reaction the calcium cation was dominant among exchangeable cations in Pomeranian tills of the Drawskie Lake District. Its participation in acid tills ranged 58-68% of CEC. A similar contribution of calcium cations was noted in the leached Poznań tills located on the foreground and subsidiaries of the Obkaska marginal moraine [DŁUGOSZ 2002]. The exception was the till from the Siemczyno profile localized in the forest complex where the contribution of that cation fluctuated in the range 33-38% of CEC [DŁUGOSZ 2002]. A significantly higher contribution of the calcium cation took place in the saturation of tills containing calcium carbonate, where it reached 90% of CEC.

THE CHARACTERISTIC OF SOIL COVER FORMED FROM GLACIAL TILL

Soils classified as Cambisols have been formed, with the dominant Eutric Cambisols, on the base of the Drawskie Lake Districtict glacial till. It was concluded according to the pedological-agricultural maps drawn in the 1:100000 scale. The contribution of Luvisols, known sometimes as "pseudopodzols", has been low. However, recent research carried out on the studied area indicated that the great part of the soils shown on the pedological-agricultural maps as Eutric Cambisols fulfill the criteria of

Luvisols. One of them is the occurrence of clear clay infiltrations in the enrichment horizon (B), which further was classified as Bbr and depicted in the profiles studied (Fig. 5).

Fig. 5. The clay films from the enrichment horizon of investigated area

Other evidence for the lessivage process is the enrichment horizon's texture, showing a clear (exceeding limit values for the argillic horizon) clay fraction content increase (18-31%, mean 23%), (Fig. 6).

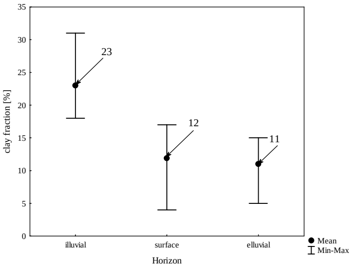

Fig. 6. The range and the mean of clay fraction of studied soil horizons

The contribution of a clay fraction in the enrichment horizons was clearly higher than in the surface ones (4-17%), (Fig. 6). Similar mean values of the clay fraction in the surface (12%) and eluvial horizons (11%) are probably the result of mixing the top part of the eluvial horizon with humic horizon as a consequence of agrotechnical measures. This phenomenon appears very often in arable land localized on moraine areas. On other areas like these, e.g. in the neighbourhood of Kluczewo occurs also a soil in which the eluvial horizon has been completely connected with the humic horizon. Soils like those, commonly called top-soil-free soils, are found on the area of the Poznań glaciations [DŁUGOSZ 1997]. The confirmation of the lessivage process in these soils could be, apart from increasing clay fraction content (Fig. 7a), a higher free iron concentration in the illuvial horizon (Fig. 7b).

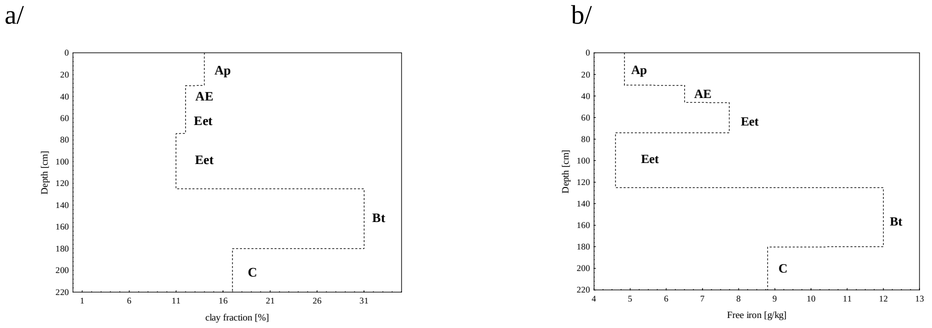

Fig. 7. The profile distribution of clay fraction (a) and free iron oxides (b) in Luvisols from the Drawskie Lake District area

The average value of free iron in the enrichment horizons accounted for 7.25 g·kg^{-1}, while in the loam level and in the surface horizon the mean value of free iron form was determined at the level of 5.52 and 5.09 g·kg^{-1}, respectively (Fig. 8).

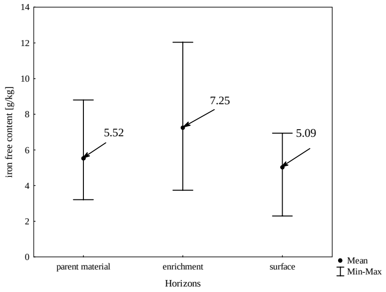

Fig. 8. The range and the mean of free iron oxides of studied soil horizons

The amount of free iron in the illuvial horizon was close to the content noted by DŁUGOSZ [2002] and KUŹNICKI et al. [1979] in Luvisols formed from the Warta till. The visual effect of that was its brown colour. Another effect of the lessivage process, which appeared in soils under study, was the existence of the lowest cation exchange capacity in the eluvial horizons, which ranged from 7.10 to 12.35 cmol(+)·kg^{-1} with the mean value being 8.65 cmol(+)·kg^{-1} (Fig. 9). The decreasing cation exchange capacity (CEC) in these levels was due to the leaching of the clay fraction together with iron oxides complexed with it. A clear increase of CEC in illuvial horizons was the results of this process. The CEC increase reached the maximum values ranged from 10.0–20.5 cmol(+)·kg^{-1} with the average account for 14.6 cmol(+)·kg^{-1} (Fig. 9).

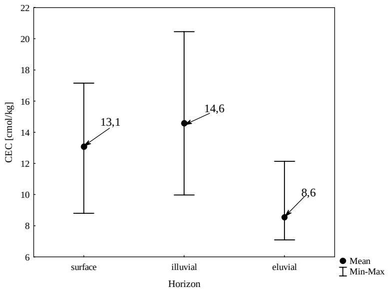

Fig. 9. The range and the mean of the cation exchangeable capacity (CEC) of studied soil horizons

The CEC amounts determined in illuvial horizons were also higher than the ones found in glacial till. However, the surface level of soils under study despite a lower content of a clay fraction, were characterized by CEC (8.8 – 17,15 cmol(+)·kg^{-1}) similar to glacial till and only a little lower that obtained for the illuvial horizon. The reason of a phenomenon like that was the presence of humic compounds in the surface horizon found in soil organic matter commonly called “humus”. The compounds on account of their structure are characterized by a high cation exchange capacity coming up even to 300 cmol(+)·kg^{-1}. It is commonly accepted that organic carbon content of is considered to be the index of soil humus content. Humic horizons contained from 5.7 to 11.1 kg^{-1} and it was the concentration occurring in arable soils. A small amount of organic carbon was observed also in lower genetic horizons of the studied soils. A CEC profile distribution like that is typical for Luvisols aside from a structure they were formed from. It was confirmed by CEC results obtained by KOBIERSKI and DĄBKOWSKA-NASKRĘT [2005] and DŁUGOSZ [2002] in Luvisols formed from the Poznań till.

The results of the soil horizons’ reaction showed a clear acidity increase in solum, where exchangeable acidity given in pH units ranged from 3.66 -5.08. Even the humic horizons of the profiles under study were characterized by acidic and very acidic reaction (pH in 1M KCl 3.91-5.08), (Fig. 4). The intensive acidification process may be supported by the fact that even profiles containing carbonate till in soil horizons showed very acid character (pH in 1M KCl 4.64–5.0; Cieszyno soil profile). Similarly the acid character was shown for the soil formed from the Poznań till in the neighbourhood of Obksu investigated by DŁUGOSZ [2002]. The confirmation of the acidic character of the soil under study is the high value of hydrolytic acidity (Hh) ranging from 1.15–8.25 cmol(+)· kg^{-1} . The highest Hh values appeared in the surface horizons of the studied soils, where the mean accounted for 4.12 cmol(+)·kg^{-1} (2.75–8.25 cmol(+)·kg^{-1}). The effect of the discussed soils acidity was also a very low contribution of calcium ions in exchangeable complex. In the surface and eluvial horizons did not exceed 50% of CEC

(Fig. 10), which in comparison with other soils formed of tills was low [DŁUGOSZ 1997]. The exchangeable potassium content was shaped inversely because the research showed its high contribution in the whole soil profile, not excluding parent rock, where the participation of K^+ in CEC ranged from 2.2 -12.3%. The lowest percentage of K^+ ions (2.2%) was found in CEC of carbonate till. In non-carbonate tills, however, the contribution of K^+ ions in CEC ranged 4.31–12.2%, which may be the result of strong weathering of minerals containing potassium ions, e.g. muscovite and illite. It may lead to the liberation of potassium ions or potassium leaching from soil horizons.

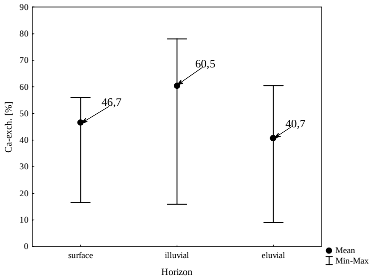

Fig. 10. The range and the mean of exchangeable Ca^{2+} ions of studied soil horizons

The leaching process has been suggested by the preliminary mineralogical analyses of the fine clay fraction, which showed a high contribution of illite minerals, both in the parent material and the soil horizons [DŁUGOSZ 2002]. Another confirmation of the fact that a high contribution of the exchangeable potassium in non-carbonate till of the area is the effect of leaching process may be a lower participation of that ion in soil levels CEC. According to the research the lowest contribution of potassium cations was shown in the CEC of eluvial and illuvial horizon (Fig. 11).

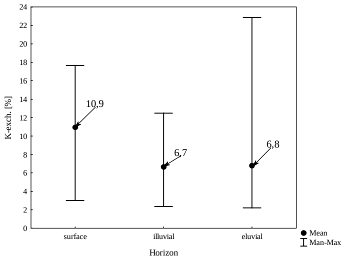

Fig. 11. The range and the mean of exchangeable K^+ ions of studied soil horizons

The elevated content of the discussed cation in the surface horizon may be caused by the long-term high potassium fertilization or more intensive weathering in the surface horizons [JACKSON 1948]. The average contribution of potassium cations (10.9%) in the surface level is higher than that given by FILIPEK [2001] in acidic and very acidic soils. Therefore high potassium ions contribution in the floor part of the studied profiles may be the evidence of the occurrence of the leaching process.

CONCLUSIONS

As results from the presented data, the Drawskie Lake District area is characterized by a very complex geological and geomorphological texture, which reflects the differentiated soil cover. The typological and physico-chemical differentiation was influenced by both processes occurring in the early phase of soil cover formation causing the leaching of deposited material, and later connected with human activity. The results indicated the further transformation of soil under study probably in the process of continued leaching. The processes resulted in further increasing of acidity, a decreasing amount of calcium ions in exchangeable complex as well as an increase of potassium ions in the parent material CEC. The process induces that the soils of a good crop-making potential are not totally exploited. The results showed that the liming of the soils under study was given up, which resulted in the acidity process increasing. The studied soils undergo the typological evolution, which means that the soils have transformed from Eutric Cambisols to Luvisols, as classified during the cartographic evaluations. Characteristic diagnostic horizons of Luvisols were observed during the research. Also in the area of the Drawskie Lake District, the Luvisols of moraine surface under cultivation more and more often become the form of so called “top-soil-free soil”, i.e. without eluvial horizon.

The results of the research suggested that because of their very acidic character the soils formed from the Pomeranian till from the Drawskie Lake District are especially susceptible to all factors triggering their transformation. They may be both changes of physico-chemical properties and mineralogical composition of clay fraction which was shown by the primary mineralogical composition analyses. That is why, for a better illustration of transformations of the studied soil a further research embracing both practical and genetic research must be done. It will allow the explanation of the leaching effect as well as intensified weathering process as a result of it.

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