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Micromorphologic Features of Fossil Soils in Loesses of the Lopatki Profile (SE Poland)

Mikromorfologiczne cechy śródlessowych gleb kopalnych w profilu Lopatki (Polska SE)

ABSTRACT

Results of physico-chemical and micromorphological investigations carried out on loesses of the Lopatki outcrop are presented. On this basis interglacial soil older than the interglacial Eemian soil as well as typologically differentiated interstadial soils of different age have been distinguished and characterized.

INTRODUCTION

Investigations of the loess exposure at Lopatki, which was demonstrated during the symposium of the INQUA Commission on Loess in 1985 (H. Maruszczak 1985) were carried out using pedologic methods. They constituted a basis for our attempts to determine the structure of the soil material (matrix) consisting of the skeleton, soil pores and plasma (colloidal clay) in particular layers with the prevalence of lithogenesis or pedogenesis. The texture of the mineral material was also determined as well as two forms of iron, calcium carbonate, content of organic carbon and, for interglacial soil clay minerals.

In the light of results obtained up to now (H. Maruszczak 1987, H. Maruszczak, M. Tkacz 1987) the well-developed fossil lessivé soil in the outcrop under study was assigned univocally to the Lublin and not the Eemian interglacial. It is then a very interesting question, how micromorphologic features are formed in the lessivé soil, which is older than the forest lessivé soil of the Eemian interglacial. Are soil-forming processes running like in interglacials of different age? Are they much more clearly marked in the soil material?

Soil thin-sections for micromorphologic investigations were prepared using the Kubiena's method from samples of undisturbed structure. They were taken from differently developed soil horizons confirmed by geochemical analyses. Iron was determined in the 20% HCl extract and as free iron using the Jackson's colorimetric method. Carbon was determined by the Tyurin's method and carbonats by the Scheibler's method. For clay minerals the thermic differential method was used.

Samples for pedologic analysis were taken in the outcrop at Łopatki described by H. Maruszczak and M. Tkacz (1987) with the observation of an identical stratigraphic division and letter symbols of layers. The results of chemical investigations are shown in the Fig. 1 and those of micromorphologic investigations in Photos 1–24. The paper does not deal with the profile of the soil occurring contemporarily on the surface, as it has been transformed antropogenically.

CHARACTERISTICS OF INVESTIGATED LAYERS AND SOIL HORIZONS

Layer d, sample taken from the depth of 175–190 cm, with the bottom built from ferruginous fibre over gleyed layer e_1. The skeleton is fine-grained, oval pores mostly empty, sometimes only fragmentarily filled up with calcium carbonate. The whole profile, however, displays advanced decalcification confirmed by a small amount of $CaCO_3$. The whole thin section is unuvenly saturated with iron (Phot. 1, 2), occurring in rather large quantities, both free and soluble in 20% HCl. There occur locally small ferruginous-humous irregular concretions. Small amounts of skellattisepic plasma appear sometimes. This material was most probably displaced by solifluction.

Layer e_1, two thin sections of the sample taken from the depth of 190–210 cm. This is the horizon A of a poorly marked interstadial fossil soil. In the upper part of the layer the skeleton is fine-grained, typical for loess, the horizon is very porous, with many oval and oblong pores. Some of them are empty, others paved with calcium carbonate; it is the zone of the carbonate precipitation (Phot. 3, 4). There occur, too, small concentrations of organic matter, but there are no ferruginous concentrations. In some pores silasepic plasma occurs, in which the main role is played by silt and not by colloidal particles. In the lower part crystic-type plasma and in pores large spheroliths of calcite occur. There also occur post-root pores, paved with iron or empty. In the soil bulk of a part of the A horizon concentrically arranged ferruginous-manganese or ferruginous concretions can be found, the latter with embedded quartz grains. Poor lamination of the mineral material with small admixture of organic matter can be observed also in the thin section. This is the mineral-organic substratum displaced by solifluction.

Layer e_2, sample taken from the depth of 210–250 cm. Poorly developed weathering horizon B with visible decalcification and mobilization of iron in relation to under- and overlaying layers with fairly large amount of colloidal particles. The skeleton is fine-grained, at an almost complete lack of post-root pores. The material occurs in situ and forms an almost homogenous mass with ferruginous fibres in some places (Phot. 5, 6). In contains small amounts of skelsepic-type plasma, sometimes saturated with iron, what means a certain isolation and orientation on the skeleton grains. It may be supposed that it is an older layer not related genetically to the above described overlaying A horizon and weakly connected with carbonate loess occurring below.

Loess layers from the depth of 250–420 cm were not examined micromorphologically. This is the carbonate loess, which going downwards contains decreasing quantities of free iron and iron soluble in 20% HCl as well as of organic carbon.

Layer g_1, sample taken from the depth of 420–435 cm. Traces of soil-forming processes documented by a certain amount of organic matter and weakly marked gleyification. Fine-grained skeleton, in few, maybe post-root pores ferruginous and ferruginous-humous poorly developed concretions occur. Some of them contain an admixture of manganese. Few pores are filled up with crystic-type carbonate plasma, others — with secondary carbonates in the form of calcite (Phot. 7, 8). It is not unlikely that this could be the destroyed A horizon of the interstadial chernozem of early Vistulian.

Layer g_2, sample taken from depth of 435–445 cm. It is similar to the described g_1 layer with the calcite microcrystals and a small amount of silasepic-type plasma.

Layer h_1, sample taken from the depth of 445–500 cm. This may be a weakly marked weathering horizon with the calcium carbonate and slightly more free iron amount. Fine-grained skeleton, post-root pores practically absent. It contains traces of skelsepic and silasepic calcite-type plasma. In the upper part of the layer manganese and ferruginous concretions can be found; they constitute outwashed forms typical for superficial (periodical) gleyification. In the lower part non-outwashed ferruginous-humous concretions, maybe non-outwashed manganese ones, occur (Phot. 9, 10). The above features suggest preservation of traces of the lower part of Bt horizon.

Layer h_5, sample taken from the depth of 600 cm. A fragment of this layer with the fine-grained skeleton, strongly cemented with organic matter and iron (or maybe also with silica), in the form of bright and brown lamels, was investigated.

Layer i_1, sample taken from the depth of 640–660 cm. The skeleton is fine-grained, but with a certain amount of greater sand grains. Pores large, sometimes filled up with calcite microcrystals. This is a porous material with a small amount of organic matter and tiny ferruginous concretions as well some amount of silasepic-type plasma.

Layer i_2, sample taken from the depth of 660–714 cm. Features similar to the above described ones, but with outwashed often laminated ferruginous concretions with embedded coarser material. Small amounts of skelsepic-type plasma. Upper part of the layer is enriched in both iron forms.

Layer j_1, sample taken from the depth of 714–735 cm. This is the upper part of the soil horizon A. The skeleton is mainly fine-grained, with greater admixture of larger grains. This material has been most probably displaced by solifluction or outwashed, sometimes laminated silt, sand (Phot. 11, 12). Pores are filled up with organic matter or partly decomposed roots (Phot. 13, 14) or with clayey-ferruginous-humous substance, non-flowing, but rather of stress character. Sometimes weakly marked excrettions of plasma can be observed. The dispersed organic matter occurs in the form of amorphous mullicol, sometimes mulliskel. In the laminated material many tiny ferruginous concretions, both fresh and older well-crystalled ones of brown colour (Phot. 15, 16) with embedded quarts grains, can be found. Weakly visible skelsepic-type plasma occurs in small amounts. No carbonateous incrustations can be encountered in this horizon.

Layer j_2, sample taken from the depth of 745–760 cm. This is a lower part of the soil horizon A. The skeleton is fine-grained, with a certain amount of greater sand grains. Many post-root pores, often with outwashed conglomerates of iron compounds. Simultaneously, ferruginous concretions sharply cut off the soil material with skeleton microcrystals characteristic for superficial gleyification can be found here. Silt-sand lamels with frequently encountered organic matter in the form of mullicol occur. Organic matter occurs sometimes in the carbonized form. Plasma mainly skelsepic; no calcium carbonate.

Layer k, sample taken from the depth of 760–775 cm. This is the Eet soil horizon of outwash and overlapping superficial gleyification. The skeleton is fine-grained, with well-formed network of post-root pores; the material is porous, with symptoms of outwash of the initial material. In the lower part of the horizon well-formed ferruginous concretions, so-called nodules occur with high concentration of iron in relation to the ambient mineral substrate, or post-root ferruginous concretions (small pipes, Phot. 17, 18). Plasma of the silasepic type, also a certain amount of the stress-type plasma can be found there.

Layer l_1, sample taken from the depth of 775–800 cm. This is the upper part of well-formed illuvial horizon of Bt argillic. The skeleton is fine-grained, pores large, filled up with flowing plasma of the vosepic type (Phot. 19, 20). Some of them are filled up fully with many-layered sinters. In large pores several generations of flowing plasma of different golden-yellowish or brown-yellow colour, often separated by skeleton, can be found sometimes. In the pores padded with plasma secondary ferruginous concretions occur. They are younger than the accumulated colloidal clay. Also the masepic-type plasma occurs in the form of coarser darker lamels in the soil material, well-separated, with spotted orientation, apparently non-connected with pore walls and grain surfaces. Still in this horizon the vosepic-type plasma prevails (Phot. 21, 22). In large pores some symptoms of the plasma destruction can be observed (Phot. 23, 24). They manifest themselves in broken padding of pores, their deformation and sometimes in embedding of plasma into the soil material. In the plasma fragments stratification is often preserved.

Layer l_2, sample taken from the depth of 800–830 cm. This is the lower part of the horizon Bt argillic. The skeleton is fine-grained, pores padded with somewhat thinner vosepic-type plasma layer, sometimes disturbed. Some pores are empty. Also a certain amount of organic matter connected with iron and tiny ferruginous concretions with frayed rims can be found.

Layer l_{2-3}, sample taken from the depth of 830–875 cm. This is a transition of the illuvial Bt horizon into the C horizon, from which the soil developed. The skeleton as above. Some pores are padded with small amount of weaker formed vosepic-type plasma. In greater amounts the skelsepic-type plasma occurs. Also weakly formed ferruginous concretions slightly outwashed, can be found.

No micromorphologic analyses of the loam underlying the l_3 layer were performed.

An important diagnostical index for the pedogenesis process is iron. When determined in 20% HCl, it characterizes the loess substrate. It is

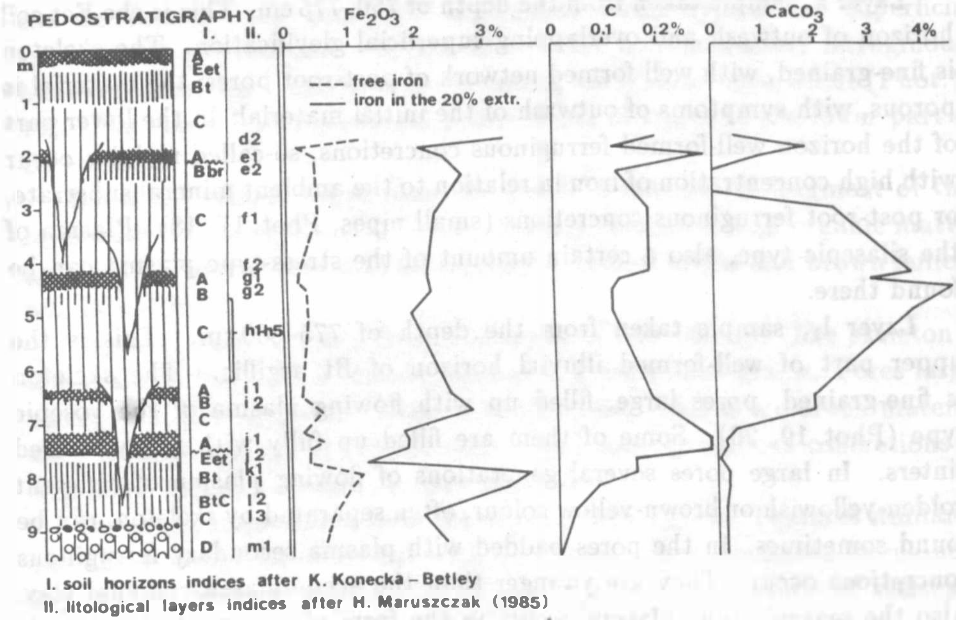


Fig. 1. Loes section at Lopatki

connected with alumosilicates and some its amounts occur in non-compound form as free iron (Fig. 1). Free iron is forming as a consequence of the chemical weathering mainly of alumosilicates, with simultaneous formation of clayey minerals. Apart from mobilization of iron also its displacement occurs depending on the intensity and consequences of soil-forming processes connected closely with climate and plant cover. This element is often migrating with the clay fraction or as bivalent iron connected with the intensifying superficial gleyization process. The content of this iron form correlates usually with the content of colloidal particles. In loesses and interstadial soils there is 5–10 fold less free iron than iron soluble in 20% HCl, whereas in interglacial soils there is only threefold less free iron than iron soluble in 20% HCl.

INTERPRETATION AND FINAL REMARKS

In the Lopatki exposure interglacial soil (k, l_1, l_2 layers) two interstadial soils: younger (e_1, e_2 layers) and older one, probably bipartite (j_1, j_2 layers) were found. Also two layers with weakly marked soil-forming processes (g_1, g_2 layers and i_1, i_2 layers) were distinguished. Holocene soil was not examined. Still two layers with the symptoms of beginning soil-forming processes were distinguished by H. M a r u s z c z a k (1987). Upper part of the exposure to the g_2 layer constitute younger loesses (Vistulian), lower part — older loess (Wartanian). Most clearly marked micromorphological and chemical changes connected with the soil-forming processes were observed in interglacial soils, in the horizon of Bt argillic (l_1, l_2 layers). This is a diagnostical horizon for lessivé soils. It is characterized by accumulation of colloidal clay and free iron under the influence of the lessivage process. A basic clayey mineral in this soil horizon is montmorillonite. A well-separated vosepic-type plasma occurring in high amounts can be found in the main part of this horizon. In lower part also skelsepic-type plasma occurs. Soil pores are padded or fully filled up by vosepic plasma. Also destruction or deformation of plasma and displacement of its fragments over secondary deposit are observed. This phenomenon should be connected with the effect of seasonal frozen ground. Often older, large fragments of plasma of yellowish-brown colour are surrounded with younger thin layer of colloidal clay of golden colour. This can suggest that the oldest soil at Lopatki, related by TL method (M a r u s z c z a k 1987) and by the paleomagnetic method (M a r u s z c z a k, T k a c z 1987) for the Lublin interglacial, should be polygenetic soil. However, the A horizon of the humus accumulation is not preserved or only slightly preserved in it.

Overlaying layer (j_1), from which humus horizons of soil or interstadial soils developed were not especially thick. Therefore the pedologic processes comprising over-lying loesses could deepen some features of older processes in interglacial soil.

Such a recognition is confirmed by properties of older interstadial chernozem soil developed from Wartanian loesses (j_1, j_2 layers). It is represented by a rather thick pedologically transformed A horizon. Inside of the earlier formed A horizon, in its upper part a certain enrichment in clayey particles and, first of all, in free iron, can be observed. This suggests a running weathering process. The not especially abundant skelsepic-type plasma already separated and oriented on the skeleton grains has been found also in it. The occurrence of plasma of this type confirms the pedogenesis processes running probably in the last phase of soil occurrence with the plant cover of boreal forest. Such a plant cover has been confirmed also by the humiskel-form humus with greater amount of non-decomposed organic matter. All the phenomena as described above are not especially clearly marked, but nevertheless constitute a proof that the interstadial chernozem initially displaced most probably by solifluction has been overlapped by the later second soil-forming process. Then the formation of the weathering horizon Bbr cambic diagnostical for interstadial soils in older humus material began. Lower part of the A horizon did not undergo the above transformations and the organic matter occurs there in the mullicol form. The j_1 and j_2 layers, and particularly the j_1 layer (A horizon), are not connected genetically with the interglacial soil, although they lie directly on the latter. Ferruginous or ferruginous-manganese concretions of different size occurring in this horizon are characteristic for the superficial and not for ground gleyization.

The younger interstadial soil developed already from Vistulian loesses (e_1, e_2 layers) is characterized by the solifluctionally displaced A horizon. In lower part carbonateous incrustations or even large crystals of calcium occur in pores. In the soil bulk ferruginous-manganese concretions occur proving the superficial gleyization phenomena. The Bbr cambic horizon is poorly formed, decalcified and non-gleyed, with a certain amount of the skelsepic-type plasma. It was formed in situ and is not connected genetically with the A horizon and the loess lying below.

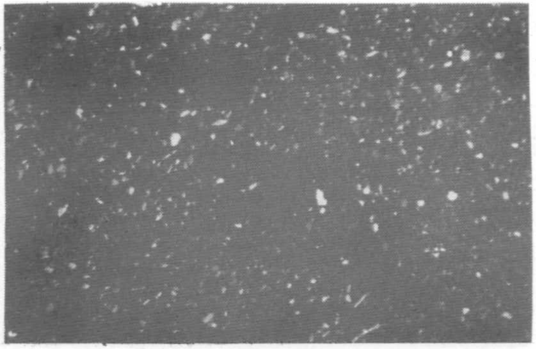
Apart from typologically formed soils, also layers with weakly marked pedogenesis processes occur at Lopatki. This are g_1 and g_2 layers developed from the lowest Vistulian loess with a small amount of organic matter and weakly formed ferruginous-humous concretions. This can be presumably a weakly preserved A horizon of the oldest Vistulian, interstadial soil with secondary carbonates filling up some soil pores.

Other similarly recognized layers occur at the depth of 6.40–7.14 cm in older loesses. This are i_1, i_2 layers with a small amount of organic matter. In the i_1 layer the silasepic-type plasma occurs and in the i_2 layer the skelsepic type plasma and enrichment in both iron forms occur. In view of occurrence of greater amounts of sand grains and lamination with coarser material it can be presumed that this would be substrate on the secondary deposit, though with symptoms of initial soil-forming processes occurring within both separated layers.

Superficial gleyization in some outcrop parts is not marked as strongly as to be distinguished as the superficially gleyed soil type. This is, as a rule, a secondary and in the loess medium sometimes a periodical feature.

In loesses of the Lopatki outcrop it is difficult to establish a logical pedostratigraphy based on distinguished soil types characteristic for interglacial and interstadial periods as well as periods of lower rank. The lithostratigraphy with pedo- and cryo-stratigraphy elements was presented up to now by Maruszczak.

Fossil soils as Quaternary stratigraphy units are distinguished on the basis of characteristic genetic horizons connected with plant communities.



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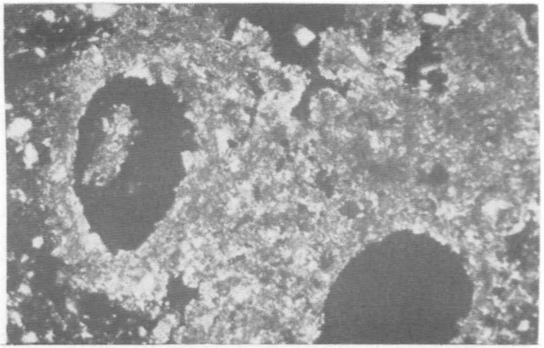

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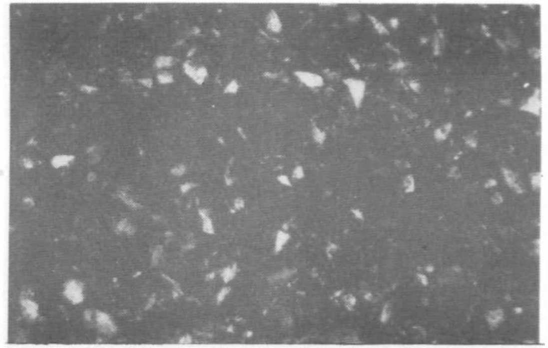

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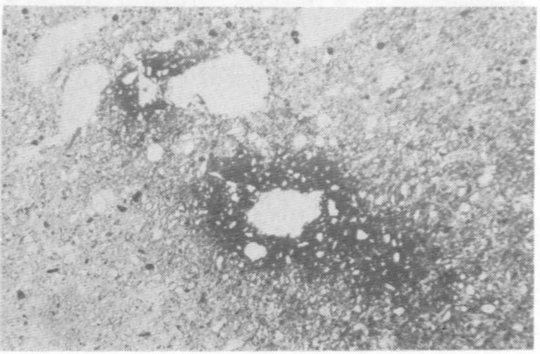

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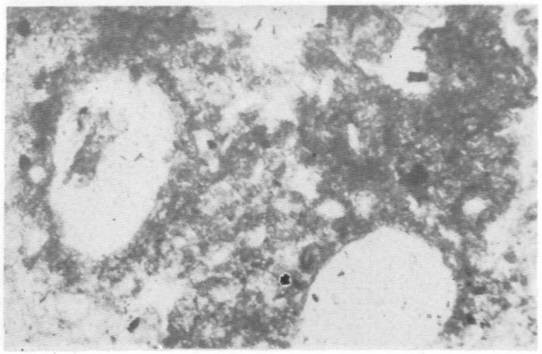

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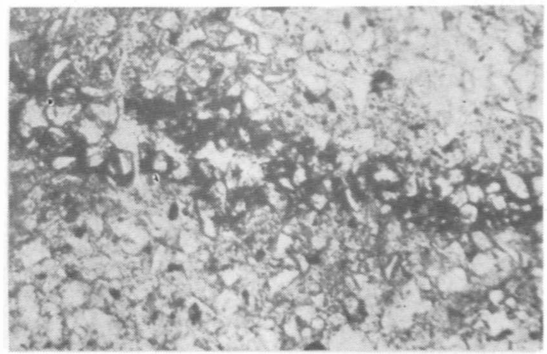

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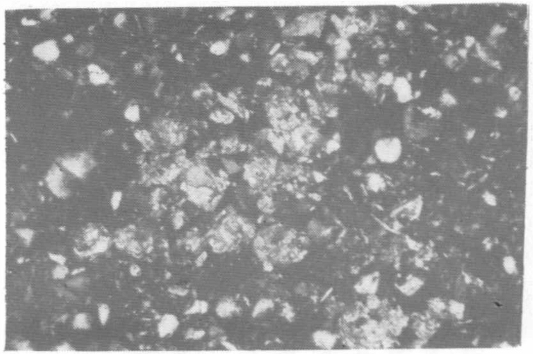
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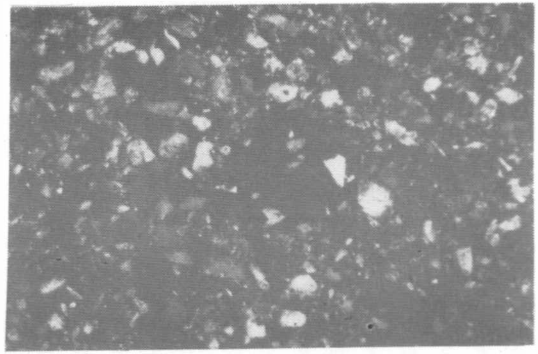
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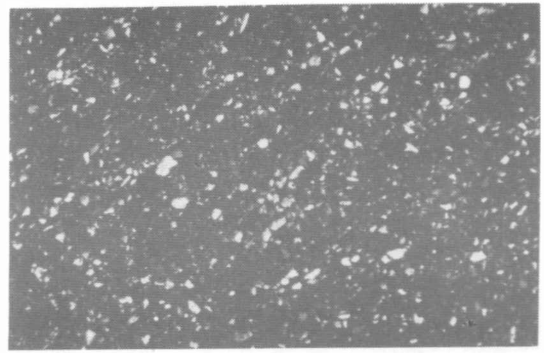
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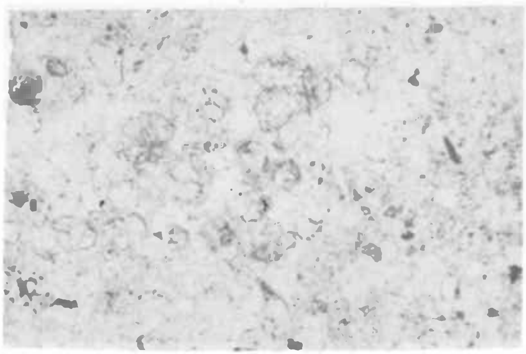
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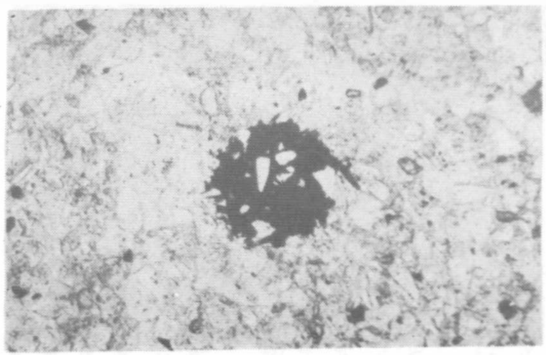
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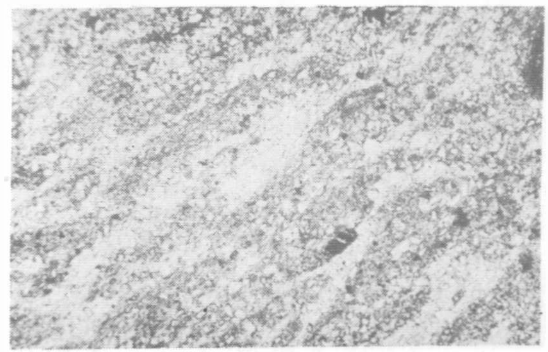
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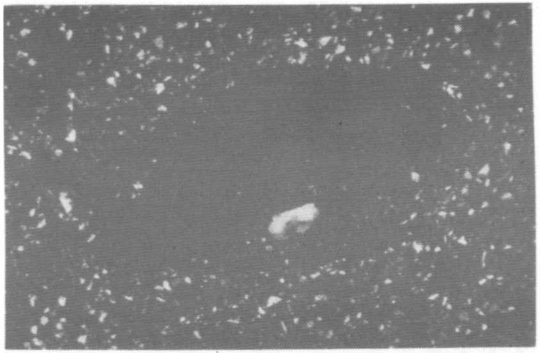

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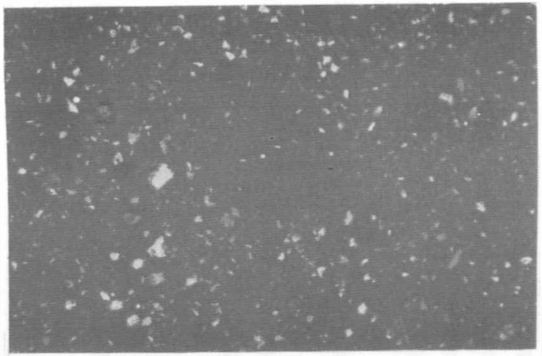

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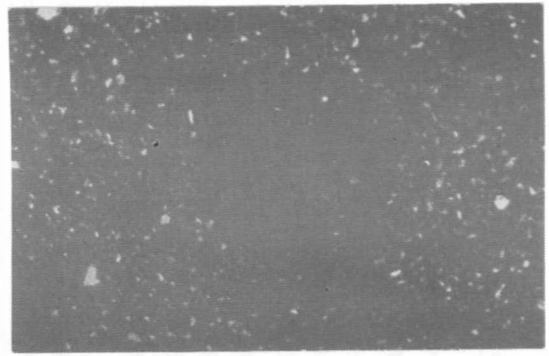

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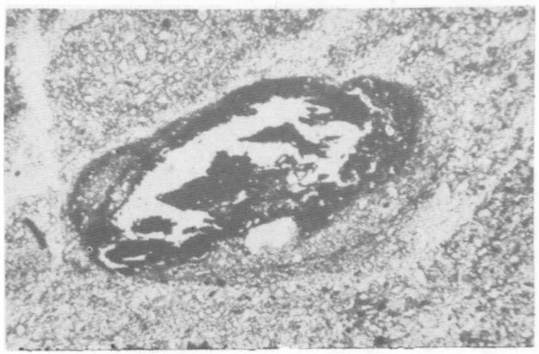

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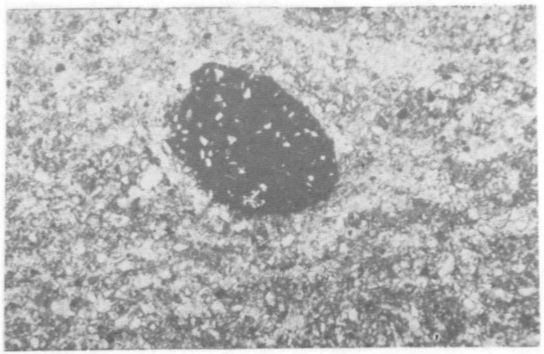

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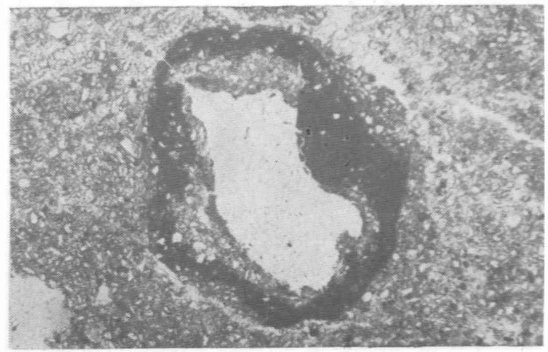

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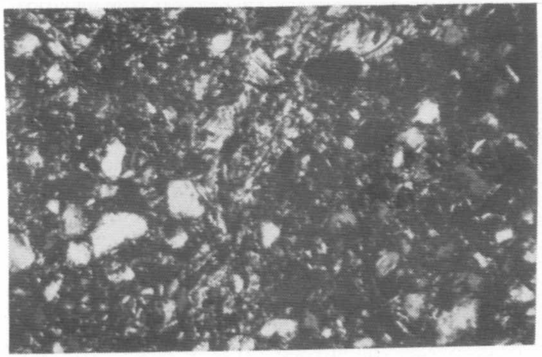
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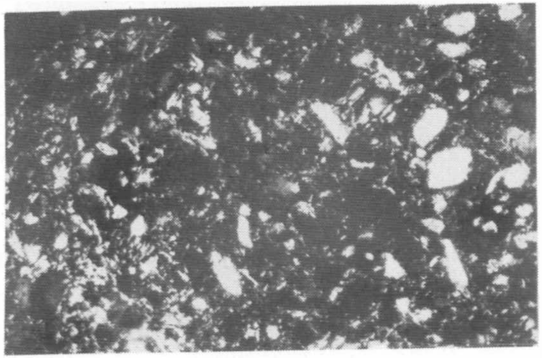
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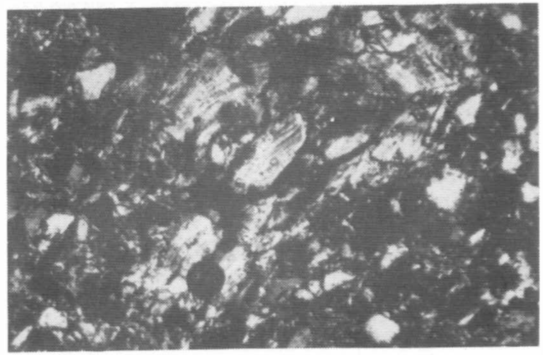
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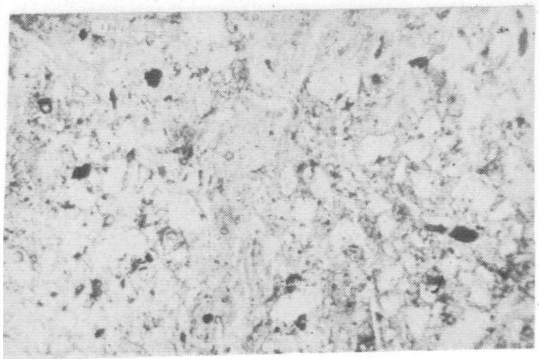
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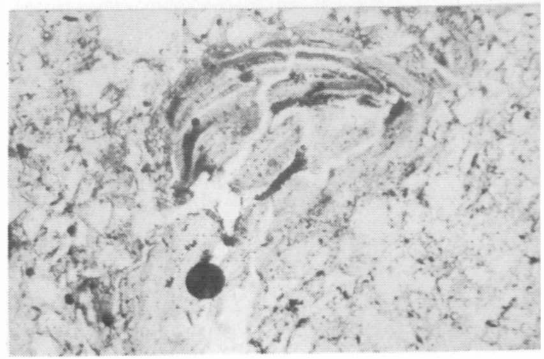
Photo 24

Also physico-chemical and micromorphologic diagnostical features are taken into consideration (Konecka-Betley et.al.1987). Some genetic horizons in the outcrop under study have been fully or partly denuded and some displaced by solifluction onto the secondary bed. Thus partly "shortened" and/or truncated and sometimes fully destroyed soils occur there.

While summing up all the results obtained characterizing pedologic features, the following have been distinguished in the Lopatki outcrop:

1) interglacial lessivé soil probably older differing from soil of the Eem interglacial with stronger developed Bt argillic horizon and destructed vosepic-type plasma;

2) interstadial chernozem with symptoms of strong weathering in upper layer of the A horizon in the form of weekly formed Bbr cambic horizon with the skelsepic-type plasma and marking pseudogleyization process; this is the soil probably developed from Wartanian loess forming with the interglacial soil a complex of older interglacial-interstadial soils;

3) weakly formed usually single-horizon interstadial soils developed from loesses of different age, some of them with the symptoms of superficial gleyization;

4) soils or horizons with weakly marked pedogenesis symptoms of lower rank.

The final typologic determination of fossil soil of the outcrop investigated can take place only upon analyzing greater number of similar loess profiles.

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PHOTOGRAPHS

Tabl. I. Layer d, depth of 175-190 cm; unequal accumulation of iron around pores in the mineral material: Photo 1 — crossed nicols, magn.35x. Photo 2 — parallel nicols, magn. 35x. Layer e_1, depth of 190–270 cm; carbonate precipitation zone: Photo 3 — crossed nicols, magn. 100x. Photo 4 — parallel nicols, magn. 100x. Layer e_2, depth of 210–250 cm; ferrous fibres in soil bulk: Photo 5 — crossed nicols, magn. 100x. Photo 6 — parallel nicols, magn. 100x.

Tabl. II. Layer g_1, depth of 420–435 cm; calcite crystals in soil pores: Photo 7 - crossed nicols, magn. 100x. Photo 8 — parallel nicols, magn. 100x. Layer h_1, depth of 445–500 cm; ferruginous-manganese concretions, non-outwashed: Photo 9 — crossed nicols, magn. 100x. Photo 10 — parallel nicols, magn. 100x. Layer j_1, and j_2 depth of 714–735cm; solifluctionally mixed up, weakly laminated mineral substrate: Photo 11 — crossed nicols, magn. 30x. Photo 12 — parallel nicols, magn. 30x.

Tabl. III. Layer h_1, depth of 445–500 cm; decomposing root in the soil pore (humiskel): Photo 13 — crossed nicols, magn. 30x. Photo 14 — parallel nicols, magn. 30x. Layer h_1, depth of 445–500 cm; old crystalline ferruginous concretions with embedded quartz grains: Photo 15 — crossed nicols, magn. 30x. Photo 16 — parallel nicols, magn. 30x. Layer k, depth of 760–775 cm; iron accumulation in post-root pore (small pipe): Photo 17 — crossed nicols, magn. 30x. Photo 18 — parallel nicols, magn. 30x.

Tabl. IV. Layer l_1, depth of 775–800 cm; flowing vosepic-type plasma: Photo 19 — crossed nicols, magn. 100x. Photo 20 — parallel nicols, magn. 100x. Layer l_1, depth of 775–800 cm; zonal plasma of the vosepic-type: Photo 21 — crossed nicols, magn. 100x. Photo 22 — parallel nicols, magn. 100x. Layer l_1, depth of 775–800 cm; well-formed but destroyed vosepic-type plasma: Photo 23 — crossed nicols, magn. 100x. Photo 24 — parallel nicols, magn. 100x.

STRESZCZENIE

Kopalne gleby odsłonięcia Łopatki, jako jednostki pedostratygrafii czwartorzędu, wydzielono na podstawie charakterystycznych poziomów genetycznych, które zostały ustalone na podstawie niektórych cech fizyczno-chemicznych, a przede wszystkim mikromorfologicznych, diagnostycznych dla poszczególnych typów glebowych. Niektóre z tych poziomów są całkowicie lub częściowo zdenudowane, inne zostały soliflukcyjnie przemieszczone na wtórne złoże. Występują więc tu gleby częściowo "skrócone" lub "oglowione". Charakterystyczne cechy pedologiczne umożliwiły wydzielenie w odsłonięciu Łopatki (ryc. 1):

1) gleby płowej interglacjalnej, najprawdopodobniej starszej od gleby interglacjału eemskiego, z bardzo silnie rozwiniętym poziomem Bt argillic z destrukcją plazmy typu vosepic i dużym nagromadzeniem iłu koloidalnego i żelaza wolnego;

2) gleby interstadialnej, czarnoziemnej z oznakami silnego wietrzenia w warstwie górnej poziomu A, ze słabo wykształconym poziomem Bbr cambic, z plazmą typu skelsepic i zaznaczającym się procesem odgórnego oglejenia; jest to gleba wytworzona z lessu, stanowiąca z glebą interglacjalną zespól gleb, czyli wyższą jednostkę taksonomiczną pedostratygrafii;

3) gleby słabo wykształcone na ogól jednopoziomowe lub ze słabo zaznaczonym poziomem B, interstadialne, wytworzone z różnych wiekowo lessów, niektóre z oznakami oglejenia opadowego;

4) gleby czy poziomy ze słabo zaznaczonymi oznakami pedogenezy, o niższej randze wiekowej.