THIRD INTERNATIONAL WORKING-MEETING ON SOIL MICROMORPHOLOGY
WROCŁAW, 1969

ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1972 z. 123

Micromorphology of some brown soils

A. OJA

Estonian Agricultural Academy, Tartu, U.S.S.R.

The latest investigations on the composition of soils in the Baltic Republics have shown that the area under brown soils is much more extensive than it was thought to be. These soils were established and described by Zonn [7], Shleinis [6], Reintam [5] and others on a level territory in Estonia, Latvia, Lithuania and the Kaliningrad Region. As has been pointed out by Zonn, northwestern brown soils are of biolithogenic origin. These soils have been formed on rich aluminosilicate or calcareous rock under broad-leaved or spruce-deciduous forests and are therefore distributed on small areas among sod-podzolic soils.

On Estonian territory we find brown soils mainly on yellowish-gray calcareous moraine, which is very widespread in the central part of the Estonian S.S.R. In the current nomenclature these soils are listed as leached and podzolized sod-calcareous or sod-podzolic soils. Yellowish-gray moraine has been derived from local calcareous material as well as from the weathering products of the Fennoscandian crystalline rocks. The calcareous content of this moraine varies in our profiles from 14 to 40%. These soils lie on a weakly undulating moraine plain under spruce or spruce-deciduous forests as well as in fields. The depth of the underlying calcareous horizon determines the character of the soil profile. Soils of two profile types have been formed on this moraine, and alternate very irregularly. In typical brown soils we may identify a humus horizon (A_1) followed by the textural B-horizon (B_t), but in brown lessivé soils the A_1-horizon, the eluvial A_l- and B_t-horizons are found on the matrix (C-horizon). To determine the character of the horizontal distribution of top soil on the underlying part, a piece of land (36 m^2) was opened from above. Some large cleavages were found to be resembling cryogenic clefts in contemporary soils of eternal frost regions. Between these cleavages a small morainic landscape has been formed with hills and valleys filled by lighter soil material. But the horizontal relief was not connected with pockets and corners in the vertical soil profile. We are of the opinion that a differentiation of that kind was caused by decalcification and decolmatation in the periglacial zone during the postglacial period. The

Table. Genetical characteristics of soils formed on yellowish-gray moraine (after Reintam)

Characteristics	Horizons	n	$\bar{x}^a$	σ	$\sigma_{\bar{x}}$	$P_{0.95}$	V
pH_{KCl}	A_1	19	6.1***	0.6	0.1	4.4	9.5
	A_l	10	6.0**	0.7	0.2	7.9	11.0
	B_t	19	6.6***	0.4	0.1	3.2	6.6
	C	19	7.3***	0.4	0.1	2.5	5.3
Degree of base saturation (%)	A_1	15	82.1**	11.9	3.1	7.9	14.5
	A_l	9	76.6	14.4	4.8	14.6	18.8
	B_t	15	93.5***	5.8	1.5	4.4	6.2
	C	19	100.0***	0.0	0.0	0.0	0.0
$\frac{\text{Humic acids}}{\text{Fulvic acids}}$	A_1	13	0.7	0.2	0.1	19.2	31.9
	A_l	10	0.4	0.1	0.0	23.0	25.0
	B_t	14	0.3	0.1	0.0	28.7	33.3
Content of particles 0.001 mm	A_1	16	9.7	2.7	0.7	14.7	27.5
	A_l	10	8.2	2.0	0.6	16.5	24.4
	B_t	19	23.4**	3.9	0.9	8.0	16.7
	C	15	27.1**	3.1	0.8	10.3	18.4
$\frac{SiO_2}{R_2O_3}$ in soil	A_1	14	10.7***	0.8	0.2	4.1	7.5
	A_l	8	11.3***	1.0	0.3	6.4	8.8
	B_t	14	7.7***	0.9	0.2	5.6	11.7
	C	14	9.3**	1.3	0.4	9.3	14.0
$\frac{SiO_2}{R_2O_3}$ in clay	A_1	13	2.5***	0.2	0.1	5.4	9.0
	A_l	8	2.4***	0.1	0.0	4.7	5.7
	B_t	13	2.4***	0.2	0.0	4.1	6.8
	C	11	2.6***	0.3	0.1	6.9	10.1

[a] Allowable inaccuracy is 10% at the significance level of 90% (*), 95% (**), 99% (***).

character of these processes in some European soils was pointed out by Gerassimov [2].

Analytical data (Table) indicate a R_2O_3-fulvate humus character, a high degree of base saturation (60-90% in topsoil and more than 84% in the underlying part), a neutral or weakly acid reaction above (pH_{KCl} 4.9-7.0) and effervescing with dilute hydrochloric acid at a depth of 35-70 cm. An increase in the clay as well as iron content in the B-horizon and an accumulation of iron in the whole soil profile is shown by molecular relations and by analyses of Tamm's extract.

MICROMORPHOLOGICAL STUDIES

The micromorphological structure of yellowish-gray moraine shows pieces of dense calcareous rock (Fig. 1) and parts of highly dispersed minerals divided by winding fissures into aggregates of undetermined angular form. Calcareous rock pieces consist mainly of light-gray finegrained calcite, packed very dense, but also contain inclusions of quartz, feldspars, carbonates and other mineral grains. In the other parts of moraine, sand fragments are unevenly distributed in the light-brown or yellowish unoriented clay material.

Many small dots (up to 0.05 mm) and loose rounded formations (from 0.1 to 0.2 mm in size) are observed. On that kind of matrix soils have been formed by weathering, leaching, organic matter accumulation and humification. They have the following micromorphological characteristics.

The A_1-horizon has an irregularly blackish brown colour. The organic part consists of moder or moder-like mull humus and numerous more or

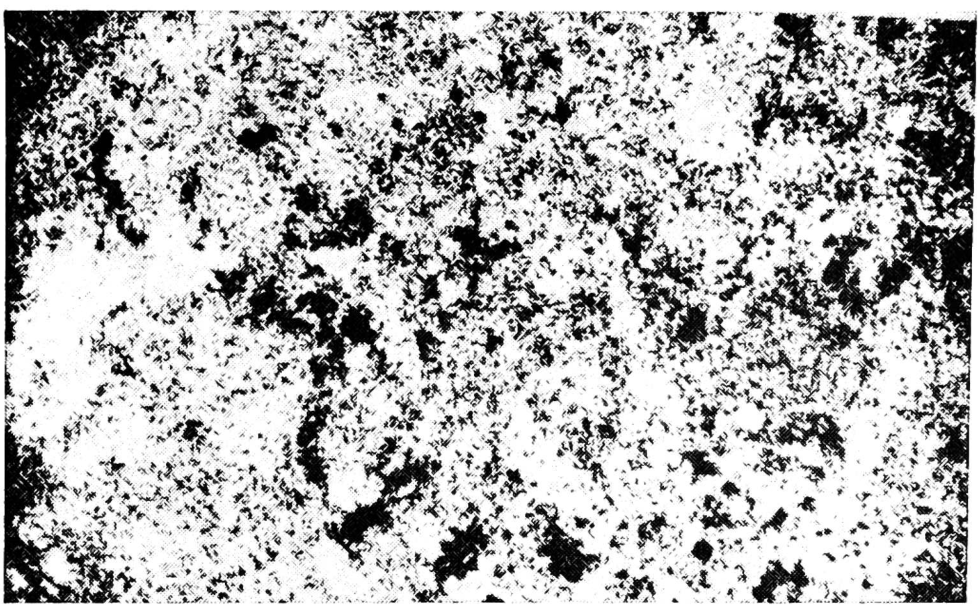

Fig. 1. Piece of calcareous rock with ferrous formations. Magnif. 9×10, N X.

less decomposed ferruginous plant residues. The organic and mineral parts are weakly bound. Well humified organic matter has gathered into small clots, which give the horizon a spotty appearance. The horizon has a loose fabric with numerous sinuous pores of undetermined shape. The size of mineral grains is predominantly < 0.2 mm, larger grains occupying about 15-25% of a thin section. They are mainly quartz and feldspars (predominantly plagioclase), a small amount of hornblende, epidote, granate, etc. Under 45× magnification some large grains (up to 5×10 mm) and ferrous-organic lumps with diffused edges are observed. The concretions of a dense packing of ferruginous clay, humus and mineral grains are very rare. Ferrous pseudomorphs are seen on feldspar grains.

In typical brown soils the humus horizon is followed by the B_t-horizon. The upper part of this horizon contains abundant plant residues, noticeably decomposed and ferruginous, and also fine humus material. Pores and fissures occupy about 8% of a thin section. There are quite large clayed areas in a thin section, the horizon has an irregular brown to yellow colour. Considerable claying has taken place, but most of the clay is characterized by the absence of double refraction, usually associated with iron and humus content. The highest degree of birefringence is observed in the cuffs surrounding mineral grains. Due to these cuffs the clay forms a net-like structure between sandy grains. A ferruginous fluidal structure of clay is rarely observed in pores.

In some parts of the B_t-horizon at a depth of about 25-40 cm the most intensive argillization has taken place. The whole of the plasma consists of relatively large patches with striated extinction patterns, the patches virtually adjoining each other. Large grains have plasma separations with striated extinction patterns associated with their surfaces. Perpendicular fibrous and criss-cross fibrous textures (Fig. 2) are most frequent. In the parts containing numerous sand and silt particles, the spaces between the sandy grains are filled with similarly arranged elongated scales of optically oriented clays and silt about 0.1-0.3 mm in size, forming a scaly texture. Along the cracks and pores, a flow structure of optically oriented clay can be observed in thin sections of this part, but not very often. The clay shows a higher doubly refracting ability and orientation degree than above.

Loose clay and iron formations are noted and on several mineral grains ferrous pseudomorphs are seen.

In brown lessivé soils the humus horizon is followed by an eluvial horizon of lighter colour and varying depth (up to 35-55 cm). Plant residues and humus traces are frequently observed. Sometimes there is an almost twice greater quantity of larger grains than in the A_1-horizon. The clay fraction has no uniform distribution. Clay is yellow, almost isotropic, and forms cuffs around mineral grains; it is coalesced into clots of 0.1 to 0.5 mm. A few yellowish-brown small parts of optically oriented clay with a scaly structure are observed against a mottled background.

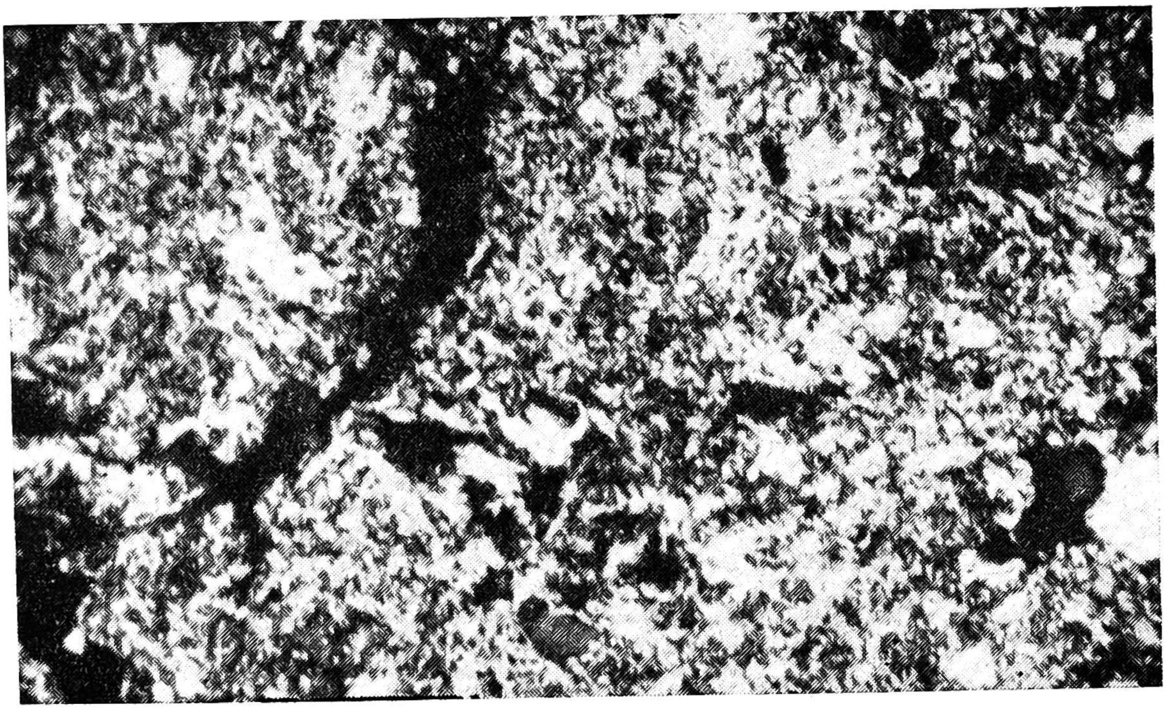

Fig. 2. The clayed part of the B-horizon. Magnif. 9×10, N X.

Fig. 3. Flow structure of optically oriented clay in B-horizon. Magnif. 9×10, N II.

The B-horizon has a yellowish-brown non-uniform colour. The upper part contains plant residues; clay clots are observed in thicker parts. Clay is optically oriented to a different extent, primarily having a lattice structure. In the parts which are rich in clay material, the criss-cross fibrous texture is most frequent. In the medium part of the B-horizon a flow structure of optically oriented clay (Fig. 3) can be observed along the numerous cracks and pores, having a reddish-brown or dark-brown colour (associated with iron hydroxides). A parallel-fibrous structure is found near the pores (Fig. 4) and a criss-cross fibrous structure of highly dispersed mineral material is observed inside the clayed parts. The yellow colour of clay near the pores indicates a decrease in the iron content.

Fig. 4. Parallel-fibrous structure of clay. Magnif. 9×10, N X.

Numerous dark-brown dots and larger loose formations in the horizon. In the lower part the diminishing of the clay quantity and of double refraction is observed.

Thus we see that a wide variety of micromorphological clay structures caused by several processes are taking place in these soils. Perpendicular-fibrous and criss-cross fibrous structures of optically oriented clay are connected with intrasoil weathering [3, 4], while the flow structure is due to illuviation [1, 3]. The variability of the clay colour and the formations of iron hydroxides show the movement of iron and its simultaneous accumulation in the soil horizons. This is also confirmed by mineralogical studies since red-brown iron hydroxide coatings are observed on feldspars and carbonates. Mineral grains indicate signs of intensive weathering in all soil horizons. Data on clay fraction studies indicate an abundance of hydromicas and a small quantity of kaolinite inherited from moraine components. Chlorites are often noticed and vermiculite or mixture-layered minerals are found in the topsoil of some profiles. Accumulation of crystalline iron hydroxides is pronounced in the soil profile and particulary in the B-horizon.

CONCLUSIONS

Micromorphological studies of soils on calcareous yellowish-gray moraine carried out in connection with their chemistry and mineralogy show that various processes have taken place or are taking place in these soils. They include:

1. The differentiation of soil profiles as a result of soil-geological phenomena.
2. Decrease of the carbonate content in the soil profile by leaching.
3. The brunizem-process implying accumulation of R_2O_3-fulvate complexes and intrasoil argillization.
4. Lessivage, which is proved by a homogeneous chemical composition and the translocation of clay-iron complexes.

SUMMARY

The micromorphology of brown forest soils and soils bruns lessivés of biolithogenic origin was investigated in connection with their chemistry and mineralogy.

Micromorphological investigations of soils may be summarized as follows:

1. The micromorphology of parent material shows gray compacted carbonate rock which contains grains of quartz, feldspars, epidote, calcite, etc., and some loose clayed material in cracks.

2. The organic part consists of moder or moder-like mull humus and numerous more or less decomposed ferruginous plant residues.

3. The mineral skeleton mainly consisting of quartz and feldspars has a loose fabric and a nonuniform distribution.

4. The distribution of finely dispersed soil material is irregular, argillization has taken place in varying degrees. In the upper horizons (particularly in the typical brown soils) the clay in unoriented and has a clotty character.

5. Some structural types of anisotropic clay with varying degrees of orientation are observed. Clay has a high double-refraction in the cuffs surrounding mineral grains in all profiles. Due to these cuffs the clay forms a net-like structure in places rich in mineral grains. In the other parts parallel-fibrous or cross-fibrous structure of more or less oriented clay is found. In soils bruns lessivés numerous pores are partially filled with flow structures.

6. Neoformations are the following: dark-brown dots and loose clots of ferrous hydroxides, rarely some concretions and membranes on mineral grains in the upper horizons. Secondary iron gives a yellow-brown colour to all the clay found present in soils.

7. These micromorphological characteristics, including argillization *in situ*, lessivage and burozem-formation, are confirmed by the data of chemical and mineralogical analyses.

REFERENCES

1. Brewer R., Haldane A. D., 1957. Preliminary experiments in the development of clay orientation in soils. Soil Sci. 84, 4.
2. Gerassimov I. P., 1960. Soils of Central Europe and questions of physical geography connected with them. Moscow, (Russian).
3. Minashina N. G., 1958. Optically oriented clays in soils. Pochvovedenie 4, (Russian).
4. Parfenova E. I., Yarilova E. A., 1958. Problems and methods of microscopic soil-mineralogical investigations. Pochvovedenie 12, (Russian).
5. Reintam L., 1967. Some aspects of the genesis of Estonian soils. Transactions of Estonian Agricultural Academy 55, (Russian with summaries in Estonian and English).
6. Shleinis R. A., 1965. On humus composition of soils of oak stands in the Lithuanian S.S.R. Pochvovedenie 6, (Russian).
7. Zonn S. V., 1966. On the Brown Forest and Brown Pseudo-Podzolic Soils in the North-West Region of the U.S.S.R. Transactions of Estonian Agricultural Academy 49, (Russian).