THIRD INTERNATIONAL WORKING-MEETING ON SOIL MICROMORPHOLOGY
WROCŁAW, 1969

ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1972 z. 123

Micromorphology of cinnamonic and meadow cinnamonic soils of Georgia

E. K. NAKAIDZE

The Vakhushty Institute of Geography, Academy of Sciences of Georgian S.S.R., U.S.S.R.

Cinnamonic soils were first described as original soil formations by Zakharov [6] in Georgia in 1904. But this accurate suggestion of Zakharov was neither duly recognized, nor developed, although it had a definite influence on view-points of several researches. His interesting ideas were forgotten for many years to come.

In all the works following, cinnamonic soils were not separated into a special type; they were usually observed in the general group of brown soils and were distinguished under the heading of "dark brown soils" [11] or saturated dark-brown forest soils [8].

The priority of reestablishment of the genetic independance of cinnamonic soils as a type belongs to Gerasimov [1, 2, 4]. The analysis of the literature available, and his own materials enabled Gerasimov to prove the genetic independance of cinnamonic soils and to reveal the geographical areal of their distribution. Soil-geographical observations carried out by Gerasimov [3-5] on the territories of Bulgaria, North Africa, Greece, Yugoslavia and other countries and continents showed that the cinnamonic soils have widespread distribution. On this basis he considered that the genetic type of cinnamonic soils is the most characteristic soil formation for all the mediterranean and submediterranean territories, which have altogether, rather similar bioclimatic conditions of soilformation.

Cinnamonic soils in Georgia occur in the eastern piedmont and low-hilly parts of the country. Their zonal distribution is as follows: in the lower part of the belt they border with black soils (greatly resembling Bulgarian smolnitzes), in the upper part the cinnamonic soils change into brown forest soils.

The cinnamonic soils of Georgia are being formed under the conditions of variably humid climate, for the most part on calcareous rocks under the oak and oak and hornbeam "dry" woods, and at the same time under the brushwood and meadow and steppe vegetation. The average annual temperature in the area of their distribution is equal to 9-12°C, average January temperature 0-2°C, average July temperature 20-22°C. The quantity of rainfall is 500-700 mm. The main share of rainfall comes on spring, constituting 40% of the annual amount; minor maximum coming on autumn. Cinnamonic soils develop with the nonleaching water regime and in case of deep occurrence of ground water.

Meadow cinnamonic soils are frequent in occurrence in the zone of cinnamonic soils and are being formed under the conditions of increased humidity (ground, surface or mixed). They are met with on lowlands at the foots of mountains and on river terraces. The soil forming rocks are — alluvial or talus-colluvium deposits. Natural growth — meadow-steppe vegetation. A considerable part of meadow-cinnamonic soils receives an additional moistening through irrigation.

Characteristic features of cinnamonic soils as a soil type are [9]:

— deep penetration of soil forming processes and a considerable thickness of soil profile (in cases when it is not hampered by compact rock);

— a rather high humus content of upper horizons (4-7% under the natural vegetation) and a comparatively deep penetration of humus matter down the profile of the soil (up to 0,8% of humus at the depth of 1 m), high degree of claying of the whole profile, especially in the middle part of it;

— comparatively narrow molecular relations SiO_2:R_2O_3 (4-5) and usually a certain narrowing of this relativity in the middle of the profile;

— the tendency of clay formation in cinnamonic soils in the direction of montmorillonitization determines the formation of colloid complex with a high capacity of absorption;

— neutral or weakly leached reaction in upper horizons and leached in lower ones (see Table).

Micromorphological analyses of sections of genetic horizons of cinnamonic soils revealed, that the microaggregate structure of the humus horizon was of the first, more rarely of the second order. The middle part of the profile of these soils is divided into fragmentary units formed obviously as a result of a periodical modification of the bulk of soil mass by periodical wetting and drying. Thin dispersed humus is closely connected with clayey particles, sometimes humus formations are observed. The upper part of humus horizon contains in small amounts vegetation remnants to different degree, deeper their content abruptly diminishes. Cinnamonic soils are characterized by a considerable claying of the whole profile and especially of its middle part. The structure of the optically oriented clay is fibrous with flaky elements or parallel (Fig. 1a). Rarely in pores sintered optically oriented clays are to be observed (Fig. 1b). High clayization of the whole profile of cinnamonic soils, especially of

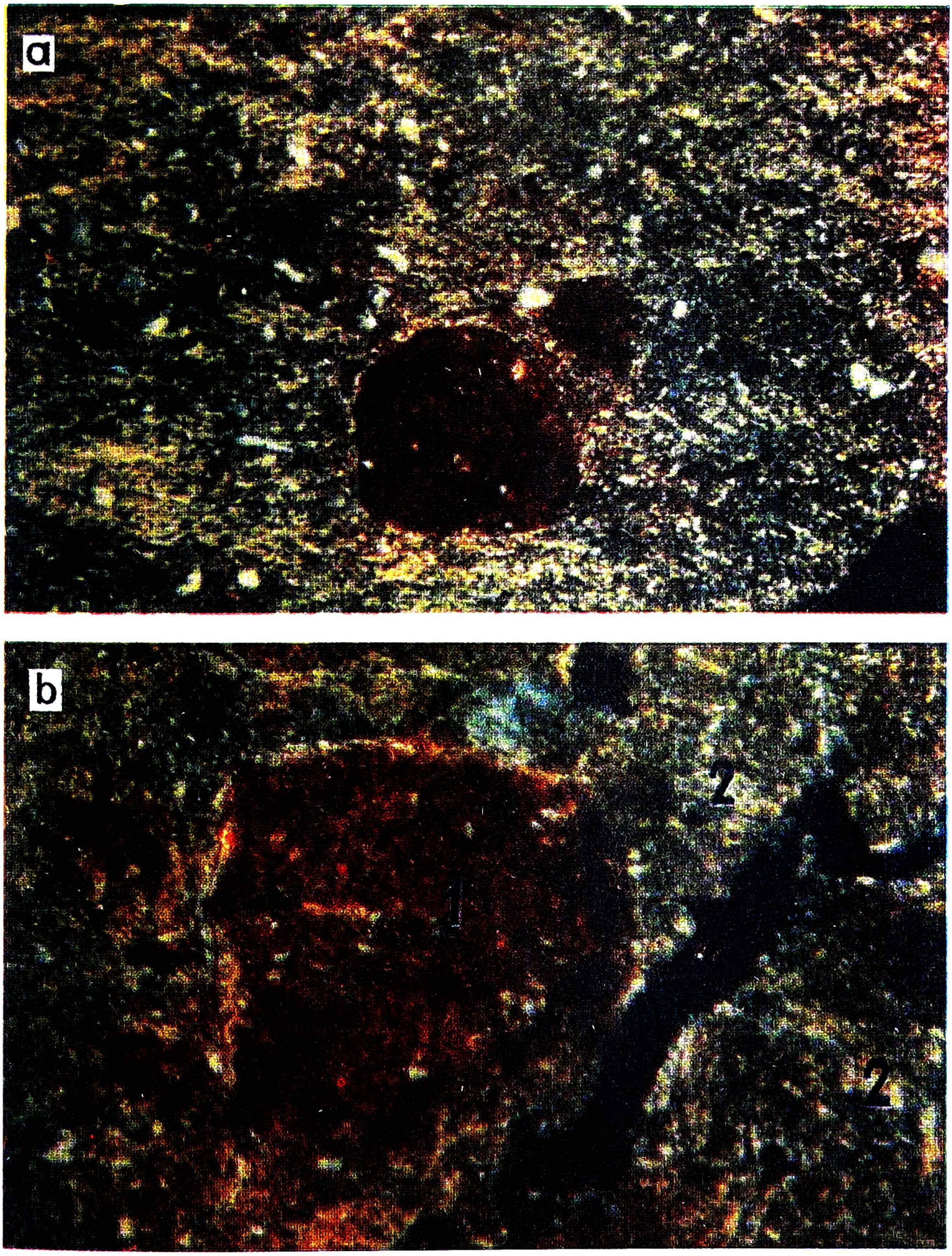


Fig. 1 *a*, *b*. Microstructure of cinnamonic soils. *a* — parallel orientation of clay and round rusty ferrous formations (depth 10 cm, Nicols +); *b* — horizon of claying, ferrous formations (1), optically oriented clay (2), (depth 60 cm, Nicols +).

Table. Analyses of cinnamonic and meadow-cinnamonic soils of Georgia

Soil	Depth cm	Humus %	<0.001 mm	<0.01 mm	$\frac{SiO_2}{R_2O_3}$	$CaCO_3$ %	pH water
	0-10	6.9	29.5	62.4	4.49	No	6.8
Cinnamonic	20-30	3.1	32.1	68.1	4.22	,,	6.5
leached	50-60	1.2	41.7	70.2	4.09	,,	6.6
	80-90	0.8	37.4	69.9	4.23	,,	6.9
	110-120	—	26.8	60.8	4.95	24.6	7.6
	0-10	5.2	32.3	58.6	5.13	No	6.9
Cinnamonic	20-30	2.3	30.7	63.1	5.01	,,	6.7
typical	50-60	1.0	40.0	66.7	4.82	,,	7.1
	70-80	0.9	34.2	59.0	4.90	10.1	7.3
	100-110	—	28.7	60.4	5.44	18.2	7.6
	0-10	4.5	28.1	60.9	5.66	2.4	7.2
Cinnamonic	15-25	2.2	31.3	64.7	5.44	7.5	7.3
carbonate	45-55	1.1	33.2	62.9	5.51	6.8	7.3
	65-75	0.7	30.5	63.1	5.78	10.7	7.5
	120-130	—	27.6	56.3	6.12	20.4	7.8
	0-10	3.8	40.1	77.6	5.00	5.6	7.6
Meadow	25-35	1.2	43.0	76.1	5.20	7.8	7.5
cinnamonic	55-65	0.9	42.4	78.8	5.09	10.9	7.7
	80-90	—	44.1	75.3	5.15	15.6	7.8
	130-140	—	43.7	74.0	5.24	16.8	7.8
Meadow	0-10	2.4	44.9	69.9	5.74	9.5	7.6
cinnamonic	15-25	1.3	39.5	71.3	5.82	11.8	7.7
	50-60	0.7	43.7	74.1	5.91	16.0	7.7
	90-100	—	44.3	72.4	5.67	18.4	7.9
	120-130	—	31.9	62.8	6.03	19.1	7.9

its middle part, determining the increased content of slimy fraction (see table), is mainly due to intra-soil weathering.

However, we can't deny the fact, that the spreading of mechanical elements along the profile is influenced by side waters. The cinnamonic soils are marked with a high degree of iron accumulation of the whole soil mass with the maximum in the middle part of the profile. Oval formations of iron can be traced (Fig. 1a, b). They are clearly expressed in the humus horizon (Fig. 1a); but in horizons of maximum claying they are characterized by diffuse edges or microconcretions of diffuse character (Fig. 1b). Calcium carbonates are washed into the horizon C and form calcareous illuvial horizon in the cinnamonic soils. High percentage of carbonates in the illuvial horizon is the result of weathering and soil formation as well as carbonate supply from the outside (Fig. 1d).

It is necessary to note here, that in some places of the cinnamonic soil belt the recent evolution of landscapes is directed towards a tendency

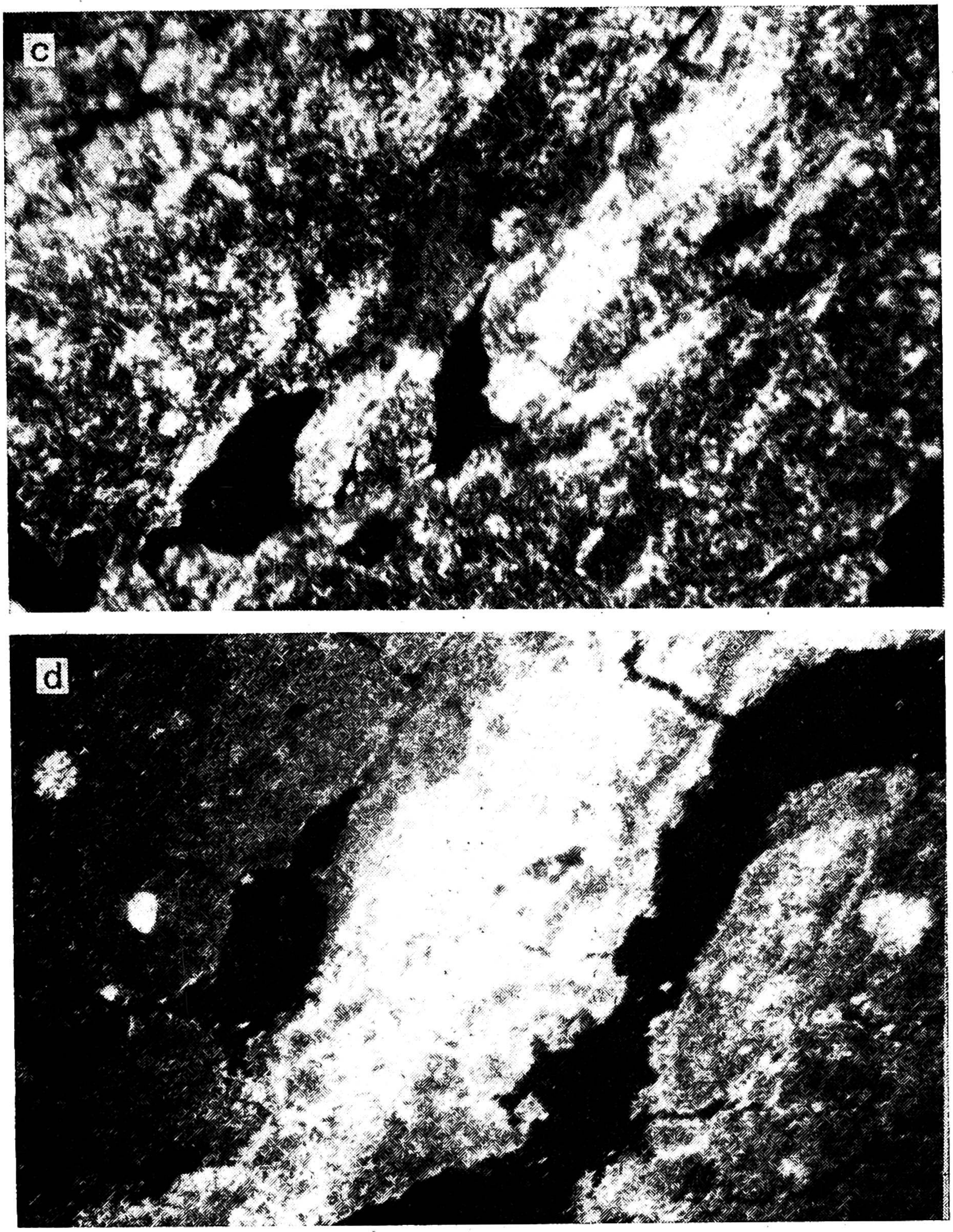


Fig. 1 *c, d.* Microstructure of cinnamonic soils. *c* — sintered clay in the lower part of the horizon of claying (depth 80 cm, Nicols +); *d* — microcrystalline calcite on the walls of pores in a carbonate-illuvial horizon (depth 110 cm, Nicols +).

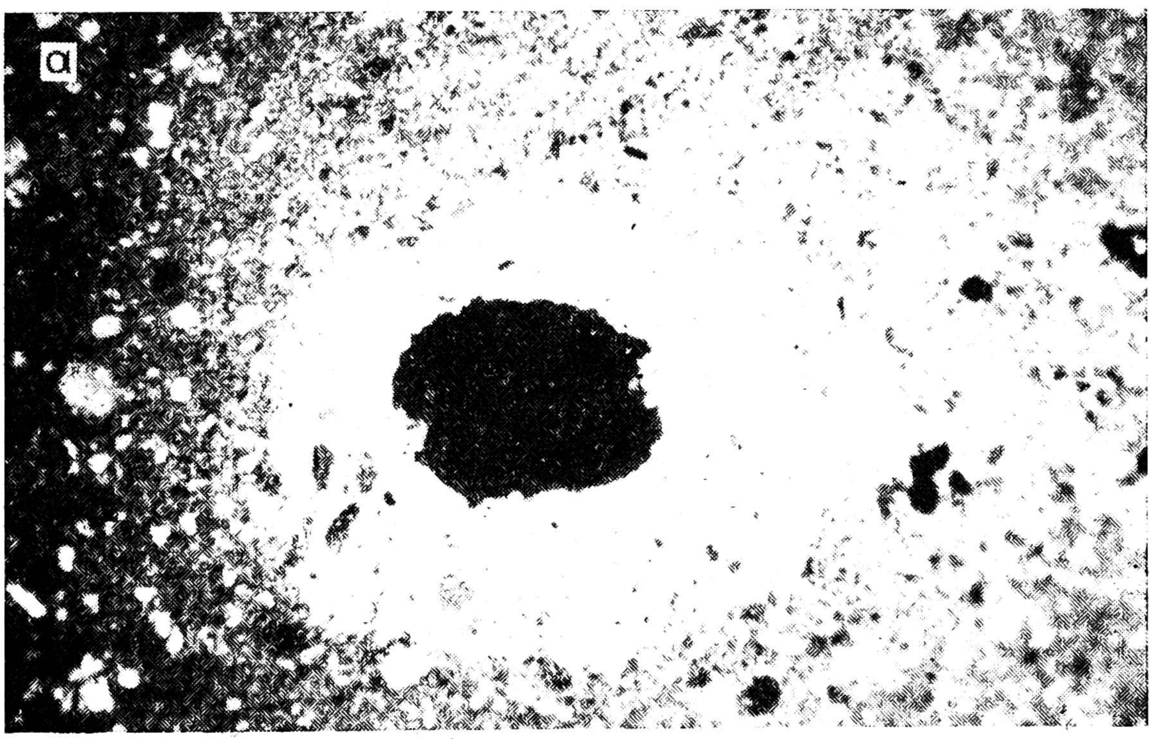
of transformation into steppe, as a result of economic activities of people. Thus in these places the cinnamonic soils once again accumulate carbonate and contain calcium carbonates from the very surface. The carbonates hamper or considerably reduce the destructive effect of weathering agents on the lattice of minerals. The clay formation is most intensive in cinnamonic leached soils in weakly acid and neutral medium, which leads to gradual reduction of the claying degree of the middle part of the profile of cinnamonic soils, from leached ones, through weakly leached (typical) to carbonate soils. In connection with this the cinnamonic soils are divided into three subtypes — leached, weakly leached (typical) and carbonate. • In cinnamonic leached soils the initial signes of lessivage processes (Fig. 1c) are observed, expressed by sintered forms of oriented clays.

Following characteristic features are common for the meadow-cinnamonic type of soil [10]:

— generally a considerable thickness of the soil profile somewhat surpassing the thickness of profile of cinnamonic soils;

— more or less high degree clayzation; the presence of dove-coloured or rusty stains in the whole profile or in the lower part of it;

— high degree of claying of the whole of soil profile, often somewhat more intensive than in cinnamonic soil;



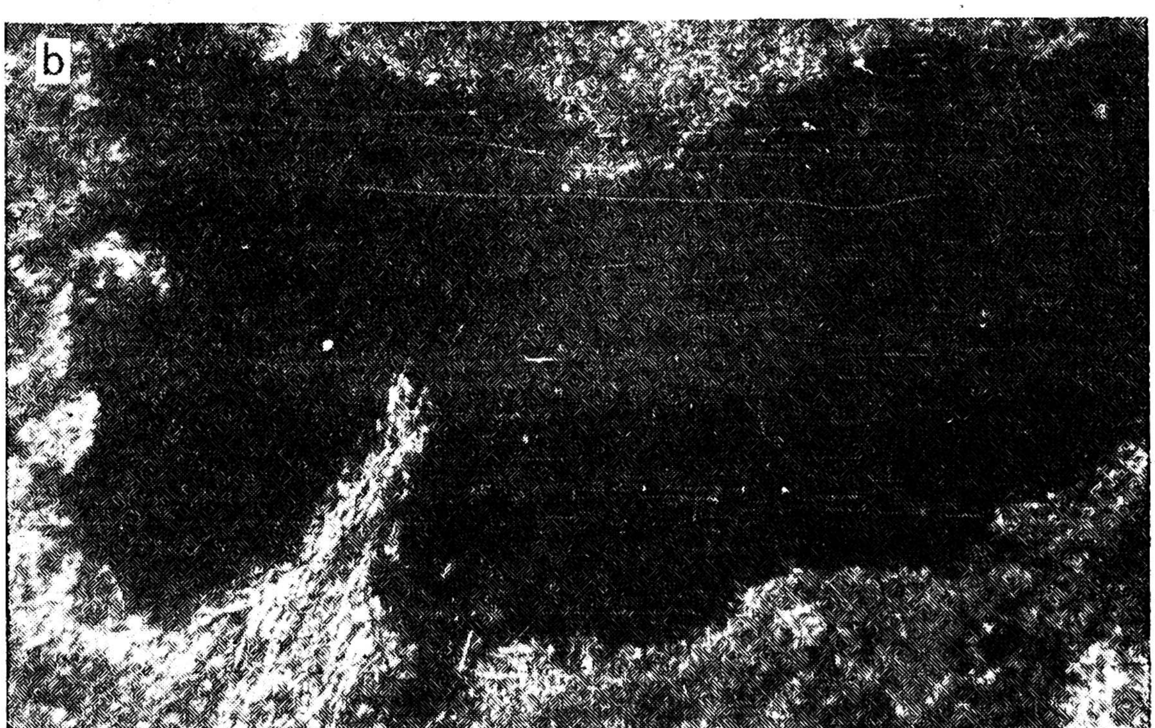


Fig. 2*a*, *b*. Microstructure of meadow-cinnamonic soils. *a* — microcrystalline calcite around the pore (depth 120 cm, Nicols +); *b* — lublinite around the pore (depth 120 cm, Nicols +).

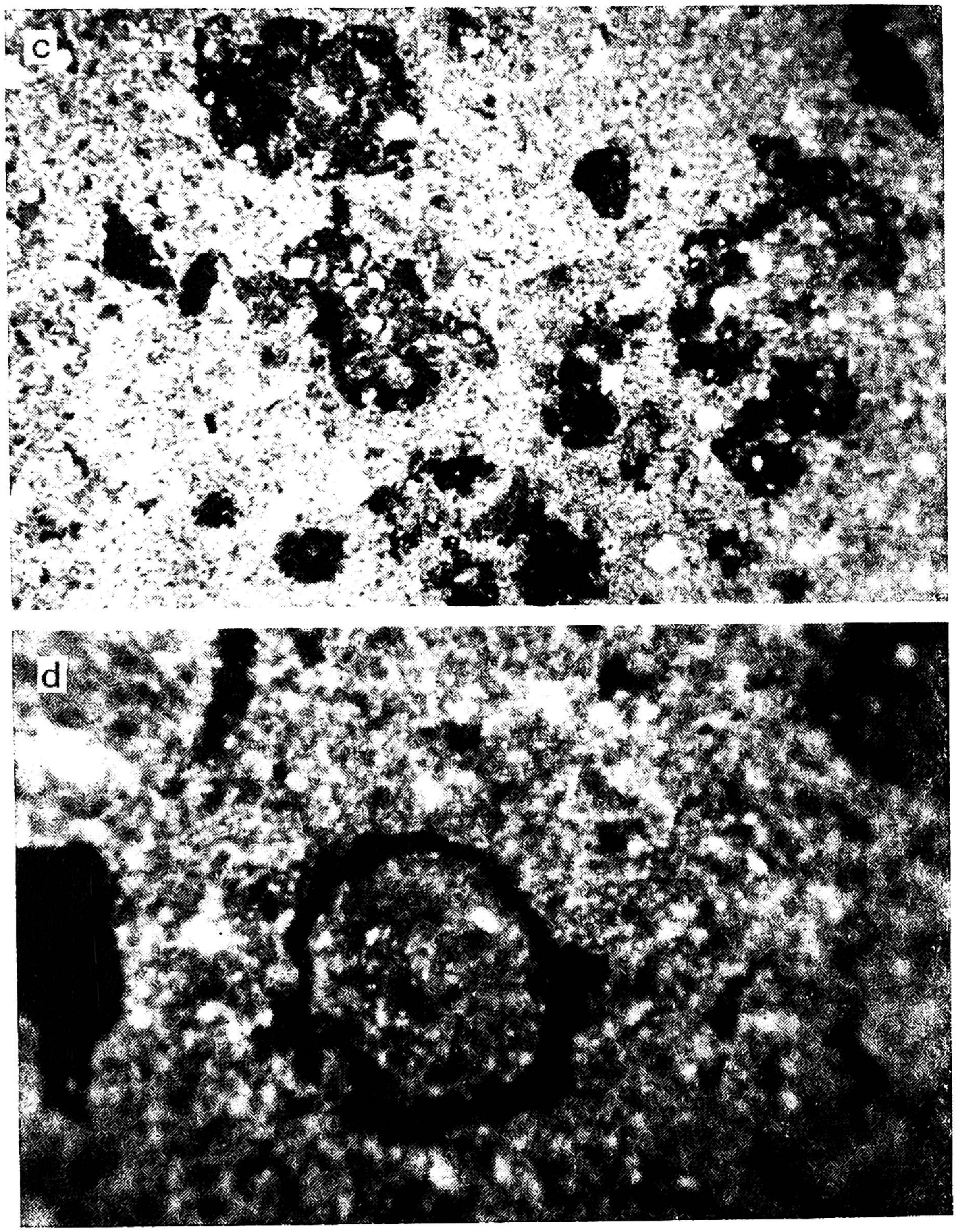


Fig. 2*c*, *d*. Microstructure of meadow-cinnamonic soils. *c* — flaky formations of iron (depth 120 cm, Nicols +); *d* — diffused ferrous ring with condensation on the periphery (depth 140 cm, Nicols +).

— comparatively low humusness of upper horizons (about 2-4%);

— uniform distribution of silicon acids and sesqui acids in the profile with the relation of SiO_2:R_2O_3 same as with the cinnamonic soils;

— the low capacity of absorption with its gradual decrease down the profile;

— a weak alkali reaction in upper horizons and a weak alkali or alkali reaction in the lower ones (see the table).

Micromorphological analyses of the sections of genetic horizons of meadow-cinnamonic soils have revealed that the microaggregation of their humus horizon is weakly expressed. The soil itself is characterized by low porosity. Small content of vegetation remnants indicates their intensive decaying. The humus is thin dispersed, in a small quantity. In some places the humus is distributed unevenly, often in the form of clusters, rarely — in the form of point segregation.

Movement of the humus over the profile does not take place. Grains of primary minerals are small in number, they are submerged into the dense, main thin-dispersed mass cemented by calcium carbonates. In the humus horizon, where the saturation of soil by carbonates is low, optically oriented clay of flaky structure is to be found. In meadow-cinnamonic soils calcium carbonates are met with from the very surface, with growing depth, their content increases. Microcrystalline calcite is diffused in a thin-dispersed mass, which indicates a high concentration of the solution, as a result of which its salts separate before the solution reaches the pores. In lower horizons there are incrustations of microcrystalline calcite on the pore walls which is due to nearness of bicarbonnate calcite ground waters. Microcrystalline calcite is formed as a result of precipitation calcium bicarbonnate out of the soil solution during the evaporation inside the thin dispersed mass [7]. At high concentration of the solution, eflorescence have microcrystalline form (Fig. 2a), and at the low one — the form of thin, long needles i.e. needle crystalls of calcite (Fig. 2b). These forms of newly formed calcite, are mainly observed in pores; their formation in meadow-cinnamonic soils is promoted by intensive evaporation. In the horizons having the immediate contact with ground waters, ferrous stains of dark-brown or black colours are met with (Fig. c, d). The dark portions of ferric oxide have an irregular form, often with more solid flaky formations, inside them. At the rims the ring is usually more solid, but the inside part of it is smaller and lighter in colour (Fig. 2d).

Meadow-cinnamonic soils are formed on loose (alluvial), sedimentary rocks, which contain mainly, the most stable primary minerals (e.g. quartz etc.), which in the stratum of soil turn out to be a rather conservative element. The influence of weathering and soil formation are manifested here, mainly through a further destruction of resistant, residual primary minerals and a partial transformation of the secondary (clayey) minerals. All this, without doubt, explains the absence of the claying horizon in the meadow-cinnamonic soils, which is the most characteristic feature of the cinnamonic soils.

SUMMARY

Micromorphological investigations of cinnamonic soils of Georgia (U.S.S.R.) have shown that the microaggregation of their humus horizon is that of the first order. The middle part of the profile is divided into fragmentary separates. The structure of the optically oriented clay is

fibrous with flaky elements in the upper humus horizon. Cinnamonic soils are divided into three subtypes: leached, typical (weakly leached) and calcareous soils. In cinnamonic leached soils the initial signs of lessivage processes can be observed, which manifest themselves in sinter forms of oriented clays. Iron accumulations in the whole profile of cinnamonic leached and typical soils are also observed. In cinnamonic calcareous soils there is noted a secondary carbonate accumulation of the upper humus horizons. A high content of carbonate in the illuvial horizon is a result of weathering and soil formation as well as carbonate supply from the outside. Also is noted a gradual decrease of the degree of clay accumulations in the middle part of cinnamonic soils from the leached to typical ones. In connection with this, the differentiation of profiles in cinnamonic leached soils is evinced better than in cinnamonic typical soils while in cinnamonic calcareous soils it is weakly expressed. Clay formation is the most intensive one in cinnamonic leached and typical soils in a subacid and neutral medium. In the cinnamonic calcareous carbonates hinder or considerably reduce the destructive influence of weathering agents upon the lattice of minerals.

The microaggregation of the humus horizon is weakly expressed in meadow-cinnamonic soils in contrast to cinnamonic soils. The structure of the optically oriented clay is scally in places where there are no carbonates. In meadow-cinnamonic soils there is observed a rise of carbonates from lower layers and their separation in the shape of various new-formations. Carbonate enrichment of these soils takes place at the expense of bicarbonate-calcareous ground waters. In the lower soil horizons the processes of iron accumulation are noted. The degree of their display depends on the flowage of ground waters. Meadow cinnamonic soils are formed on loose sedimentary rocks, composed of most stable primary minerals (i.e. quartz, etc.) which turn to be sufficiently conservative elements in the soil strata. The influence of the weathering and soil genesis manifest themselves in subsequent destruction of stable residual primary minerals and in partial transformation of secondary (clay) minerals. All this, undoubtedly, conditions the absence of the clayization horizon which is one of the most typical characteristic of cinnamonic soils.

REFERENCES

1. Gerasimov I. P., 1949. Cinnamonic soils of dry forests and brushwood meadow-steppes. (V. V. Dokuchaev soil Institute's papers, vol. 30). In book: Materials in geography and cartography of soils of U.S.S.R. M-L.
2. Gerasimov I. P., 1954. Cinnamonic soils of the Mediterranean area. Papers at the V International Congress of Pedologists. Published by the Academy of Sc. U.S.S.R.
3. Gerasimov I. P., 1956. The Soils of African Mediterranean. In book: Papers of

the V International Congress of Pedologists. V commission, Classification of soils. M.

4. Gerasimov I. P., 1959. Essays on the Physical Geography of Foreign Countries. Geografizdat, M.
5. Gerasimov I. P., 1964. About the Soils of Greece. In book: The Soils of South-East Europe. Published by the Bulgarian Academy of Sc. Sofia.
6. Zakharov S. A., 1924. About the Chief Results and the Main Problems of the Study of Soils of Georgia. Published by Tiflis Politechnical Institute, publ. 1, Tiflis.
7. Kubiëna W. L., 1938. Micropedology. Ames, Iowa.
8. Mikhailovskaya O. N., 1936. About Genesis of Brown Forest Soils of Transcaucasia. Collection of Soviet Subtropical Soils. M.
9. Nakaidze E. K., 1967. About Genesis of Cinnamonic Soils of Georgia. Pedology 6.
10. Nakaidze E. K., 1968. About genesis of meadow-cinnamonic soils of Georgia. Pedology 12.
11. Prasolov L. I., 1947. Mountain-forest soils of the Caucasus. Papers of the Soil Institute of the Academy of Sc. of the U.S.S.R. vol. XXV.