THIRD INTERNATIONAL WORKING-MEETING ON SOIL MICROMORPHOLOGY
WROCŁAW, 1969

ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1972 z. 123

Micromorphological peculiarities of fossil soils and some problems of paleogeography of the Mikulino (Eem) Interglacial on the Russian Plain

T. D. MOROZOVA

Geographical Institute of the Academy of Sciences of the U.S.S.R., Moscow, U.S.S.R.

The study of buried soils is of great interest for reconstruction of paleogeographical conditions at the time of their formation. Soil as a genetic type develops under the influence of a certain combination of natural factors, first of all of climate and vegetation. Thus, fossil soils are a rather exact indication of physico-geographical conditions under the influence of which the soils have developed.

This investigation has been carried out at the Institute of Geography of the Academy of Sciences of the U.S.S.R. on the basis of studying Upper Pleistocene buried soils in the thick loess of the Dnieper's left bank. Some data on the structure of the fossil soils of the Mikulino (Eem) Interglacial for this territory have been published previously [1, 6]. However, new data, obtained later, made it possible to introduce some essential changes and additions to a scheme suggested earlier.

METHODS OF INVESTIGATION

Buried soils, no longer under the influence of the biosphere, represent formations which have undergone the influence of diagenetic processes. Due to this, they have acquired a number of new features, not characteristic of their initial appearance and making their interpretation more difficult. This specification of fossil soils has been many times emphasized by Gerasimov [2], Glazovskaya [4], and other scientists. Such secondary features include, first of all, a considerable change of their salt profiles at the expense of a secondary sedimentation of carbonates and gypsum, gleification and ferritization, change of soil structure due to the pressure of cover deposits, transformation of organic matter resulting from nearly a complete decomposition of vegetation remnants (even in the case of organic matter-rich horizons), and other secondary processes depending on the influence of permafrost. These peculiarities of fossil soils recquire a special approach to their study.

To define genetic types of the soils we studied them with the help of a complex of methods. A detailed morphological description of genetic profiles was carried out in natural outcrops. While defining their chemical composition, we took into consideration the bulk composition of the soil and colloids, carbon dioxide of carbonates, general content and a group composition of humus [7].

However, analyzing the results of many years of investigations, we came to the conclusion that the most efficient method of studying buried soils is a micromorphological one [11]. Soils were studied in oriented thin sections by means of a polarizing microscope. We have chosen this method because a number of features of the soil's microstructure are very stable. Therein we may include microstructure of aggregates, shapes of pores, microstructure of clay matter, and some clay-humus formations.

Stability of the main features of soil fabric, determining genetic types of soils, in relation to a time-factor and diagenesis, makes it possible to raise a question of their use for studying present-day soils. Good results may be achieved, for instance, by singling out relic features of soils, which often cannot be done only on the basis of soil morphology and chemical composition.

SOME PECULIARITIES OF PALEOGEOGRAPHY OF THE MIKULINO (Eem) INTERGLACIAL

Epochs of accumulation and formation of loesses in the Upper Pleistocene in East Europe have repeatedly been interrupted by different periods of soil formation. In this connection, most strongly pronounced was the Mikulino (Eem) Interglacial, when a thick polygenetic soil — Mezinsk Complex — formed above the Upper Pleistocene loesses.

This soil horizon is well preserved and can be found along nearly the whole periglacial zone of the East-European Plain, beginning from the border of the Moscow Glaciation and up to the northern coast of the Azov Sea.

Natural conditions of the Mikulino Interglacial were determined by a maximum influence of oceanic climate (during the phase of a climatic optimum), conditioned by a broad development of marine transgressions. At that time, in the North Europe, there was a large archipelago of islands, washed by waters of epicontinental seas which penetrated deep into the continent. In this connection, the increase of the degree of continentality to the east was much lesser than at present [5]. This peculiarity of climate has been reflected in the structure of interglacial soils.

It must be emphasized that the thickness of ancient soils surpassed that of the present-day soils of the same genetic types, which is probably conditioned by a greater duration of the Interglacial (120,000-70,000 years ago), and the complex history of the development of nature at that time.

As the present-day soils of the East-European Plain, the ancient soils considered here are subjected to the law of a horizontal zonality in their distribution. The general feature of the horizontal zonality of soils is a southward intensification of the influence of sod formation, associated with the emergence of a steppe landscape.

The lower part of the Mezinsk Complex in the Middle of the East-European Plain is characterized by soils of a forest type of soil formation, in the north (Bryansk region) by pale podzolic, lessivé, (a strip between Trubchevsk and Krolevets) — pseudo-podzolic soils. The development of thick humus horizons corresponds to the time of formation of the upper part of the Mezinsk soils' thickness. The formation of these humus horizons could probably take place only with the participation of an abundant herbaceous vegetation. Binomiality of the Mezinsk Complex is best seen in the middle part of the East-European Plain. To the south of the latitude of Putivl town, contrasting features of soil formation of the upper and lower parts of the soil thick are not so distinct, and at present the signs of the binomiality of soils are difficult to single out.

PECULIARITIES OF SOIL STRUCTURE OF THE MIKULINO INTERGLACIAL'S FIRST PHASE OF SOIL FORMATION

In the first phase of the Mikulino Interglacial, soils formed under forest vegetation. They were pale podzolic, lessivé and pseudo-podzolic soils. By this time, humus horizons of these soils disappeared. Pale podzolic soils (Bryansk region) morphologically were characterized by a sharply differentiated genetic profile, consisting of a greatly bleached whitish-pale 20-25 cm horizon, with abundant iron ortstein, and an illuvial horizon (1.2-1.5 m). The latter consists of yellowish-brown loam of a vescular-cloddy structure with an abundant silicon oxide powdering along the edges of a structural fragments and cracks.

According to micromorphological data, these soils are characterized by a strongly impoverished horizon A_2 in a finely-dispersed plasma and with a leaf-like fabric, an abundance of compact non-transparent micro-ortsteins and rare cutans of optically oriented clays. The illuvial horizon was non-uniform in fabric and contained much clay matter which had been brought from a bleached horizon. This brownish-yellow optically oriented clay filled the spaces between mineral particles, and outlined cracks and pores. In the pores, there formed reddish or brownish-yellow homogeneous transparent cutans of optically oriented clays with a small admixture of dark humus particles.

The genetic profile of fossil soils lessivé (Novgorod-Seversky district) consists of a brownish-grey laminar (in some places) horizon A_2 and an illuvial horizon of about 2 m thick, consisting of a yellowish-brown cloddy and compact loam. Micromorphological investigations show an impoverishment of horizon A_2 in clay matter, disaggregation of its soil mass,

Fig. 1. Cutans of optically oriented clays in the illuvial horizon of the fossil pale podzolic soil, Bryansk. Magnif. 17,5×9, one nicol.

Fig. 2. Deposits of optically oriented clays in pores in horizon B of the fossil soil lessivé, Novgorod-Seversky. Magnif. 17,5×9, one nicol.

an abundance of spots of leaching which lack clay matter, and an abundance of iron microortsteins. On the contrary, the illuvial horizon is characterized by a concentration of reddish-brown clay cutans with opaque inclusions of humus particles. Rather similar fabric of lessivé soils (parabraunerde) of the Eem time on the territory of Czechoslovakia was described by Smolíková [12].

Pseudogley (pseudo-podzolic) soils were associated with low elements of relief (Village Mezin). Their profile consisted of horizon A_2 — whitish-

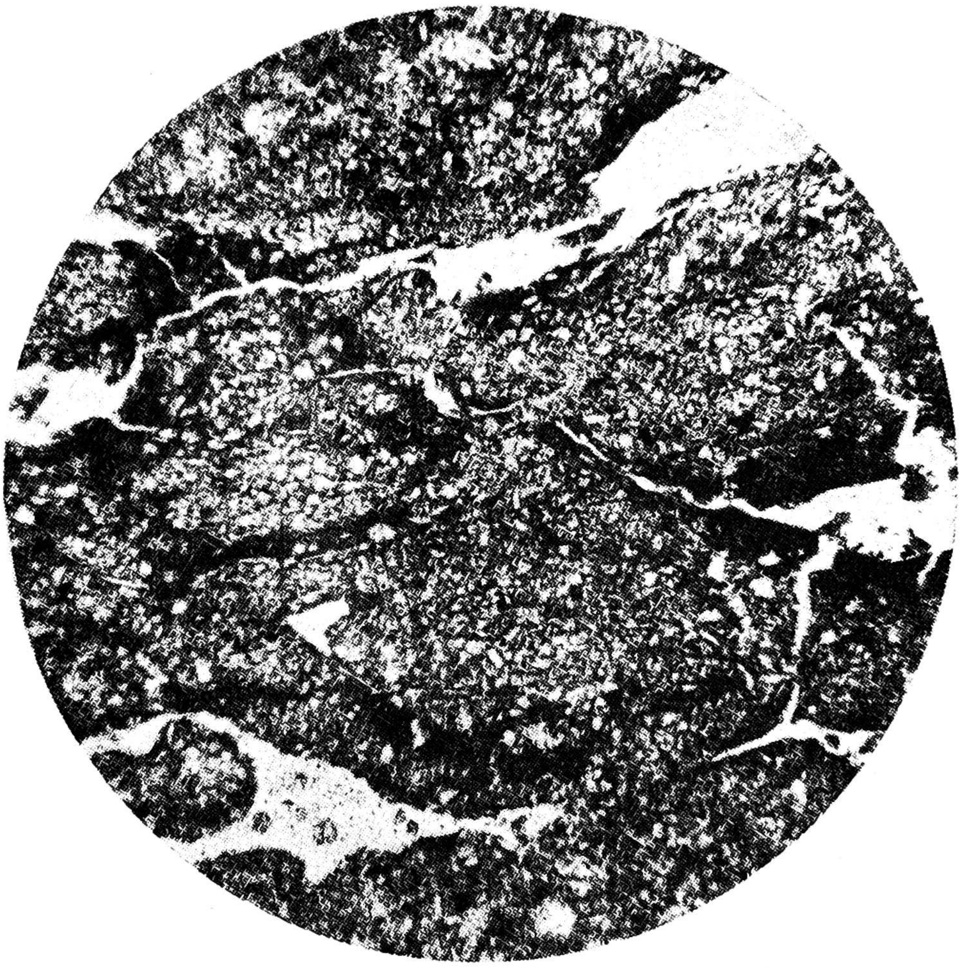

Fig. 3. Fabric of horizon B in the fossil pseudo-podzolic soil, Mezin. Magnif. 5×9, one nicol.

grey disaggregated loam with spots and contaminants of ferritization, an abundance of iron ortsteins and a dark-brown horizon B about 0.5 m thick with a distinct nuttyprismatic with dark-grey humus crusts along the edges of structural fragments, and with spots, contaminants, and veins of ferritization. The fossil soil lies directly on a compact clay moraine of the Dneprovsk (Riss) Glaciation, which prevented drainage and created favourable conditions for a surface gleyification.

Micromorphological studies of thin sections testify to active processes of translocation of the soil mass vertically, as well as inside the soil horizons themselves. Horizon A_2 was whitish in colour, with rather a compact fabric. It was disaggregated with a irregular spotty distribution of the accumulations of iron hydroxide, which alternated with spots consisting of quarts particles, lacking finely dispersed materials.

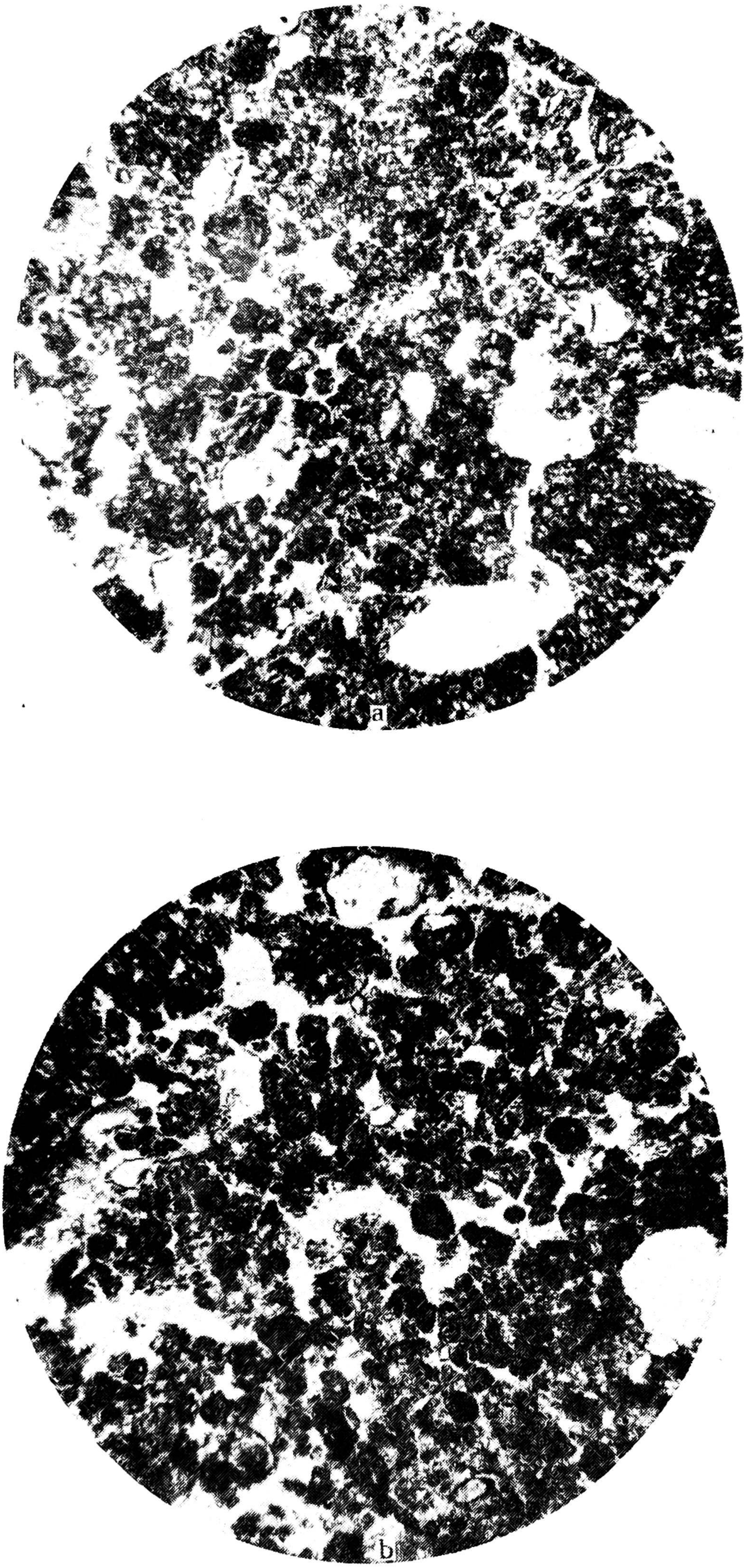

Fig. 4. Fabric of a humus horizon of the fossil chernozem. *a* — Gadyach, *b* — Mirgorod. Magnif. 5×9, one nicol.

Horizon B here, as well as in present-day soils of this type [3, 9] was characterized by a great heterogeneity of fabric, with an abundance of fragments and spots. Microspots, impoverished in finely dispersed matter, alternate here with those, enriched with ferric hydroxide in the form of irregular segregations. There are very many cutans of optically oriented clays of non-uniform fabric. Alongside with transparent light-yellow and greenish-yellow almost colourless cutans of optically oriented clays, there is an abundance of almost isotropic darkbrown cutan formations, saturated with opaque particles of humus.

The fabric of pseudogley soils indicates a sufficiently active shift of clay-humus substances and ferric hydroxide along the soil profile due to the processes of illuviation and gleyization.

The analysis of soils of the Mikulino (Eem) Interglacial's first phase of soil formation testifies to a milder and more damp climate of the middle part of the Russian Plain, as compared to the present climate. Soils which were present here at the time of the Mikulino Interglacial at present are characteristic of the warm West-European facies of the forest zone (Atlantic province according to [10]). As far as the present soil cover of the considered territory is concerned, it consists of soils of more continental facies — soddy podzolic, grey forest soils and chernozems.

It is significant that soil formation in the first phase of the Mikulino Interglacial on the territory of Middle Europe resembles in its character the East-European one (to a greater extent than at present). In the provinces of the German-Polish Lowlands at that time as well as in our days, pseudogley soils and paraburozems were common. Thus, at the time of the first phase of soil formation of the Mikulino Interglacial, the processes of soil formation in East and Middle Europe had much in common.

It is of interest that according to Grichuk [5] the considered territory of East and Middle Europe belonged to one vegetation zone. It was covered with broad-leaved forests and the northern border of the latter was 5-6° farther to the north than at present, the southern border — 1-2° to the south. The forests mainly consisted of hornbeam (at present forests with a considerable percentage of hornbeam are rare).

PECULIARITIES OF SOIL CONFIGURATION OF THE SECOND PHASE OF THE MIKULINO INTERGLACIAL'S SOIL FORMATION

After a short cold period, when there accumulated a weak layer of loess, the upper part of the Mezin Complex's thickness started to form.

As we have already mentioned above, in the second phase there formed thick humus soils of open steppe areas. Among them were soddy soils, meadow chernozems and chernozem soils.

Micromorphology of the soddy soils (Bryansk region) is characterized

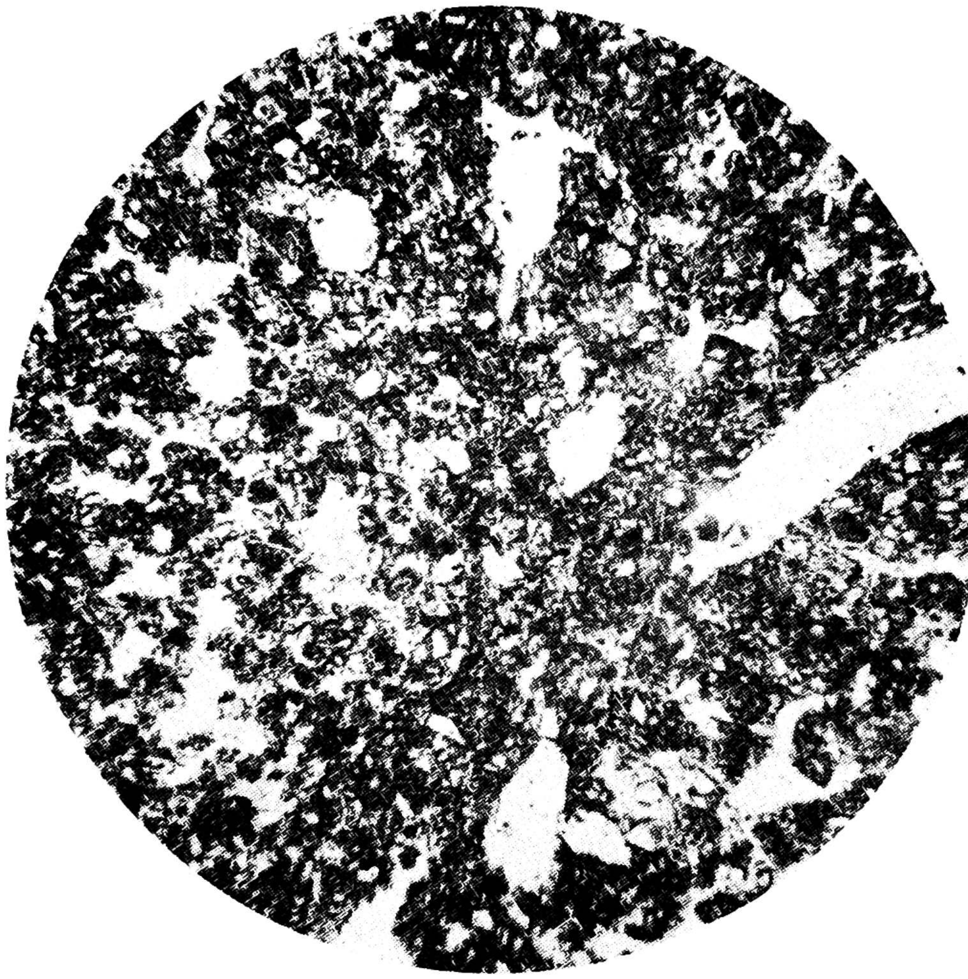

Fig. 5. Fabric of a humus horizon of the fossil meadow-chernozem soil, Krolevets. Magnif. 5×9, one nicol.

Fig. 6. Clay-humus cutans in the lower part of a humus horizon of the meadow-chernozem soil, Krolevets. Magnif. 5×9, one nicol.

by a compact fabric of a dark-grey humus horizon, weak aggregation of the clay-humus mass (coarse aggregates of orders I and II).

We must emphasize, that it is within this humus thickness that the ancient soils of this region have been greatly deformed by secondary frost processes of a cryoturbation type, caused by a cold period at the beginning of the Valdai Glaciation. These processes had changed the soils to such an extent that the definition of their types was quite relative. As a result, the upper part of the humus horizons was destroyed and their initial thickness could not be determined. At the same time, their fabric acquired a number of secondary features, conditioned by the frost processes. Primarily, it was an intensive ferritization of the clay-humus plasma, an abundance of microortsteins, segregations of iron oxides, as a result of frost gleyization. Characteristic features of these soils are the following: differentiation of the soil mass according to the size of skeleton particles, of which it is composed, with the formation of micro-circles of sandy particles; the appearance of rounded aggregates (oolites), which is probably conditioned by cryogenesis.

Fossil chernozems and meadow-chernozem soils of the second phase of soil formation of the Mikulino (Eem) Interglacial are widespread on the left bank of the Dnieper River. They have been preserved to different degrees; the upper part of their profile is often deformed or even destroyed.

This study of a number of sections makes it possible to visualize the following picture of the fossil chernozem's configuration. Its genetic profile consists of a grey almost black, with a brownish shade, loamy-humus horizon 0.6-0.8 m thick with a tongued lower contact, at the basis of which a "mole" horizon is dug and mixed by shrews. Then follows an illuvial carbonate horizon, mainly saturated with a powder calcite which can be seen on the wall of a section in the form of irregular spots and carbonate pseudomycelium. Concentrations of carbonate in the form of the so-called "beloglazka" are usually not characteristic of the considered ancient soils.

As far as the question of the configuration of a carbonate horizon of fossil soils is concerned, we cannot but emphasize the complexity of the problem. The secondary saturation of the profiles of buried soils with carbonates often makes it difficult to define its primary and secondary (diagenetic) character. In this case, interesting data is obtained by detailed micromorphological investigations and an analysis of the distribution curves of $CaCo_3$ content along the profiles of fossil soils, which as a rule have two peaks — at the top of the soil (on the border with the covering loess) and in the place of the initial carbonate horizon.

Fabric of fossil chernozems has the following peculiarities. The humus horizon is characterized by intensive dark-grey colour of the clay-humus plasma, loose microtexture, and a very good aggregation. It has aggregates of orders I, II, and III. The clay-humus plasma is fully coagulated into distinct small clods of 0.04-0.08 mm, which constitute aggregates of the Ist order. The plasma is fixed and there are no signs of its dislocation. Porosity is mainly twisting microaggregates; there are rounded biogenic pores. The total content of pores here, as compared to the present-day chernozems, is somewhat lower. This probably results from a prolonged pressure of the loess thicks lying above, which naturally caused some condensation of the soil and an enlargement of its aggregates. Tselishcheva [8] singled out aggregates of orders I-IV for the present-day chernozems and orders I-III for fossil chernozems. Unlike the present-day chernozems, in fossil chernozems vegetation remnants are absent. Instead, there are some local accumulations of humus, indicating the presence of decomposed remnants of roots. In the lower part of the humus horizon, one can notice a considerable enlargement of aggregates, their structure becomes simpler and the content of humus decreases. The clay plasma has a laminar fabric of optically oriented clays. The carbonate horizon has a loose fabric. The soil mass is saturated with micropowder calcite in the form of a "carbonate haze", and with accumulations in pores and in microaggregate spaces.

Thus, the above-mentioned data show that fossil chernozems in their fabric resemble the present-day ones, except for some peculiarities conditioned by diagenesis which have been considered earlier.

Meadow-chernozem soils, associated with lower elements of microrelief were also widespread in the Mikulino time. The thickness of their humus horizon is 60-70 cm. There are signs of gleyization in the lower part of the soil profile. The carbonate horizon is saturated with micropowder calcite. These soils have been intensively dug up by shrews. The humus horizon has brown-grey to dark-grey colour of the soil mass, loose fabric, good aggregation (aggregates of orders I, II, and III). Pores are rounded (biogenic) and twisting interaggregate of irregular forms. Organic matter is almost completely coagulated, but to a smaller degree than that in chernozems. The main mass of clay matter is isotropic, and enriched with humus. In the lower part of the horizon, in pores, there appear some cutans of optically oriented clays, saturated with humus particles. Along the soil profile, especially in its lower part, there are abundant soft segregations of ferric hydroxide. Unlike chernozems, fossil meadow-chernozem soils, as well as present-day soils of this type [8] are characterized by some features of mobility of their organic-mineral mass, namely, a few cutans of optically oriented clays, segregations of ferric hydroxide, which testify to hydromorphic features of the soils.

Micellic-carbonate nature of fossil chernozems, as well as the absence of "beloglazka", probably imply a more damp and soft climate in the second phase of soil formation of the Mikulino (Eem) Interglacial in the middle part of the Russian Plain, as compared to the modern climate, although the former is more continental than in the first phase. Fossil chernozems have, probably, resembled South European (Moldavian) carbonate micelle chernozems.

The second phase of soil formation of the Mikulino (Eem) Interglacial in the Middle Europe is associated with the formation of rather thick humus horizons, which are included in chernozems by a number of investigators. But the time of their formation is often compared with interstadials of the beginning of Wurm.

CONCLUSIONS

1. During the long and complicated period of the Mikulino (Eem) Interglacial, in the middle part of the Russian Plain, a thick polygenetic soil layer has formed (Mezinsk Complex).

2. The structure of the Mezinsk's soils reflects two phases of soil formation, with a short period of a cold snap between them, which a thin layer of loess loam has accumulated. The two phases of soil formation were conditioned by an evolution of the physico-geographical environment in the Mikulino (Eem) Interglacial.

3. In the first phase there appeared soils of a forest type of soil formation-pale podzolic, pseudogley (pseudo-podzolic). In the second phase — soils of open steppe areas, namely, chernozems and meadow-chernozem soils.

4. Micromorphological studies of fossil soils in the thin sections provide sufficiently certain definitions of their genetic types and some secondary features, acquired by soils due to diagenesis.

SUMMARY

During the Mikulino Interglacial, in East Europe, ther formed a thick fossil soil with a polygenetic profile (Mezinsk Complex), the development of which went on in two phases, connected with an evolution of the physico-geographical environment. In the first phase soils have formed which at present are characteristic of a warm facies of a forest zone (pale podzolic, lessivé, pseudopodzolic). Micromorphological study of soils of the first phase testify to a softer atlantic climate, as compared to the present time when on the same territory there form grey forest, podzolic and chernozem soils. Thick, rich in humus soils have formed under herbaceous formations in the second phase. Among them, there are chernozem and meadow-chernozem soils. Micromorphological study of fossil soil in loesses makes it possible to draw a conclusion about a great stability of the features of soil fabric.

REFERENCES

1. Величко А. А., Морозова Т. Д., 1963. Микулинская ископаемая почва, её особенности и стратиграфическое значение. В кн. „Антропоген Русской равнины и его стратиграфические компоненты", Изд. АН СССР.
2. Герасимов И. П., 1961. Погребенные почвы и их палеогеографическое значение. Материалы Всесоюзного совещания по изучению четвертичного периода, т. I, Москва.
3. Герасимова М. И., 1966. Микроморфология псевдоподзолистых почв Прикарпатья. В сб.: „Микроморфологический метод в исследовании генезиса почв" Наука.
4. Глазовская М. А., 1956. Погребенные почвы, методы их изучения и их палеогеографическое значение. Сб. статей для VIII Международного Географического Конгресса.
5. Гричук В. П., 1965. Палеогеография Северной Европы в позднем плейстоцене. В кн. „Последний Европейский ледниковый покров", Изд. Наука.
6. Морозова Т. Д., 1963. Строение древних почв и закономерности их географического распространения в различные эпохи почвообразования верхнего плейстоцена. Почвоведение 12.
7. Морозова Т. Д., Чичагова О. А., 1968. Исследования гумуса ископаемых почв и их значение для палеогеографии. Почвоведение 6.
8. Целищева Л. К., 1966. Микроморфологическое строение целинных чернозёмов и лугово-чернозёмных почв Стрелецкой степи. В сб. „Микроморфологический метод в исследовании генезиса почв", Наука.
9. Целищева Л. К., 1968. Особенности микроморфологического строения псевдоподзолистых почв Закарпатья. Почвоведение 4.
10. Kubiëna W. L., 1956. Zur Micromorphologie, Systematik und Entwicklung der rezenten und fossilen Lössböden, Eiszeitalter und Gegenwart 7.
11. Morozova T. D., 1964. The micromorphological method in paleopedology and paleogeography. Soil Micromorphology. Proceedings of the Second International Working-Meeting on Soil Micromorphology, Arnheim, The Netherlands.
12. Smoliková L., 1968. Mikromorphologie und Mikromorphometrie der pleistozänen Bodenkomplexe. Rospravy Československě Akademie věd. Rada matematických a přirodnich věd. 78, 2. Praha.