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Soil micromorphology of the piedmont zonality in central Europe

Z. BEDRNA

Research Institute of Soil Science and Agrochemistry, Bratislava, Czechoslovakia

In the hilly countries of valley and lowland regions, in the next proximity of mountains, we observe in central Europe a special piedmont soil zonality [4, 15]. In plains, the changes of soil zones occur in conformity with the changed absolute altitudes, whereas on piedmont hills, the distance of soils from the mountains and the structure of the adjacent mountain systems have a decisive influence on the zonality of soils. The essence of piedmont soil zonality consists in the climatic influence of mountains, as natural barriers, on the adjacent territories. The reason for its origin consists in successive cooling and increased humidity of the climate from the plains towards the mountains, whereby any relative ascend of the territory has no substantial importance. In central Europe, the piedmont zonality is considerably widespread, what is connected with a frequent alternation of mountain ridges and intramountain hollows.

The piedmont zonality of soils manifests itself in places of accumulated thick layers of loose sediments, where soils similar to those in extensive plains originate. In central Europe, from the extensive plains towards the mountains, we most frequently observe following soil zones: chernozems (Udolls) — brown earths podzolic (Hapludalfs) — grey-brown podzolic soils (Glossudalfs) — [2, 8, 10, 14, 21]. In conformity with the changed climatic and soil conditions, from the plains to the mountains, leaching of the carbonates from the soil profile increases and the soil reaction changes from the neutral to the acidic one. The quantity of humus diminishes and its quality deteriorates because of the higher portion of more simple organic substances. The intrasoil weathering of minerals rises and nearer to the mountains, even translocation of the clay particles and formation of eluvial and illuvial horizons in the soils occur [2, 3].

In the individual areas, we observe regional dissimilarities in the properties of piedmont zonality soils [5, 12].

METHODS USED

For detailed characteristic of the micromorphological properties of the piedmont soil zonality in central Europe, we used tens of thin-sections soil samples from all horizons of the soil profiles, typical for the different zones and regions. The thin-sections were prepared, at the beginning, after the method of Motchalova [16] later after Sirový [20]. The description of thin-sections was made after the work of Parfenova and Yarilova [18], as well as according to those of Brewer [7] and Kubiëna [13]. For the evaluation of the proper thin-sections, we likewise started from the analytical material on the chemical, physical, mineralogical and other properties of soils. Simultaneously we also used some published data on the micromorphological properties of soils which belong to some of the zones of piedmont soil zonality [1, 6, 11, 17, 19].

The majority of soils of piedmont zonality in central Europe today is intensively utilized in agriculture. Their smaller part only is under natural cultures. Our work is primarily oriented towards the cultivated soils, although, marginally some micromorphological properties of soils under natural covers will be evaluated as well.

As for the methodics of this work, we remark that it is oriented towards the changes of individual micromorphological soil properties in the zones and subzones of piedmont zonalities more than towards a detailed description of these micromorphological properties.

INVESTIGATION RESULTS

Micromorphological estimation of soils, based on the description of soil sample thin-sections from various soil horizons, showed many dissimilarities in the soils pertaining to different zones and subzones of the piedmont zonality.

Observing of *the microstructure* in soil thin-sections confirmed some analytically ascertained physical values, the aggregate and consistence status of soils. In chernozems, the soil microstructure is very marked, whereby the structure of aggregates is relatively simple. The structural elements are formed by mineral fragments and small agglomerations of organic matter compacted by a ferric, carbonaceous and humous substance. The form of aggregates is mostly round or oval. From the surface to the depth of the soil, the microaggregatedness diminishes. The soil is predominantly strongly porous, whereby this porosity is interaggregated or intraaggregated. Most pores occur in the humous horizons while in the deeper ones, they are lesser numerous. Brown earths have dissimilar microstructures in the humus-eluvial and illuvial horizons. Expressive polyhedral up to rounted microaggregates occur in the humus-eluvial horizon or arable layer, whereas in the illuvial horizon, they are sharp-edged, long-shaped and very distinctly bordered. In the majority of cases, the microaggregates are two-step ones, whereby the smaller primary peds are separated from each other by thin cracklike pores in the interior of secondary peds. In brown earths, especially in illuvial horizons, the cracklike, considerably ramified plat pores prevail over the biogenic round ones, while in chernozems the opposite is true. Within the soil profile, the textures of grey-brown podzolic soils are very dissimilar. Under woods, the humus-eluvial horizon has an inexpressive microstructure. Its porosity is considerable, but the pores do not separate the soil mass in stabile microaggregates. Depending upon the degrees of cultivatedness, however, the plough layer of grey-brown podzolic soils has more obvious and expressive microaggregates of circular shapes but uneven surfaces. The eluvial horizons have, at the basis, a single-step, lesser distinct texture. They are formed by textural elements composed from agglomerations of bleached plasma and fragments of primary minerals. The soil mass is loose with a network of veinlets, cavities and chambers. In the illuvial horizons, the microaggregatedness is very expresive and, at least a two-step one. Larger peds are edged and separated from each other by cavities and greater pores. The smaller peds are also edged and composed of the soil skeleton and plasma, whereby a clay-ferric substance is the binding material. On the whole, the illuvial horizons are compacted and little porous.

The organic substances in chernozems are represented above all by a mull-like humus. This type manifests itself in coagulated humus-clay and humus-iron agglomerations and also as subtle carbons. The whole profile contains, on the average, 17-31 kg/m^2 of humus. In brown earths and grey-brown podzolic soils under wood, the humus-eluvial horizons contain more semi-decomposed and humified plant residues. In the samples, there often occurred excrements of the zooedaphon and mycelium fibres. The eluvial and illuvial horizons of these soils contain humus substances in insignificant quantities, in organo-mineral compounds not easily identifiable by microscope. The whole profile of brown earths has, on the average, 12-28 kg/m^2, while the grey-brown podzolic soils only 8-19 kg/m^2 of humus.

The S-matrix of soils on loose sediments is mainly formed by silica. Apart from it, there also occur feldspars, micas, plagioklases and other minerals. In all soils of the piedmont zonality, in their mineral skeleton, there prevail today very heavily weatherable minerals. In chernozems, the ratio of heavily weatherable minerals to the weatherable ones is, on the average, 1:1 up to 2:1, while in the brown earths it is 2:1 to 4:1 and in the grey-brown podzolic soils 4:1 to 7:1. The intrasoil weathering of primary minerals is most intensive in the soil profile upper parts. The micas and a considerable part of feldspars are here, to a considerable extent, changed into clay minerals.

Carbonates in the soils on loess were observed at the greatest distances from the mountains only, in the carbonaceous chernozems. They contained carbonates in plasmatic form or as small agglomerations of crystalls (3-8 μm) of the secondary calcite. Sporadically, in the pores, there

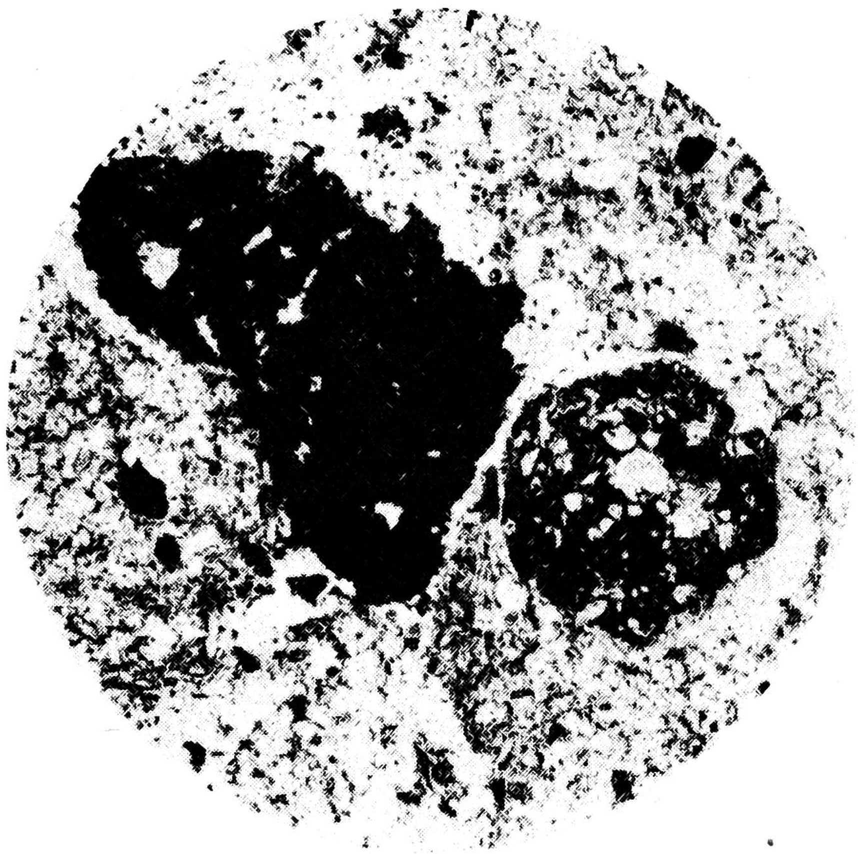

Fig. 1. Microconcretion with distinct concentrated building. Irregular black spot — excrements of zooedaphon. Brown earths — horizon E/B_t. Magnif. ×11, N II.

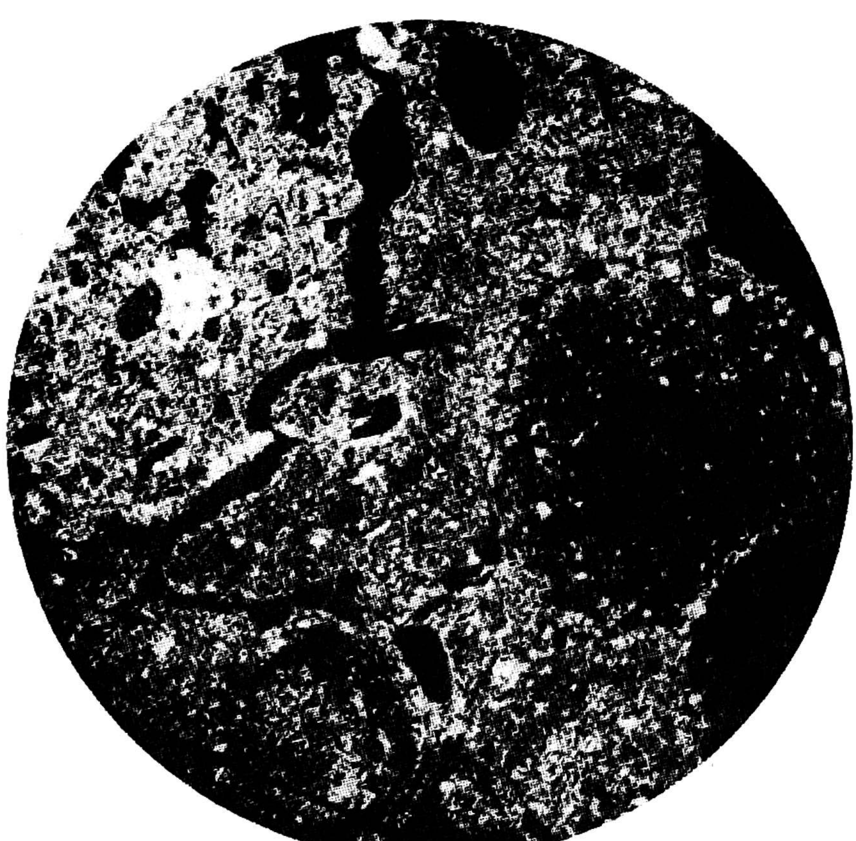

Fig. 2. Nodules in the brown earths — horizon B_t. Magnif. ×13, N X.

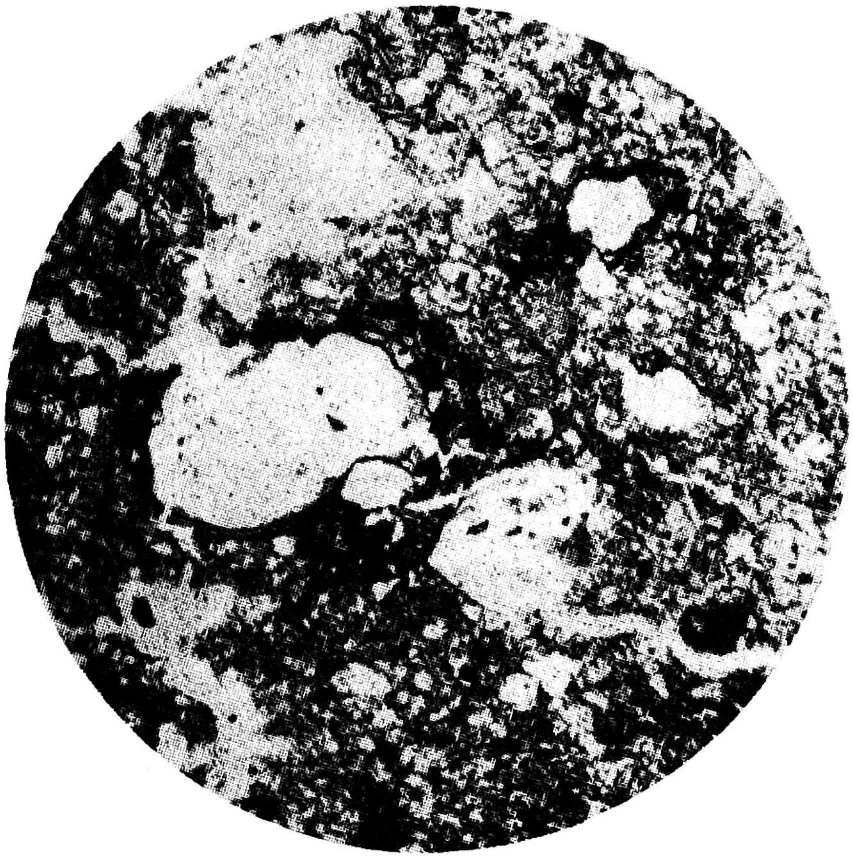

Fig. 3. Iron clay coats around voids in grey-brown podzolic soils — horizon B_t. Magnif. ×43, N II.

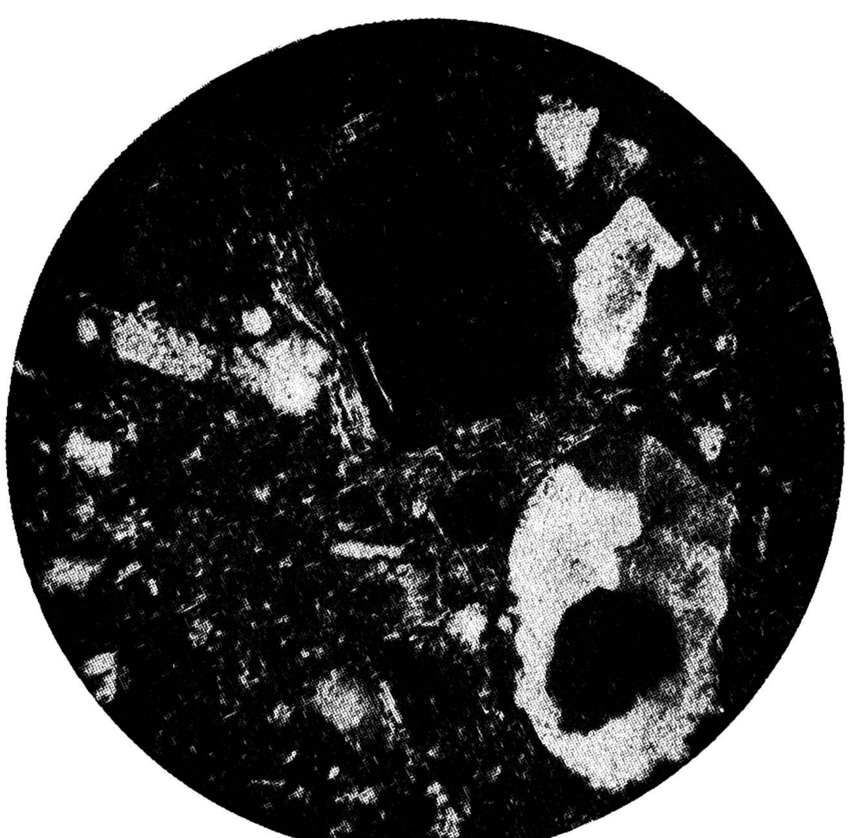

Fig. 4. Little layers optically orientated clay in the wall of void in grey-brown podzolic soils — horizon B_t. Magnif. ×126, N X.

are also larger (20-60 μm) single grains of secondary calcite. Brown earths and grey — brown podzolic soils do not contain any calcite, or in the substratum only. The micromorphological research showed that the greater part of carbonates in the loess closely beneath these soils, was of secondary origin. They precipitated on the pore walls as a subtle micro-crystalline calcite.

The soil plasma, in the soils of piedmont zonality is principally formed by clay minerals with mobile crystalline lattices (montmorillonite, illite) and mixed textures. The substantial part of clay was already contained in the original soil-forming substratum, from which the different soils were generated. But in course of the further evolution, intrasoil weathering of the primary minerals generated, in the smallest in chernozems, greater in the brown earths and the greatest in the grey-brown podzolized soils. In chernozems 1/6-1/5 of the total clay was originated by intrasoil weathering, in the brown earths 1/4-1/3.

In chernozems, the soil plasma has mostly an asepic internal structure. The clay has a scaled or fibrous orientation and is visibly not translocated in the soil. In carbonaceous chernozems, it is coagulated with the carbonates. In leached chernozems, its vertical translocation, in the soil profile, can take place, only to a limited extent and to short distances. In some regions, leaching of the carbonates, browning and claying of the soil profile without clay translocation, are accessory marks of the degradation of chernozems [6]. But in many regions, the degraded chernozems contain a considerable portion of sepic plasma, which indicates a greater mobility and translocation of clay in the soil profile. Optically oriented clay in layers or streams, between the soil skeleton, as well as clay cutans on the pore walls occur both in the brown earths and grey-brown podzolic soils. By balancing the clay in soil profiles, it was established that in brown earths, the difference between the quantity of clay originated by intrasoil weathering and by translocation was not significant, while in the grey-brown podzolic soils, the quantity of translocated clay was prevailing.

The humus-eluvial horizons, eventually arable layers of brown earths, exhibit clays in layer or network orientation. In the pores and cavities, the clay is accumulated. But in the illuvial horizon, the cutans of oriented clay are very frequent in the pores, and from the plains to the mountains, their quantity and thickness increase (from 0.01 mm to 0.04 mm or even more). Merely a small part of soil plasma does not extinct, at crossed nicols and has an irregular extinction pattern.

The humus-eluvial and eluvial horizons of grey-brown podzolic soils have a considerably mobile, bleached, eventually with iron spots saturated soil plasma. The soil plasma of illuvial horizons have most frequently an omnisepic internal fabric. All pore walls are covered with cutans and some micropores are even completely filled with a colomorphous substance, optically oriented and deposited in layers. In broader pores, the thickness of cutans attains 0.1 mm and more.

The quantity, size and structure of *new-formations* containing manganese and iron are closely connected with the oxido-reduction processes in the soils. The chernozems contain few nodules and the present ones have diameters of 0.01-0.04 mm and they form compact iron-clay agglomerations (papulae) within the soil plasma. Brown earths contain more concretions and other new formations exhibiting in the thin-sections smaller 0.01-0.04 mm, or even greater sizes of 0.1-0.3 mm, and they are conglomerated from iron-humus matter and mineral fragments. The grey-brown podzolic soils have the largest amounts of new formations which, as for their size, are the largest ones (0.2 mm and more). Most microconcretions are concentrated in the lower part of eluvial horizons, in the grey-brown podzolic soils.

DISCUSSION

In the soils of piedmont zonality, from the plains towards the mountains, the differentiation of soil profile and consequently the dissimilarity of micromorphological properties of the various soil horizons are increasing. In chernozems, the whole soil profile has a relatively homogenous microstructure, soil plasma and S-matrix [17] while the brown earths have two, and the grey-brown podzolic soils three principal horizons, with considerably heterogeneous micromorphological properties.

Micromorphological research showed regional differences in the internal fabric of soil plasma, in the degraded chernozems. But these conclusions have still to be confirmed by further data from different areas of the world. Up to now, the pertinence of grey-brown podzolic soils to the piedmont zones is not yet definitively elucidated, because the properties of these soils are considerably and frequently affected by the different substrata (chernozems or brown earths on loess, grey-brown podzolic soils on loessial or deluvial loams), by geological processes such as colmatation according to Gerasimov [9], or surficial gleyification. Therefore, they often have particular micromorphological marks though many properties of these soils are in full regularity derived from the properties of chernozems or brown earths.

Finally, it must be remarked that soils on piedmont hills, in central Europe, are greatly eroded and in different ways cultivated, what must not be omitted when evaluating the changes in their properties occurring from the plains towards the mountains.

CONCLUSIONS

1. The soils of various zones and subzones of piedmont zonality exhibit dissimilar micromorphological properties.

2. Observation of the microstructure confirmed some analytically ascertained physical values, the aggregate and consistence state of the soil.

3. Study of the intrasoil weathering of minerals and clay translocation showed that the intensity of these partial soil processes increased from the chernozems, through brown earths, to the grey-brown podzolic soils.

4. The amounts and character of new-formations indicate leaching of the carbonates of soil into the substratum and a successive rising of the intensity of oxido-reduction processes in the soil, from the plains to the mountains.

SUMMARY

In central Europe the piedmont zonality is considerably widespread what is connected with the frequent alterations of mountain ridges and intra-mountain hollows. There were most frequently observed soil zones: chernozems (Udolls), brown-earths (Hapludalfs), gray-brown podzolic soils (Glossudalfs). The micromorphological study of these soils based on the description of soil sample thin sections from various soil horizons showed many dissimilarities in the soils pertaining to different zones and sub-zones of the piedmont zonality. The intrasoil weathering intensity of minerals and the clay translocation increased from the chernozems through the brown-earths to the gray-brown podzolic soils. The leaching of the carbonates of soil into the substratum and the intensity of the oxide-reduction process in the soil rised successively in their investigation region from the plains to the mountains.

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