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THE MICROMORPHOLOGY OF AN SENSISITVE HILLY SOIL AS HABITAT FOR MICROBIOTA DELIVERING SOIL ECOSYSTEM SERVICES

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Abstract

The paper investigated the aspects related to the intimate processes taking place in a slope soil, located in the hilly region of Buzău County (Aldeni), an area highly affected by erosion processes. The study was focused on a Cambic-Cumulic Chernozem, located in the lower part of a convex slope facing south. The results showed that the plasma leaching process is very high in the upper Apt-A/B horizons: emphasised by the abundance of the impure clay coatings, which practically coated many structural aggregates. The granulometry data weakly emphasized these aspects: the differences between the clay content in the top Ap and Aph horizons is 1.1%, while the physical clay (< 0.01 mm) showed a higher difference of 1.8%. In contrast, the hydro-physical analysis showed impressive differences, comparing to the granulometry: total porosity is 53.5% in Ap and 43.2% in Aph, while the hydraulic conductivity is 10.29 mm/h in Ap, dropping to 4.57 mm/h in Aph. These differences could be due to the impure (and rich in Fe gels) clay coating which coated and even clog many pores. In the Bv horizon the clay attended a maximum (35.9%, comparing to 30.4% in the upper and 33.5% in the lower horizons respectively), the groundmass plasma is relatively stable, while the clay coatings are rarely. In stead, the plasma from the humic coprolites "massively" leached in the void space. The macro- and mesofauna activity is very high, suggesting a friendly habitat, and showing good conditions for high level of cumulic soil services delivery.

Key words: ecosystem services, microbiota, micromorphology, Cambic Cumulic Chernozem, Cumulic soil.

INTRODUCTION

The soils from hilly regions developed in a variety of parent/rock materials as marls, gypsum, sandstones, etc.

It is known that, as many minerals, the gypsum is a sulphate mineral that occurred commonly both as geological deposits and as a soil constituent (either as traces or dominate the soil system) (Eswaran and Zi-Tong, 1991)

The gypsum in soils occurs in many climates (arid, temperate and continental) but only in the drylands (Herrero and Porta. 2000; Casby-Horton et al. 2015).

Casby-Horton et al. (2015) showed that even if the gypsum had moderate solubility, 2.4 g/l (or 2.6 g/l at 25°C as showed Herrero and Porta, 2000) the soil environment is highly dynamic (with dissolution-precipitation sequences) modifying soil characteristics.

In the agricultural soils the Gypsum content results in restricted water and nutrient retention (Casby-Horton et al. 2015).

In the temperate region, in the more humid environment, the gypsum weathered.

The weathering (according to Šamonila et al., 2020) control the “metabolic rate” of the landscape evolution, further the rates of denudation are directly controlled by the rate at which translocable debris resulted from weathering (Phillips et al., 2019). Translocation refers to the mechanical process of displacing clays (and other constituents) in their dispersed state (Schaetzl and Thompson, 2015). The translocation process is directly influenced by the both vertical and lateral water movements in the soils located on a slope.

Among the multitude of the mineral skeleton grains of the soils, the feldspars are also present, being affected by the sericitization process, a very common hydrothermal alteration (Zuo et al., 2016; Zuo et al., 2022) and also an ubiquitous characteristic (Verati and Jourdan, 2014; Zuo et al., 2022).

In the soils, the shrink and swell processes generated micro-shearing and consequently the reorganization of the clay domains with the striated b-fabric formation (Mermut et al., 1988) which are micromorphological features specific to vertic materials (very rich in clay).

In many soils the calcium carbonate appears under different crystalline forms: calcite, aragonite etc. (Sekkal and Zaoui, 2013; Sun et al., 2023). As showed Jones (2017) many calcite crystals develop through non-classical crystal growth models that involve the arrangement of nanocrystals in a precisely controlled crystallographic register.

The imprints of major soil processes can be easily deduced from specific features observed in thin sections, processes that involve clay dynamics (both translocation and swelling), waterlogging, carbonate, gypsum, etc. (Verrecchis and Trombino, 2021).

Ecosystem services are the benefits that people derive from ecosystems (Brussaard, 2012), and many of these services can be linked intuitively to the good soil functioning (Wall et al. 2004; Dominati et al. 2010; Brussaard, 2012).

The present study emphasise the investigation, at micromorphological level, of the aspects related to the intimate processes taking place in a slope soil, a Cambic-Cumulic Chernozem (formed in the lower part of a convex slope facing south) located in the hilly region of Buzău County (Aldeni), an area highly affected by erosion processes.

MATERIALS AND METHODS

The researched focused on a Cambic Cumulic Chernozem (according to SRTS-2012; and Cambic Chernozem according to WRB-SR–2014), located in the hilly region of Buzău County (Aldeni), an area highly affected by erosion processes.

The soil is located in the lower part of a convex slope facing south-east.

The mean annual temperature is 10.5°C and the mean annual precipitation is 600mm.

Disturbed and undisturbed soil has been sampled (from each pedogenetic horizon) for the physical, hydro-physical and micromorphological analysis, and further analyzed and data interpreted according to the ICPA Methodology–1987.

For the micromorphological investigation, oriented large (6x9cm) thin sections, were prepared from the undisturbed samples (after air drayed, impregnation with epoxidic resins and hardening). They were studied with a petrographic microscope and Stereomicroscope, in plain (PPL), and polarized (XPL) light, to described and interpret the soil constituents, their features and fabrics, according to Bullock et al. (1985) terminology.

RESULTS AND DISCUSSIONS

The micromorphological investigation results pointed out in the top Ap horizon the presence of granular and subangular blocky structure generated mainly by the macrofauna activity and less by the physico-mecanical processes.

The porosity consists of interconnected voids results from the loose arrangement of the (bio)structural aggregates. Many of these voids are channels (of 7 mm Ø) and chambers created by macrofauna (lumbricides) of filled with coprolites (and part of them consumed by coprophagous mesofauna).

In the lower part of the horizon, the soil is more compacted and both macrofauna channels and chambers appear isolated. Areas with spongy structure also appear locally.

From the spatial arrangement of the skeleton grains and plasma, an intertextic elementary fabric results, while the monic fabric appears only locally in the upper part of the horizon.

The plasma is clayey-humo-ferric, and the plasmic fabric is sillasepic-insepic.

The soil skeleton is dominated by the mineral grains of silty and sandy sizes. The silty and fine-sand-sized grains appear relatively uniformly distributed in the soil matrix, while coarse sand-sized grains showed a randomly distribution.

Some voids (chambers created by macrofauna activity) are filled with the mineral grains depleted of the plasmic material (fig. 1) fallen in the cracks from the surface, during the drying periods that generate wide cracks.

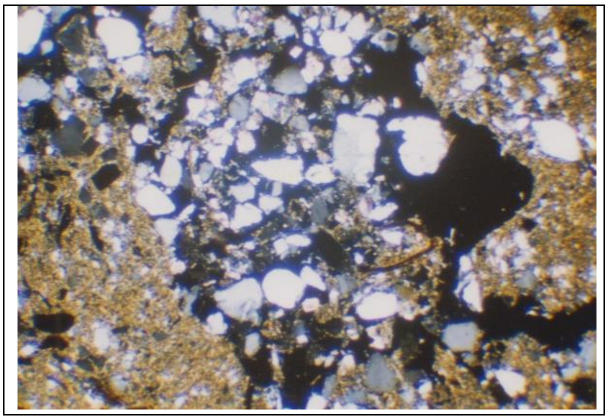

Figure 1. Depleted mineral grains concentrated in a void (chamber). XPL.

In what concerning the composition of the soil skeleton, it could be mentioned the presence of the quartz grains (angular-subangular and very rarely rounded); feldspars (potassium) with angular-subangular shape, many of them with cracks filled with highly birefringent alteration products. There were also observed feldspars partially or totally sericitized or with thick clayey-ferric films. Mica flaks (mainly biotite) together with glauconite; green hornblende; garnets (rare); opaque fragments and strongly altered fragments partially or totally covered with thick films of ferric oxy-hydroxides, completed the multitude of the mineral grains.

The skeleton also consists of inorganic residues of biological origin: diatom shells and phytoliths (fragments of the opaline linings of plant cells, having 70 µm long and 10 µm wide).

Biological activity is intense: both macrofauna (lumbricides) and mesofauna (Enchytreides, Oribathids, etc.).

In this respect, many reddish ellipsoidal organic coprolites (generated by the Oribatid mites) appear into the vegetal remains, partially and/or totally consumed by the phitophagus mesofauna (fig. 2).

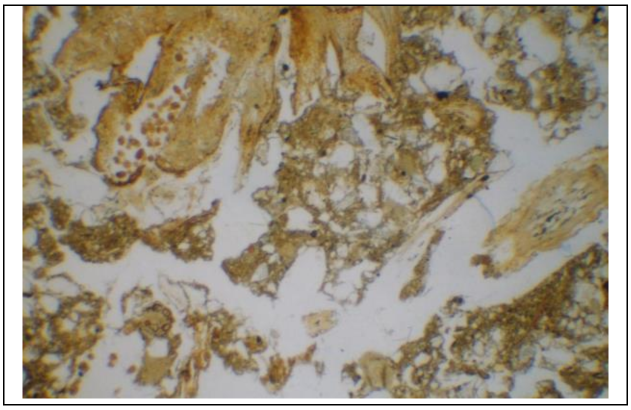

Figure 2. The reddish organic coprolites inside of a partially consumed vegetal remains. PPL.

The microbiota activity was emphasised by the blackish-brown fungal mycelium developed also on many mineral grains surfaces.

Colourless ellipsoidal formations (< 4 µm) that could be bacterial colonies appear locally in the vegetal remains vicinity.

The plant remains are either fresh, with birefringent cellulose (predominantly located in bio-pores), or in different degrees of decomposition (both in bio-pores, and integrated in the soil matrix).

Black small charcoal fragments (integrated into the matrix) were relatively rare.

Many textural and biogenic pedofeatures had been formed in the soil during the soil pedogonesis. The textural pedofeatures as pellicular and agglomeratic accumulations of clayey±humo±ferric material (without optical orientation of the clay domains) had been formed sporadically in the poral space. In the cells of a plant residue, the clay with strong optical orientation and sharp extinction has been deposited.

The biogenic pedofeatures (as coprolites produced by macro- and mesofauna) were of three types according to their composition: the most common are that containing material specific to the horizon; very rare are with bow-like structure (with semicircular bands rich in skeleton grains depleted of plasmic material and bands rich in plasma; and rich in clayey material (brought by lumbrics from the lower horizons), locally with optically oriented clay.

In the lower part of this horizon, many areas (100 – 140 µm) with yellowish-brown clayey-ferric material (without humus!) appear. The clay in these areas had a fluidal appearance, as a result of a local mobilization and reorganization under the influence of the soil solution circulation.

In this respect, the leaching plasma process is relatively high in this horizon, pointed out by the abundance of the impure clay coatings. Thus, practically all the structural aggregates appear covered by the impure coatings (fig. 3) of 10-20 µm thick, brownish-black, with different amounts of impurities (organic and ferric), with diffuse extinction zones or without extinction.

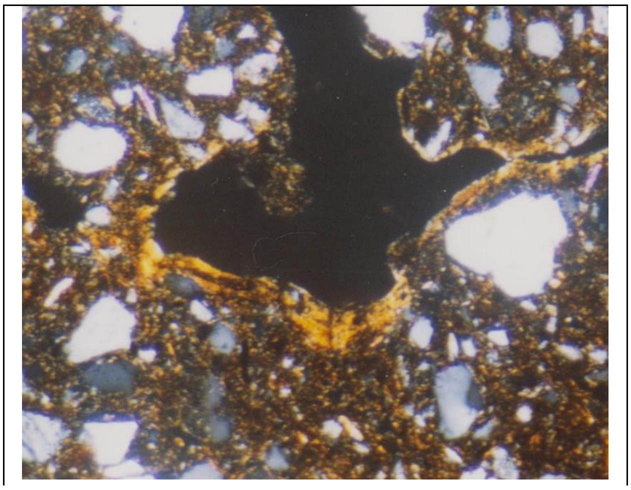

Figure 3. Clay coatings (with diffuse extinction zones) deposited on a pore walls. XPL.

Very common are also the impure „pendant coatings“, which had a thickness of up to 50 µm, as well as the deposits that clogged some small pores, either partially, or completely (those of 100 µm diameter).

The coatings „abundance“, both embedded in the matrix and deposited in the pores, shows that the clay illuviation process were very active during a long period of time and continues even today.

The coatings morphology reflects the environmental conditions in which they were formed and deposited: some of the coatings are the result of a massive deposition in the interconnected voids, reflecting more humid environmental conditions. These coatings had also high Fe content. In some older coatings, without organic impurities, Fe appears as parallel laminations, which could suggest that the coatings were formed during the successive depositions.

Coatings thicker than 30-50 µm, blackish-brown and moderately birefringent (with diffuse extinction), locally had a schistose appearance (reminiscent of the lamellar habitus of biotite).

In addition, the eluvial process developed, highlighted by the presence of some plasma-depleted areas (many of them located inside the old coprolites).

The analytical data of the granulometry do not faithfully reflect these aspects.

In this respect, the differences between the clay (< 0.002 mm) content in the top and the Aph horizons is 1.1% (33.4% and respectively 34.5%), while the physical clay (< 0.01 mm) showed a higher difference of 1.8% (43.8% in Ap and 45.6% in Aph, respectively).

However, the hydro-physical analysis data highlighted more clearly the micromorphological characteristics, comparing to the granulometry: the total porosity is 53.5% in Ap and 43.2% in Aph horizon respectively, while the hydraulic conductivity is 10.29 mm/h in Ap, and dropping to 4.57 mm/h in Aph.

These differences could be due to the presence of the textural pedofeatures (impure clay coating or clay coatings rich in Fe gels) which coated and even clogged many fine pores and strongly influence the soil solution flow.

The micromorphological investigation of the transitional A/B horizon showed very important mobilization and migration of the plasma: practically all aggregates are covered with impure clay coatings.

Even in the chambers with coprolites, the illuvial plasmic material is very abundant, covering all the coprolites, the sand-sized skeleton grains, as well as the walls of the chambers. The clay in the coatings is better oriented optically, compared to the previous horizon, while the amount of Fe is similar to that in the matrix (observed in oblique light), and the amount of organic matter is lower than in the matrix.

The differences between the A/B and the overlying horizon are (both corresponding to the cumulic influence):

- the plasma is more abundant due to the humus content (1.44% compared to 1.32% in the previous horizon), despite of a smaller amount of clay (30.4% compared to 33.1%);
- fine sand is more abundant (45.7% compared to 42.2% in the previous horizon);
- the pedofeatures are less, comparing to the previous horizon.

In general terms, this transition horizon have the characteristics of a Bv rather than an AB horizon.

In what concerning the cambic (Bv) horizon, representing the diagnostic character for the Cambisols class, the clay reaches a maximum: 35.9% compared to 30.4% in the overlying horizon and 33.5% in the underlying one, respectively.

The structure is spongy with predominant isolated voids (as a result of a moderately compaction). The porosity is lower than in the previous horizon.

On the general background of a light-brown horizon, with a lower amount of humus (which makes more visible the optically oriented clay domains in the matrix) foreshadowed the presence of some coprolites and pedotubules (with material brought from the surface horizons: dark brownish-grey rich in humus), generated by the lumbricidae activity.

The elementary fabric is locally massepic.

The skeleton grains are similar to that of the previous horizon, but more altered.

Pedofeatures formed within the horizon are textural and biogenic (coprolites and pedotubules).

The textural pedofeatures observed in the Bv horizon are: rare impure (more or less) clay coatings (many of them with numerous silty-sized impurities), yellowish-brown, with a reddish chroma in XPL and with weakly-moderate optical orientation.

The main characteristics of the Bv horizon that must be underlined (comparing to the upper horizons) are: the presence of the rare clay coatings, and the higher stability of the groundmass plasma.

Contrary, the plasma from the humic coprolites „massively“ leached in the void space.

Taking into account that the soil is Cambic Cumulic Chernozem, it could be underlined the permanently enrichment with the humified soil material from the upper part of the slope.

As a consequence, the soil life is very active, emphasised by the intense activity of the macro- and mesofauna, as well as of the microbiota.

In the soil profile, crystalline pedofeatures were also observed, in the lower horizons of the soil profile.

In this respect, many vegetal remains contain pseudomorphosis of $CaCO_3$: sparitic calcit and locally aragonite crystals (fig. 4).

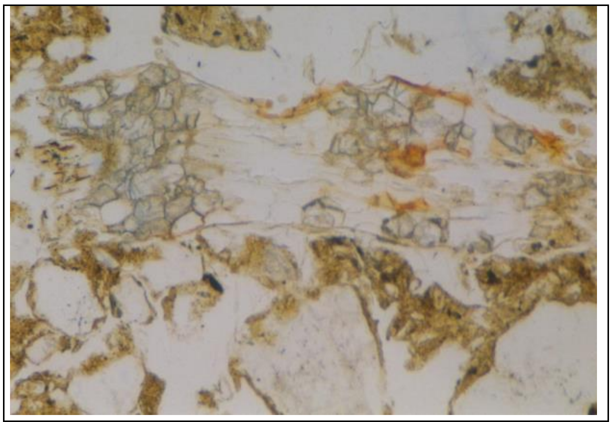

Figure 4. Sparitic calcite and aragonite crystals deposited in a root cells. PPL.

In time, in the root cells (emptied of content) calcite crystals had been grew, pseudomorphosing completely the root fragments, and forming calcite crystal tubules (fig. 5) representing crystalline pedofeatures.

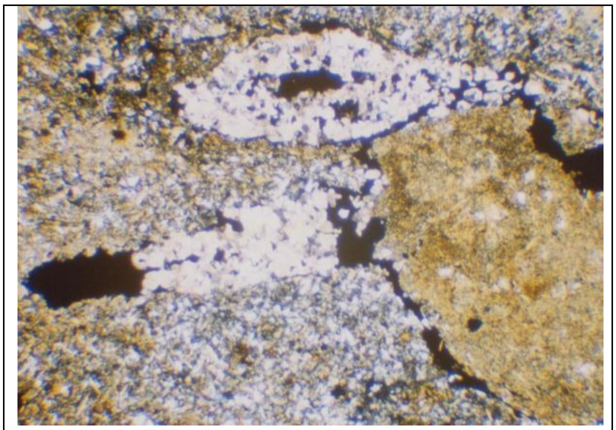

Figure 5. The $CaCO_3$ pseudomorphs on the roots (circular and transversal sections). PPL.

The cumulic soils are the most fertile soils among all the soils developed on a slope.
The high activity of soil biota underlined this characteristic and suggests a friendly habitat that assure good conditions for the higher level of the soil services delivery.

CONCLUSIONS

The micromorphological investigation of the intimate processes taking place in a Cambic-Cumulic Chernozem, located in the lower part of a slope, lead to the following conclusions:
The plasma of the upper horizon had high mobility, leading to many clay coatings formation in the upper Apt-A/B horizons (corresponding to the cumulic influence), and less in the Bt horizon where the plasma is more stable.
The textural pedofeatures (impure clay coating or clay coatings rich in Fe gels) which coated and even clogged many fine pores, had a high influence on the soil solution flow in the poral space and further on the physical and hydro-physical properties of the soil.
The granulometry do not faithfully reflect the micromorphological characteristics, comparing to the hydro-physical data.
The physical clay ($<$ 0.01 mm) values showed higher difference between Ap and Aph horizons, comparing to the colloidal clay ($<$ 0.002 mm).
However, the hydro-physical data showed a higher porosity and a much higher hydraulic conductivity in Ap than in Aph, which better highlighted the micro-morphological characteristics (comparing to granulometry).
The macro- and mesofauna activity is very high, suggesting a friendly habitat, and good conditions for a high level of the soil services delivery in the studied cumulic hilly soil.

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