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THE IMPURE CLAY COATINGS AS IMPORTANT PEDOFEATURES OF THE PHAEOZEM FERTILITY BEARING

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Abstract

The soil fertility is induced and sustained by the soil constituents. In this respect, the clay is one of the main nutrient bearing. The presence of the clay pedofeatures (coatings and pore infillings) generally shows an intense leaching process of the constituents from the rooting zone. The leaching process also includes the nutrients depletion, and consequently a pH decreased. The results of the micromorphological investigation of the Phaeozems shows the presence of many impure clay coatings (consisting of clay and a large amount of colloidal humified organic matter), in all the pedogenetic horizons. The richness of the humic substances created a favourable environment for the microbiota. As a result, many microorganisms developed on the impure clay coatings, the evidence being the presence of many fungi spores, as well as the black mycelium of the mycorrhizal fungi on these coatings. The micromorphological investigation pointed out another facet of the intimate mechanisms of the Phaeozems related to fertility (as one of the most important ecosystem services).

Key words*: micromorphology, soil fertility, Phaeozems, microbiota, impure clay coatings.*

INTRODUCTION

During the soil evolution, the processes that lead their development generate specific pedofeatures. Each type of pedofeatures emphasizes the process that generated them and consequently the environmental conditions that favoured the process development.

The clay illuviation process generated many type of textural pedofeatures, clay coatings respectively, among which the impure clay coatings are also present. These coatings contain either contrasting particles of fine silt-size (Bullock et al., 1985) of different origin or even high content of silt (Fitz Patrick, 1993).

Each pedogenetic process strongly influences the soil life and, implicitly, the quality of the ecosystem services. The agriculture services could be the services that help to support production of harvestable goods (Zhang et al., 2007), services that include, among others, soil structure and fertility enhancement, nutrient cycling and water provision (Garbach et al., 2014).

Soil fertility generally correlates with the plant production of a land and usually reflects the quality of the soil. Sometimes it is considered the quality of the soil itself, the soil fertility being regarded by farmers as the most important and representative feature, together with the production capacity of the ecosystem.

The mycorrhiza is an important part of the soil life that influences the plant wealth and development.

Martinez-Garcia (2012) synthesises that arbuscular mycorrhizal fungi are strongly influence by climatic conditions, root colonization increased with a longer period of drought (Augé, 2001), as well as in the case of plant growth under low water availability, an increased of arbuscular mycorrhizal fungi root length colonization registered (Martinez-Garcia, 2010).

Hristov (2020), studying the Phaeozems from Bulgaria, stated that these soils usually have high humus accumulation, soil texture differentiation, high base saturation, good buffer capacity in whole soil profile, with favourable physicochemical properties and soil reaction that make them suitable for crops, due to their high agricultural potential.

The age of the dark humus of an Haplic Phaeozems (studied by Bobrovsky & Laiko, 2019) corresponds to the age of an older forest-

steppe soils (tree-falls developed in late Holocene).
This conclusion pointed out the polyphasic evolution of many Phaeozems, as in the case of other soil types.
The paper objective was to emphasise, as a subject of absolute novelty, the impure clay coatings (organo-mineral coatings) as important pedofeatures of the soil fertility bearing, which showed the thigh connection and interdependence not only between the matrix constituents, but also between all the soil components, which function as a whole, to well delivery ecosystem services.

MATERIALS AND METHODS

The researches focused on a Phaeoziom argic with relict gleization (according to SRTS-2012; Sol cernoziomoid argiloiluvial with relict gleization - according to SRCS-1980; Luvic Phaeozem - according to WRB-SR-2014), located in Miercurea Ciuc Depression. The absolute altitude is 670 m. The parent material is represented by the loamy - sandy-loam deposits, while the substratum consist of alternating sands and rolled gravels (calcareous and sandstones with calcite veins).
Miercurea Ciuc Depression is located in the bioclimatic zone of the coniferous forest (spruce forests).
The mean annual temperature is 5.9°C and the mean annual precipitation is 577 mm.
The soil profile was dug in an arable land, with potatoes crop.
The soil samples were collected both disturbed and undisturbed from each pedogenetic horizon, for the physical, chemical and micromorphological analysis, and further analyzed and data interpreted according to the ICPA Methodology-1987.
Large (6 x 9 cm), oriented thin (25-30 μm) sections were prepared from undisturbed soil sampled from each pedogenetic horizon (in order that the investigation results be statistically covered), after air drayed and impregnated with epoxidic resins. Soil thin sections had been studied at micromorphological level with: microfilms reader Carl Zeiss Jena DL at 5-20 X; petrologic microscope Amplival at 50-100 X; and Stereomicroscope Nikon SM2800 at 1-6 X; in plain (PPL) and polarized (XPL) light, to describe and interpret the soil constituents, their features and fabrics, according to Bullock et al. (1985) terminology.

RESULTS AND DISCUSSIONS

When the fertility state of a soil is analyzed, the entirely soil matrix with all its constituents is approach. The soil fertility is induced and sustained by all organic and inorganic soil constituents. In this respect, the clay is one of the main nutrient bearing. But in many soils, the clay is mobilized and subjected to the leaching process, its deposition in the deeper horizon generating textural pedofeatures (clay coatings).
The presence of the clay coatings generally shows an intense leaching process both of the constituents and of the nutrients from the rooting zone, followed by the pH decreases.
In this paper, the researches focused on another facet of the clayey - humic constituents of a Phaeoziom argic with direct implication in soil fertility.
The analytical data pointed out an increase in clay content from 30.4% in the top horizon to 41.0-41.3% in the Bt horizon (Figure 1).

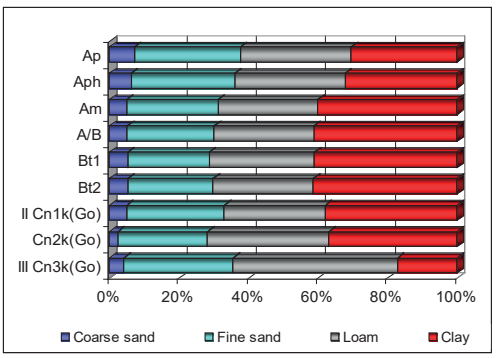


Figure 1. The granulometry of the soil

The high quantity of clay is also showed by the textural differentiation index which reaches a high value of 1.3, with important implication in the air-water soil regime; however, the natural drainage of the soil is good.
The clay is an important constituent of the soil pedobioplasma, and should have a low dynamic due to the cations presence (among which Ca is dominant).

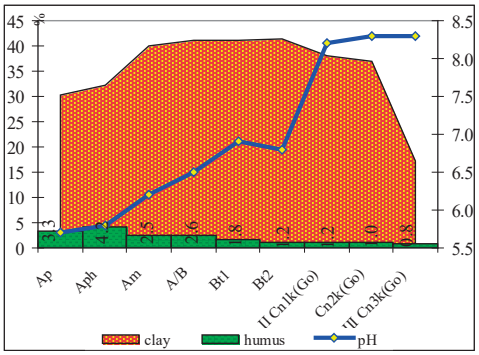


Figure 2. The main constituents of the soil fertility (clay and humus) in relation to pH values

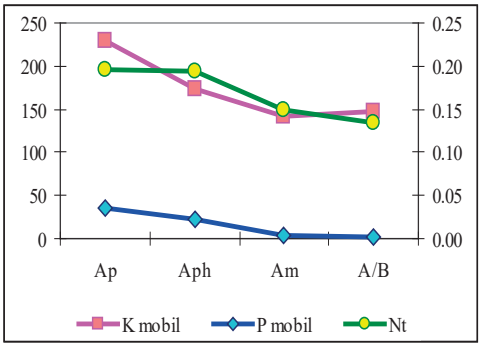


Figure 3. The content in N total, P mobile and K mobile of the soil

The organic matter content is higher (3.3-4.2%) in the top A mollic horizons and slowly decreased (to 1.2-1.8%) in the Bt horizon (Figure 2), being also present into the deepest Cnk (Go) horizon (0.8-1.2%).

The organic matter is dominated by the humified components, its characteristic emphasising the soil evolution in an older phase with a more intense hydrologic regime.

The soil reaction increased from medium acid to low alkaline. The pH values showed an important increased from 5.7-5.8 in the top A mollic horizon to 6.8-6.9 into the Bt horizon, reaching the higher values (8.2-8.3) in the bottom profile.

The parent material, rich in calcareous rolled gravels, permanently supplies Ca ions that keep the high values both of the pH and of the base saturation degree.

Therefore, the top Am horizon is mesobasic, according to the base saturation degree value, while the Bt horizon is eubasic, and the deepest one, where $CaCO_3$ is present (5.7-7.6%), the soil is saturated in base (the values of the base saturation degree reaching 100%).

In what concerning the soil nutrient supply, the N total content is medium in the Am horizon (0-46 cm) and decreased to low in the deeper horizons (Figure 3), while the soil content in P is medium in the upper two horizons (Ap-Aph) and drastically decreased to extremely low.

The C:N ratio values (11.5-14.7) showed a medium to high level of soil fertility.

The K content is high in the top horizon and decreased to medium in the underling horizons (Figure 3).

The micromorphological investigation showed that the soil matrix is humico-cleyey-Fe. The high quantity of the plasmic material is showed by the elementary fabric which is porphyric.

Despite of the relatively high quantity of clay, the plasmic fabric is dominantly sillasepic, as a consequence of the high organic matter (and Fe) that masks and/or impede the optical orientation of the clay domains.

The organic matter has low values and chroma, a metallic hue and a relatively high capacity of mobilization, as a result of an older stage of the soil under more humid conditions.

However, the humus is mull calcic.

The micromorphological investigation also showed the presence of many types of clay coatings along the soil profile (in all the pedogenetic horizons, respectively), as the main textural pedofeatures of this soil type.

The organo-mineral coatings were one of the main diagnostic characteristics of this type of soil classification, according to SRCS-1980.

The most common organo-mineral coatings (in morphological terminology) are the impure clay coatings (in micromorphological terminology) consisting of clay and a large amount of colloidal humified fraction (clayey+humic±Fe coatings - Figures 4 and 5).

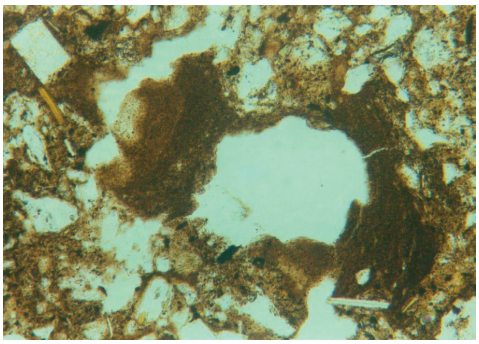


Figure 4. Impure clay coatings: rich in colloidal humified organic matter, PPL

The impure clay coatings are blackish-brown (in PPL - Figure 4) and relatively similar to the soil matrix; and yellowish-golden, with low optical orientation and diffuse to absent extinction (in XPL - Figure 5).

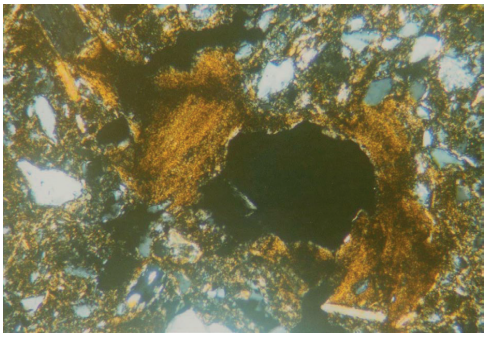


Figure 5. Impure clay coatings: with low optical orientation and diffuse extinction, XPL

Together with the coatings, pore infillings (with fluidal appearance) also formed, many of them being integrated into the soil matrix as a result of the pore collapse (Figure 6).
Compound layering coatings also appear, with the layers having graduated quantities of impurities (from very abundant to poorly pigmented).
The layering of the coatings formed manly during the deposition from the soil solution, and less by a graduated deposition in time.
The pore infillings (with fluidal appearance) had crescentic lamination as a result of the plasmic material reorganization during the deposition.
The richer they are in organic impurities, the more cracked they became (Figure 6) as a result of the weak resistance lines that impede the clay domain cohesion.

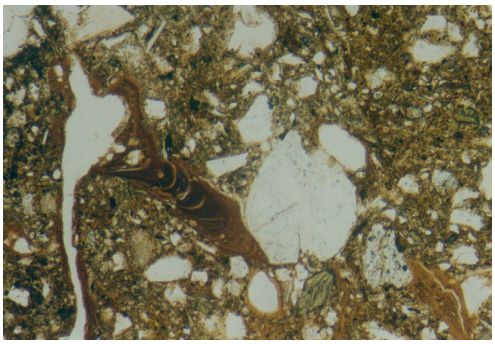


Figure 6. Pore infilling: with fluidal appearance and crescentic lamination, PPL

The presence of these coatings (and the pore infillings), their deposition way, location into the pedogenetic horizons, represents important features of this type of Phaeozem.
The richness of these impure clay coatings in humic substances created a favourable environment for the microbiota.
As a result, many microorganisms developed on the impure clay coatings, the evidence being the presence of many fungi spores, as well as the black mycelium of the mycorrhizal fungi on these coatings (Figures 7 and 8).

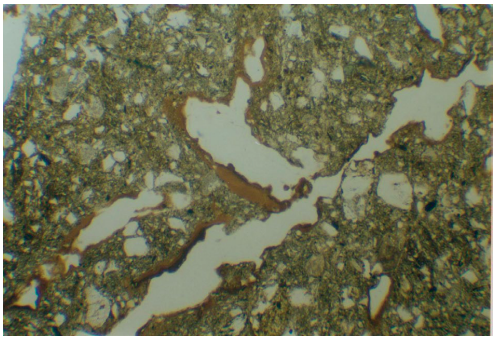
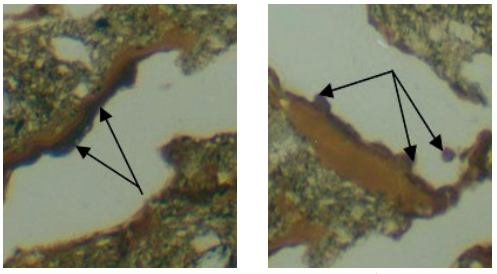


Figure 7. Impure clay coatings colonised by fungi, PPL

The abundance of the humified organic matter represents abundant food for the microorganisms that develop on the impure clay coatings, as well as on the more humic layers (in the case of the layered coatings or pore infillings).
Soil biota adapted to the food offer of the soil, and showing the high diversity of the

microorganism species that developed in the soil.
In time, the organic impurities are consumed (biodegraded) by the microorganisms, and the impure clay coatings evolves to pure clay coatings (Răducu, 2015), similar to the classical clay coatings of the argic horizons (Răducu, 2018).



a b

Figure 8. Detail from figure 6: a) mycelium of the mycorrhizal fungi on the clay coating; b) colonies of the microorganisms on the clay coating (PPL)

The evidences of the microbiota development on the clay coating rich in humic plasma are:
a) mycelium of the mycorrhizal fungi on the clay coating (Figures 7 and 8a);
b) microorganisms colonies on the clay coating (Figures 7 and 8b).
The micromorphological investigation also emphasized a high activity of the soil macrofauna (lumbricides).
The high quantity of the soil material brought from the top horizons and deposited by the soil macrofauna (as coprolites) into the Bt horizon is important (intense bioturbation process) and it is quickly integrated into the matrix.
The lumbricides proved to be important keys for the soil ecosystem, having a high influence on the organo-mineral plasma dynamic and leaching, furnishing nourishment for the microbiota.
The soil material (humic-clayey±Fe) from the mollic epipedon, transported by lumbricides along the soil profile, had a higher mobility (comparing with the constituents of the matrix in which they were deposited). The consequences were the genesis of many organo-mineral coating (and pore infillings) in the deeper horizons.
Even if in the soil science literature, the presence of the clay pedofeatures generally shows an intense leaching process of the constituents (from the upper horizons belonging to the crop rooting zone), which also includes the nutrients depletion, and consequently a pH decreased, the complex researches showed a different situation.
Impure clay coatings represent an important and suitable food support for the microorganisms, while the parent material furnishes cation that keeps the soil environment at eubasic-mesobasic level.
The micromorphological investigation pointed out another facet of the intimate mechanisms of the Phaeozems related to fertility (as one of the most important ecosystem services).

CONCLUSIONS

The paper researches concentrated on another facet of the soil fertility bearing, a characteristic type of textural pedofeatures (formed in Phaeozem): the impure clay coatings (rich in humic substances).
The clay coatings richness in plasmic organic matter represents abundant food for the microbiota that developed on these coatings.
As a consequence, mycelium of the mycorrhizal fungi, as well as the presence of the microorganism colonies had been detected on the impure clay coatings.
The lumbricides proved to be important keys for the soil ecosystem, the soil material (humic-clayey±Fe) from the top horizon transported along the soil profile have a higher mobility and therefore generated many organo-mineral coating (and pore infillings) both in the mollic epipedon, as well as in the deeper underlying horizons.
The detailed macro-micromorphological investigation, supported by the analytical data, reveals the intimate mechanisms of the Phaeozems related to fertility, as one of the most important ecosystem services.

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