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Diagnostic of soil forming processes of Zheltozem podzolic (pseudopodzolic) soils from Strandzha Mountain

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Abstract

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The paper deals with contemporary approach of macro- and micro- morphological diagnostic of the advanced soil forming processes in zheltozem podzolic (pseudopodzolic) soils, according to their intensity and place of manifestation. The complexity is driven and sustained by a combination of factors and tend to be case specific of soil forming processes in soil characterized with features that have taken hundreds or thousands of years to form. The aim is to apply the robust indicators that endorse evolution of soils result of regional specific ambient environment. The detailed diagnostic of zheltozem podzolic (pseudopodzolic) soils reveals leading soil forming processes that put their marks in genetic horizons and reorganized constituent which actually is a result of complexity of advanced soil formation. Indication for lessivage process is the mobility of fine clay and its accumulation particularly at the lower part of the illuvial horizon. Intensive and deeply affected weathering process was identified in almost all soil horizons as well indication of hydromorphic processes.

Keywords: pseudopodzolic soil; thin section; macro- and micro- diagnostic; pedogenetic processes

Introduction

The contemporary trend of evolution of advanced soil forming processes sometimes required more precise macro- and micro- morphological diagnostic aiming to identify regionally specific pedogenetic features. It is necessary to assume that some pedological features and processes are uniquely associated with specific environment and resulting from processes in the past as those produced by the same processes today. Micromorphology is the branch of soil science that is concerned with the description, interpretation and measurement of components and fabrics in undisturbed soils at a microscopic level. Micromorphological analysis is today the most reliable method for identifying and understanding the processes involved in soil formation (Stoops et al., 2018) produced by nature as well as those induced by human impact (Behrends & Morras, 2018), so that these natural objects may be properly maintained for some specific purposes.

Zheltozem podzolic (pseudopodzolic) soils are regionally compact located, on the territory of Silkosia Reserve, the first reserve in Bulgaria, established in 1933 in Strandzha Nature Park. Pseudopodzolic soils are typically forested soils. The classification of zheltozem podzolic (pseudopodzolic) soils from Strandzha Mountain was problematic during the years with different aspects due to the complexity in diagnostic of soil forming processes in soil characterized with the most prolonged soil evolution in Bulgaria (Yolevski et al., 1983).

Chemical weathering in situ takes place over the whole year in wet conditions. Various combinations of the iron oxides haematite and goethite result in color (Savin et al., 2016). Dominance of the non-silicate form of iron over its silicate form in all soil horizons is a typical feature and is evidence of advanced weathering. High content of the free forms of iron in all soil horizons is a typical feature and is also evidence of advanced weathering.

Materials and Methods

The object of the study is the zheltozem podzolic (pseudopodzolic) soil from the region of Strandzha Mountain in the south-eastern part of the country, situated nearby Kosti village in a place where is conserved relict vegetation of beech and oak forests with undergrowth of evergreen shrubs *Rhododendron ponticum*, laurel, ilex, *Daphne pontica.* The area covers wooded zone of Valley of Veleka River, with coordinates 42.06838 north latitude and 27.80789 east longitudes, and the altitude 59 m. The representative soil sampling was competed in 2019 (Shishkov & Dimitrov, 2021) launched after the Russian-Bulgarian expedition in the region by geologists and pedologists. The soil is unique at the regional soil association which is consisted of Luvisols, Cambisols, Leptosols, Lithosols (FAO-UNESCO-ISRIC, 1990; IUSS WORKING GROUP, 2015). The area of soil localization is not compacted distributed at the foot slopes of Strandzha Mountain. Climate is warm, humid, with low seasonal temperature amplitude due to the influence of the Black Sea. Maximum seasonal precipitation is during the autumn-winter respectively the dry period is in summer. The parent soil-forming materials are deeply weathered sandy-clay shales and sandstones. Hydrothermal conditions favor the biological activity as well as soil development throughout the year.

The profile of the zheltozem podzolic (pseudopodzolic) soil is formed by deep hydrolysis. There are three clearly distinguishable parts – the upper humus-eluvial, lower illuvial-metamorphic, zone of intense weathering, known as lithomarge; and below is a rotten stone of weathering rock (Figure 1). Lithomarge is a rock fragment with brightly colored layers which retains its shape and structure, but is quite soft and is transformed mineralogically.

The morphological diagnostic of profile of zheltozem podzolic (pseudopodzolic) soil revealed the genetic horizons, as follows:

O thin loose litter, at the top of which leaf tissues are visible, and at the bottom of which are moderate to strongly decomposed remnants, below

A 0-4 cm; a thin quite homogeneous mineral horizon, with light gray (10YR 7/2, dry) and brown (7,5YR 4/2, moist) color; a sandy clay loam texture, and a weakly developed structure, very friable that was very fine-sized (<1 mm), and a weakly developed granular structure (spheroids and polyhedrons) that was fine-sized (1-2 mm diameter), the compound aggregates were moderately developed granular, very coarse-sized (>10 mm diameter), packing density was low <1.40 g cm^{-3}, abundance of fine roots <0.5 mm and others 0.5-1.0 mm size, grades into;

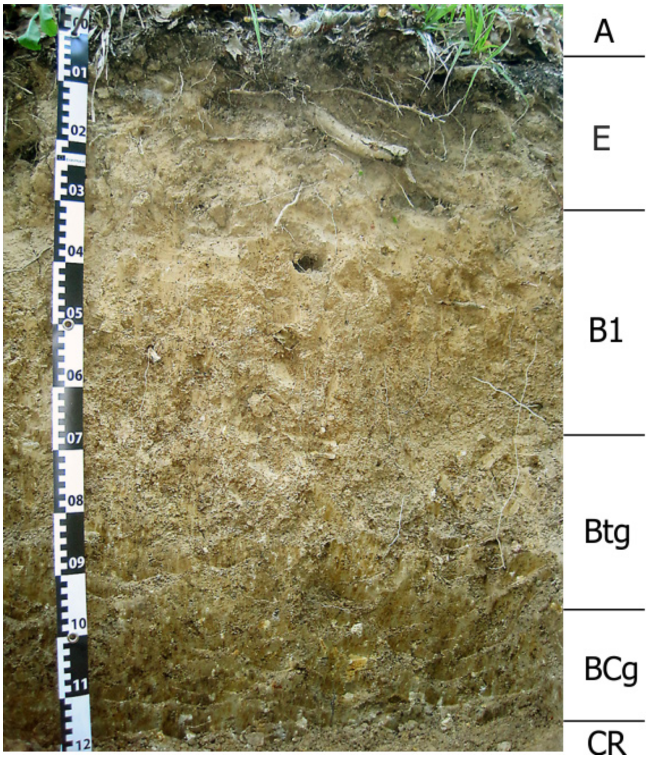

Fig. 1. Profile of zheltozem podzolic (pseudopodzolic) soil from the region of Strandzha Mountain

E 4-32 cm; a mineral eluvial horizon, with very pale brown (10YR 7/3, dry) and yellowish brown (10YR 5/4, moist) color; a sandy clay texture, a soft, very friable consistency and a weakly developed, structure in subangular blocks that was very fine-sized (<5 mm diameter); the compound aggregates were weakly developed, medium-sized, (10-20 mm diameter), horizon was with medium packing density 1.40-1.75 g cm^{-3}, many fine roots <0.5 mm and 1.0-2.0 mm size, clear boundary;

Bt 32-69 cm; an illuvial horizon, mixed, with light yellowish brown (10YR 6/4, dry) and brown (7,5YR 5/4, moist) color, the internal state of the clods was parti-colored showed yellowish red (5YR 5/6) color of spots; a clayey to very clayey texture, structure was very fine-sized (<5 mm diameter) in subangular blocks (blocks having mixed rounded and plane faces of aggregates), compound aggregates were of medium pedality grade, medium-sized (10-20 mm diameter), consistence was firm, with medium packing density 1.40-1.75 g cm^{-3}, few of fine roots, diffuse boundary;

Btg 69-96 cm; an illuvial-metamorphic horizon, mixed, with pale brown (10YR 6/3, dry) and brown (7,5YR 5/4, moist) color, the internal state of the clods was parti-colored showed yellowish red (5YR 5/6) color of spots; a clayey to very clayey texture, structure was firm, strongly developed in subangular blocks medium-sized (10-20 mm diameter), compound peds were strongly developed, coarse-sized (20-50 mm diameter), with lithomargic and gleyic pattern, the surfaces of peds and pores were coated with stress clay cutanes rather than illuviated, with abundance of black Mg concretions and medium packing density 1.40-1.75 g cm^{-3}, diffuse boundary;

BCg 96-126 cm; motley, with very pale brown (10YR 7/3, dry) and brown (7,5YR 5/4, moist) color, the internal state of the clods showed yellowish red (5YR 5/6) color of spots; a clayey to very clayey texture, structure was firm, strongly developed in subangular blocks medium-sized (10-20 mm diameter), compound peds were firm, strongly developed coarse-sized (20-50 mm diameter), with lithomargic and gleyic pattern, abundance of Mg black segregations and concretions, medium packing density 1.40-1.75 g cm^{-3}.

It is essential to establish an intimate connection between the morphological description in the field and the description of the thin section (Dufeu, 2017; Menzies & Meer, 2018).

Micromorphological study contributes to distinguish and examine some diagnostic features, like content, quantity, mobility, degree of transformation and localization in situ, which are significant for the soil processes diagnostic (Plotnikova et al., 2020). The discrete entities on the image were identified according to size classes, shape types, or combinations of both (Juhasz et al., 2007). Chemical, physical, physic-chemical and mineralogical analyses require representative samples from genetic horizons of zheltozem podzolic (pseudopodzolic) soil and the results are mean data (Shishkov & Dimitrov, 2021). This is not the case in micromorphology, which allows the interpretation of exceptional features, which frequently have a clear genetic meaning (Stoops, 2003). Different types of light are used for analysis: plane polarized light (PPL) and cross-polarised light (XPL).

Results and Discussion

The technique of description and interpretation is to a high degree based upon data from pedogenic studies. In the practice of determining the podzolic process, the morphological features have acquired great importance, and in most cases, is based on formal morphological features particularly in diagnostic B horizons (Bryk, 2016). Thus the bleaching horizon has become a major feature of podzolic formation. This is bleaching of the upper layer, which resembles the eluvial horizon of podzolic soils.

Zheltozem soils are formed with gradual loss of rock structure as a result of deep chemical weathering in situ (lithomarge). The minerals are weathered in such a way that the thin dispersed material slowly peels off with practically no mechanical destruction. Under conditions of high humidity most of the basic cations and iron have been leached.

Finally, clayey material is formed consisting of quartz, kaolinite, gibbsite, and goethite with low capability for weathering minerals. The yellow color is due to the presence of goethite which indicates that the soils were formed in a moist environment.

The content of the dithionite extractable iron compounds and the content of the crystalline forms are high and indicate more advanced stages of weathering, migration, and crystallization (Hadzhiyanakiev, 1989). The amorphous form of iron bounded with organic matter showed lack of mobility down the profile and is not influenced by waterlogging at the surface layer. Generally, the distribution of Fe forms strongly reflects the thermo-moisture regime of the soils; the distribution of Mn forms reflects the gley process; and the distribution Al forms reflects migration and lessivage processes (Jokova & Boyadzhiev, 1998). Chemical weathering in situ takes place over the whole year in wet conditions. Dominance of the non-silicate form of iron over its silicate form in all soil horizons is a typical feature and is evidence of advanced weathering.

Particle fractions distribution confirmed textual differentiation in the soil especially at the depth. Soil is characterized by a very strongly acidic reaction of environment and by the low values of the degree of base saturation.

The study of zheltozem podzolic (pseudopodzolic) soil was carried out by means of a polarizing optical microscope under plain polarized light (PPL) and crossed polarized light (XPL). A reference slide collection for soil micromorphology was used for the benefit to employ soil micromorphological techniques. The thin sections were photographed with a device of a color digital camera coupled to a stereomicroscope digital microscope set at the Faculty of geology and geography in Sofia University "St. Kliment Ohridski" that combines software and powerful algorithms to accelerate the microscopy overview image acquisition, sample area detection, and focus adjustment.

The skeleton is represented by quartz, feldspar, mica and mineral relics. While the composition is stable with the depth of profile, the content significantly decline from the surface to the deeper horizons. Minerals fragments are of different size and shape. With the depth of soil the most of surfaces are damaged; some are with thin iron-clay coatings. These micromorphological features are indicative of intensive weathering process *in situ.*

The next morphological change taking place is horizon differentiation (Sauer et al., 2013) into (E, Bt and Btg) horizons due to the fine-textured sediments. The process leading to the morphological change in the soil profile is a clay illuviation in the soil. Soil pH in the upper (Bt) horizon of the soil is enough for significant clay mobilization. Progressive clay illuviation in (Btg) horizon is recorded by the increasing thickness of clay coatings and proportion of clay coatings.

In the thin section the organic matter is presented by residual tissues and with some fine dispersed humus, incorporated in the micro mass (Figure 2).

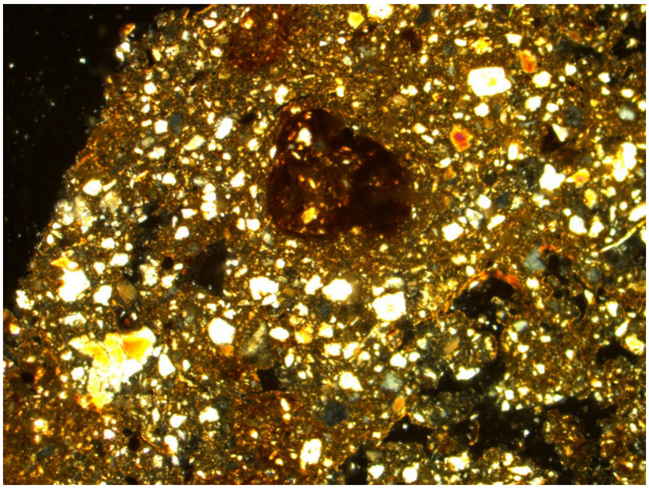

Fig. 2. Part of a thin section from a natural soil structure in surface horizon of zheltozem podzolic (pseudopodzolic) soil

At the eluvial horizon (E), corresponding to the color and degree of ray refraction, residual tissues are at the various stages of transformation (Figure 3a,b). The chair coal particles of plant tissues were identified. These micro morphologic features indicate the complexity and fragmentary of the process of the organic matter decomposition, the result of natural bioactivity as well the ambient conditions with strongly acidic pH and seasonal low drainage. Pores are of all sorts. Micromorphological features can be grouped as the arrangement of the plasma (material smaller than 2 μm) visible under crossed polarized light, because of the high birefringence increasing with the clay content.

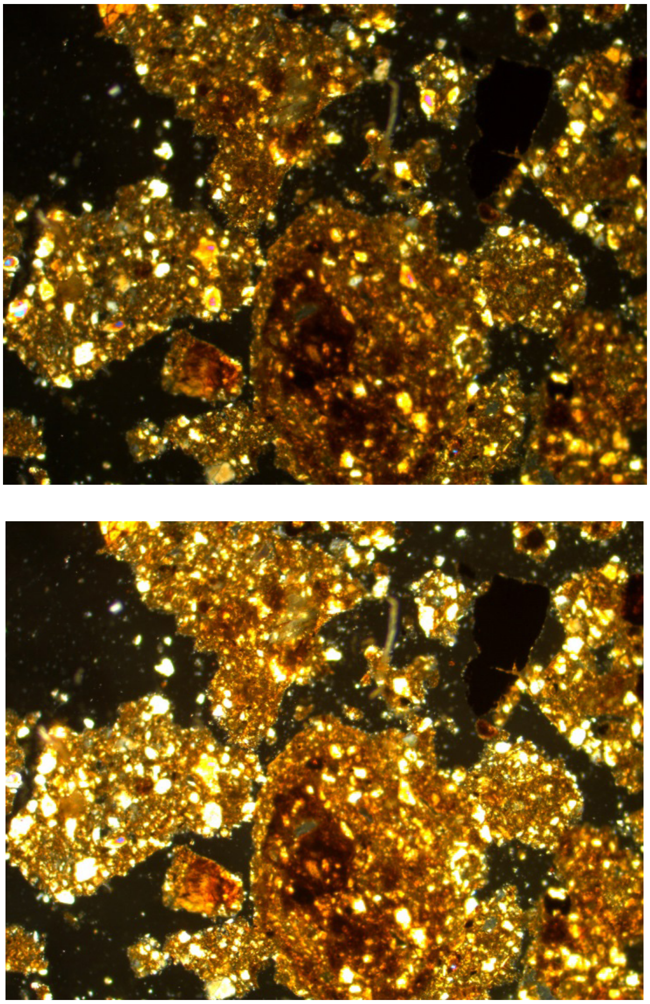

Fig. 3. Part of a thin section from a natural soil structure in eluvial (E) horizon of zheltozem podzolic (pseudopodzolic) soil: a) under plain polarized light (PPL) b) crossed polarized light (XPL)

The thin sections S-matrix at the eluvial horizon is inferior to the quantity (P<S), with reddish-brown color, organic-mineral composed, weakly mobile, locally masepic oriented.

In the illuvial (Bt) horizon (Figure 4), the plasma color changes from yellowish-red to dark brownish-red due to the presence of amorphous iron (Fibla Cebrian et al., 2020).; the quantity and mobility is increasing, with pronounced manifestation of ma-, vo-, skelsepic oriented plasma and iron-clay and clay-iron composed illuvial cutanes, observed at the lower part of (Btg) horizon (Figure 5). The presence of clay coatings, infillings and amorphous pedofeatures (ferruginous nodules), as well as fine and most thick clay coatings are eas-

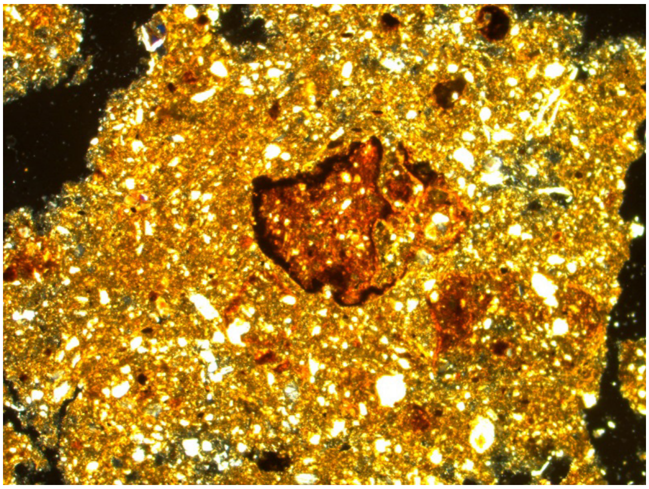

Fig. 4. Part of a thin section from a natural soil structure in illuvial (Bt) horizon of zheltozem podzolic (pseudopodzolic) soil

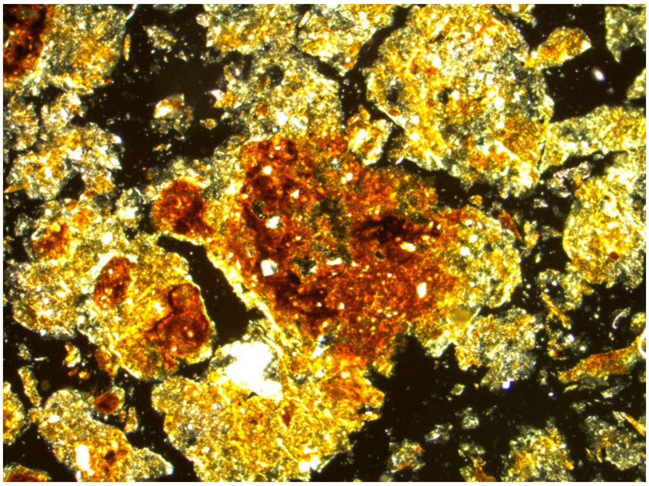

Fig. 5. Part of a thin section from a natural soil structure in illuvial (Btg) horizon of zheltozem podzolic (pseudopodzolic) soil

ily recognized, but thin clay coatings are extremely difficult to identify.

Micromorphological diagnostic of inclusions has fixed existence of intensive process of lesivage and both by presence of papules throughout the illuvial part of the soil which is the evidence of intensive minerals transformation *in situ.*

In the illuvial (Bt) horizon large pores like cracks with smooth surfaces are observed, coated with pronounced iron-clayey cutanes. New formations mainly clay-iron and iron-manganese nodules of different shape, size, composition and surface are observed throughout the entire thickness of illuvial horizon but especially in its lower part. Concentration of clay-iron plasma is red spotted in color with diffuse boundaries within the soil matrix. Clay mobilization in the upper (Bt) horizon was identified, whereas weathering, iron co-eluviation and formation of clay minerals and iron oxides continue, leading to formation of a (Btg) horizon. Deep transformation is observed throughout at the (BCg) horizon (Figure 6).

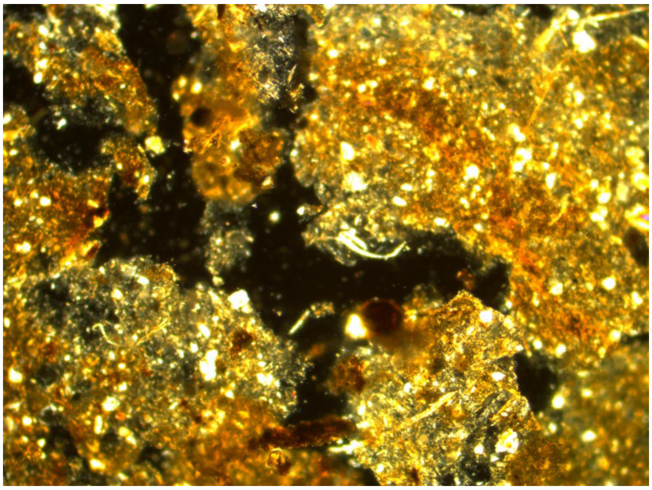

Fig. 6. Part of a thin section from a natural soil structure in deeply transformed (BCg) horizon

These diagnostic features that have taken hundreds or thousands of years to form show functioning of the intrinsic processes of internal translocation, redistribution and concentration of soil components along the depth of the soil profile in the extreme conditions of ambient environment especially during the periods of seasonal over wetting due to low drainage capacity or soil dryness (Pires, 2008).

Conclusion

Detailed macro- and micro- diagnostic of profile of the zheltozem podzolic (pseudopodzolic) soil allows distinguishing the main morphologic categories – sceletone, plasma, organic matter, texture, content and iron new formations. The intensity, performance and location in the horizons is driven and sustained by a combination of factors indicative for soil processes inflicted profile development, as follows:

- indication of the intensive and deeply affected weathering process in all soil horizons is significant destruction of skeleton grains and illuviation trend of the non silicate iron distribution;

- indication for lessivage process is mobility of the fine clay and accumulation particularly at the lower part of the illuvial horizon. Data of particle size distribution are correlated with the great amount of the clay-iron micromass, like cutanes and localization around coarse fragments and pores;
- indication for the hydromorphic processes is macro and micromorphologic occurrence of the iron-manganese nodules, gleyic stains throughout the solum and diffuse cutanes at the lower part of the illuvial horizon;
- the process of alitisation is due to the prevailed non-silicate iron forms distribution, most pronounced at the lower part of the illuvial horizon.

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