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MANAGING THE INTELLIGENT TOOLS IN THE STUDY OF SOIL BIODIVERSITY ACTIVITY AS AN ECOSYSTEM SERVICE PROVIDER

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Abstract

Two important intelligent tools were used in the present paper: low temperature ashing (LTA) and SEM-EDAX to investigate qualitatively and quantitatively the redox features generated by the soil biodiversity activity as an important provider of ecosystem services. The LTA was applied on uncovered soil thin sections to „ashing", in situ, organic components, in order to qualitatively identify the organic components from the mineral ones, as well as their spatial distribution into the dark amorphous redox features. The SEM-EDAX was used to quantitatively identify (in situ in soil thin sections) the constituents of the dark amorphous redoximorphic features, before and after LTA treatment. The soil is a drained Gleysol with mollic epipedon, formed in the alluvial stratified deposits. Oriented uncovered soil thin sections were analyzed and treated following the sequence: micromorphological study → LTA treatment → SEM-EDAX micro-analysis. The results of the micromorphological observation emphasize the presence of many types of redoximorphic features, which appear in plain polarized light as black amorphous redox concentrations. While in the oblique light, the Fe features clearly distinguish by their reddish colour, whereas the Mn and the organic matter showed black colours. During the LTA treatment, the black organic matter was oxidized (with the minimum disturbance of the thin section) revealing the presence of mineral compounds. In contrast to the micromorphological observation and despite of the very spread blackish features (which could suggest high quantities of Mn), the SEM-EDAX micro-analysis had been detected only few percent of Mn. In this respect the combined use of the intelligent tools (LTA and SEM-EDAX) proved to be a valuable technique for in-situ investigation (on thin sections) of the amorphous redox features generated under aquic conditions, by the biodiversity as an ecosystem services provider.

Key words*: *Low temperature ashing, redox features, hydromorphic soils

INTRODUCTION

In hydromorphic soils, the formation of redoximorphic features is used for the identification of aquic conditions [10]. „Although redoximorphic features are visible in the field with both the naked eye and a hand lens, micromorphological analysis can further enhance our understanding of how these features form and how to interpret them correctly" [7].

Organic matter (OM) occurs in a large variety of forms and combinations into the soil with aquic conditions. Thus, very often, dark isotropic OM was mixed with dark Fe-Mn oxihydroxides or coated redoximorphic features. In these cases it is extremely difficult to distinguish between organic and inorganic components.

The Gleysols have feri±mangano±organic pedobioplasma; and the genesis of the redoximorphic pedofeatures depends not only by the activity of microorganism but also by the macro- and mezofauna activity which is highly impressive in Gleysols [8].

The formation of the redoximorphic pedofeatures with the amorphous organic matter into the hydromorphic soils (as a result of the biological activity) provided important ecosystem services as regulation of the nutrients and their uptake and C sequestration. The interaction between the biotic (soil life) with the abiotic constituents are provided with the „regulation of the nutrients and their uptake", one of the most important ecosystem services, as soil fertility [9].

While, increasing soil C sequestration at a global scale, represents one of our best tools in the fight against climate change; but it is still unclear how these C stocks are currently changing so it is difficult to establish meaningful sequestration targets [4]. One of the greatest threats to global C sequestration is rising atmospheric temperatures: if warming drives the loss of even a small proportion of soil C into the atmosphere, it could initiate a positive land C-climate feedback that could cause additional planetary warming [1, 6].

Among all soil groups, Haplic phaeozems had the highest soil organic carbon (SOC) density and Endogleyic solonchaks had the largest carbon sequestration potential (CSP) [3].

D'Acqui et all [5], showed that „a relatively recent promising approach to disentangle the role of physical protection to SOM (soil organic matter) is based on Low-Temperature Ashing (LTA) by oxygen plasma, which enables a controlled removal of SOM from the surface of soil samples inwards without damage of the inorganic constituents". Low-Temperature Ashing (LTA) by oxygen plasma, is a technique able to progressively remove SOM with minimal or no damage to mineral constituents and soil fabric.

The approach used in a study provided insights into the amount of "physically protected C" „in minesoils confirmed that the LTA technique could give an important help for the assessment of the potential of soils in sequestering C" [5].

The aim of the paper was to emphasize the efficiency of using intelligent tools based on modern and excusive techniques (low temperature ashing and SEM-EDAX, together with the micromorphological observation) to investigate qualitatively and quantitatively the redoximorphic features formed due to the aquic conditions and under the influence of soil biodiversity activity as an important provider of ecosystem services.

MATERIALS AND METHODS

The soil is a drained Gleysol from Romania, with mollic epipedon, formed in the alluvial stratified deposits, reclaimed for cropping. The water table is at 1.5 depths.

Oriented uncovered soil thin sections were analyzed and treated following the sequence: micromorphological observation → LTA treatment → SEM-EDAX micro-analysis.

The LTA is a new technique used in premiere in Romania. It was applied on uncovered soil thin sections to oxidize (ashing), *in situ*, organic components, with minimum disturbance of soil thin sections, making possible the observation of the inorganic constituents (covered by the black organic accumulations).

Uncovered soil thin sections were treated with oxygen plasma during 150 minutes.

While the SEM-EDAX was used to identify and quantify (also *in situ* in soil thin sections) the constituents of the dark amorphous redoximorphic features, before and after LTA treatment.

Undisturbed soil had been sampled from each pedogenetic horizon, in micromorphological boxes, air drayed and impregnated with epoxidic resins. After hardening, oriented thin sections (25–30 μm and 5/7 cm) had been made from each sample and studied with Documator (20 X) and optical microscope (50–100 X) in PPL (plain polarized light) and XPL (cross polarized light), as well as in oblique light.

Also oriented uncovered soil thin sections (25–30 μm and 2/4 cm) were made for LTA treatment and SEM-EDAX micro-analysis.

The terminology used for micromorphological description was according to [2, 10].

RESULTS AND DISCUSSIONS

Each type of soil has its own pedofeatures (pedological features or pedological neoformations). The pedofeatures may also represent taxonomic criteria for the classification of different types of soils.

This is also the case of the studied Gleysol, to which characteristic pedofeatures, as redoximorphic features, generated by the waterlogging of soil, are the criteria for taxonomic classification.

The studied soil is a Gleysol, which belongs to the large group of Hydromorphic soils, and is usually located to the slope foot and occupy 1.51% of the Romanian territory (359769.82 ha – Fig. 1).

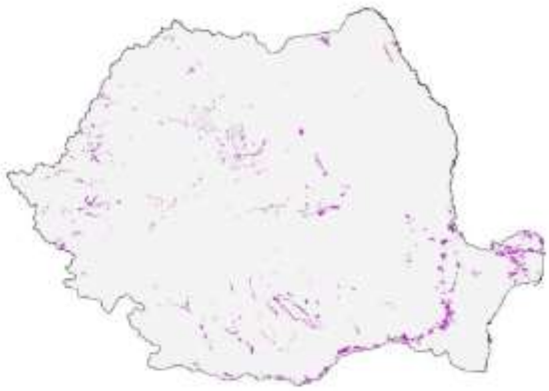

Fig. 1. Gleysol distribution in Romania
Source: Own determination.

The redoximorphic features are not specific to Gleysols, because they also form in other soil types, but they are characteristic, due to their abundance and spatial extension in the matrix of pedogenetic horizons affected by aquic conditions.

The oxidation-reduction (redox) processes are the dominant pedogenetic processes in Gleysols being favoured by the hydromorphic conditions, processes that generated two main types of redoximorphic features:

- redox depletions (in clay, organic matter, Fe, Mn, etc.), and
- redox concentrations (in Fe, Mn, organic matter, etc.).

Micromorphological observation

The results of the micromorphological study emphasize the presence of many types of redoximorphic features (Fig. 2), which appear in plain polarized light as black amorphous coatings, hypo-coatings and quasi-coatings; as well as accumulations, nodules and concretions into the soil matrix. While in oblique light, the Fe features clearly distinguish by their reddish colour, whereas the Mn and the organic matter showed black colours.

Ferric pseudomorphosis on vegetal remains is frequent in many biopores (Fig. 2).

The genesis and the evolution of the redoximorphic features is dependent on the biological activity of the hydromorphic soils.

Fig. 2 Black redoximorphic features in soil matrix and red ferric pseudomorphosis on a bio-pore wall
Source: Own determination.

The activity of macro- and mesofauna in Gleysols is rarely mentioned in pedological literature, the priority being reserved to micro-biodiversity due to its influence on the oxidation/reduction processes.

The biological activity of the studied Gleysol is high, although the specific water regime of these soils may suggest the opposite.

In the pedogenetic horizons, the presence of biopores (both with and without coprolites) had a positive effect on the soil drainage. The soil solution and the air circulation through poral space generated textural and amorphous coatings and hypo-coatings.

The genesis of the pedobioplasma organic components is closely linked, practically dependent, on the microbial activity.

The microbiological activity was pointed out (in the soil thin sections) by the fungi fruiting (mycelium fragments and spores) and resistance (sclerotium) bodies that appear mainly in the surface horizons, either in the poral space or in the soil matrix.

The humified organic matter in the studied soils is hydro-mull or anmoor. It was formed under the excessive hydromorphic conditions followed by seasonal periods of dryness (and oscillation of groundwater level) which favoured the humification and the rapid polycondensation of humic compounds. Consequently, the organic matter is

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dominated by the humic acids and humines present in relatively high quantity.

The black organic compounds coated amorphous redox features and/or are mixed with Fe and Mn oxihydroxides.

Due to the similar optical properties of the black organic matter (melanized) and the Mn oxihydroxides and some Fe oxihydroxides respectively, the distingtion between them is very difficult.

Furthermore, the presence of Mn in some redoximorphic features is questionable, given that some of these features were initially plant residues.

The nodules are, usually, composed of Fe±Mn oxihydroxides. If the Fe oxihydroxides are easily detected by their reddish colour, the identification of Mn presence into the redox features is difficult. In this respect, the need for other detailed techniques as chemical micro-analysis *in situ* on soil thin sections arises.

SEM-EDAX micro-analysis *(before the LTA treatment)*

The SEM-EDAX (electron microscope equipped with an energy dispersive X-ray spectroscopy) micro-analysis revealed the complex composition of the redox concentrations.

Thus, together with Fe and Mn, other elements such as Al, Si, K, Ca has been detected (Fig. 3).

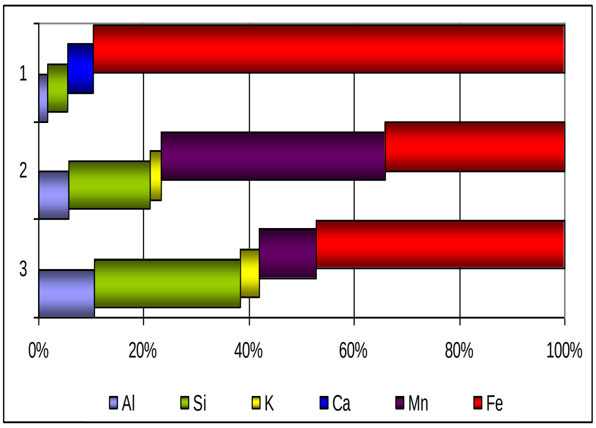

Fig. 3. EDAX micro-analysis of Fe pseudomorphosis on a vegetal remains (1); matrix (2); and redoximorphic feature (3)
Source: Own calculation.

The micro-analysis (Fig. 3/1) of a Fe pseudomorphosis on a vegetal remain (Fig. 3 and 4) detected the presence of Ca (5.07%), while into the soil matrix (Fig. 3/2) and the redoximorphic feature (Fig. 3/3), the Mn appeared in relatively high quantities (42.69% and 10.81% respectively).

The LTA treatment

When black, isotropic organic matter covers the redoximorphic features or is mixed with the oxihydroxides (ferric and manganese) become difficult, if not impossible to distinguish between the organic and the inorganic components (due to their optical properties which are similar).

In this respect, the LTA became a useful tool.

The LTA treatment was applied to the soil from the oriented uncovered thin sections. After the treatment the dark amorphous redoximorphic features practically disappeared (Fig. 3).

During the LTA treatment, the black organic matter (abundant into the soil matrix – Fig. 2) was oxidized (with the minimum disturbance of the thin section) which make possible the observation of the mineral constituents (Fig. 4).

The colour of ferric oxihydroxides in the matrix accumulation became bright red, being accentuated by acquiring intense tones during the oxidizing treatment.

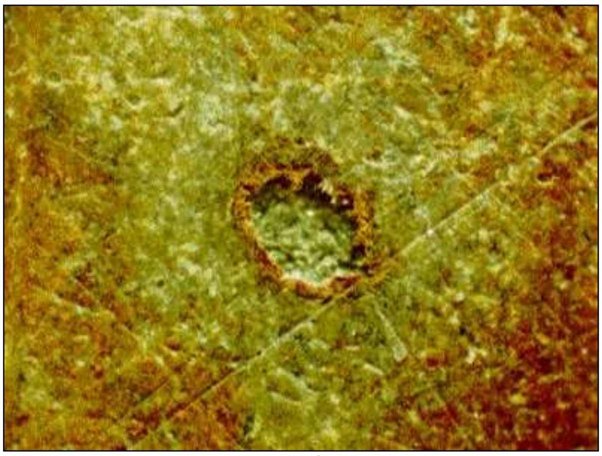

Fig. 4. The soil thin section after LTA treatment
Source: Own determination.

In addition, the organic matter that covers the oxihydroxides has also a protective role, against the dissolving soil solution.

***SEM-EDAX micro-analysis** (after the LTA treatment)*

The SEM-EDAX micro-analysis had been applied after the LTA treatment to detect the presence of mineral constituents (Fig. 5).

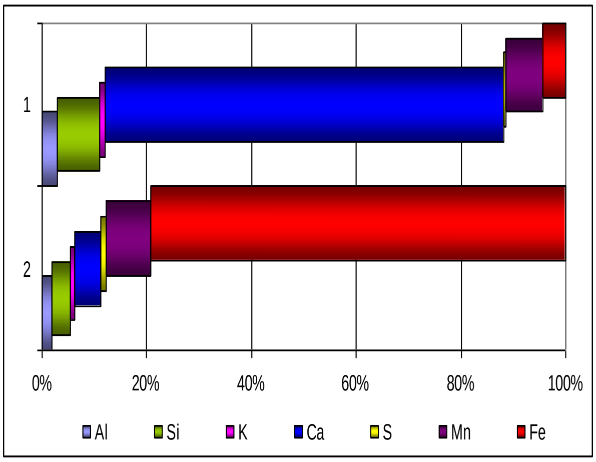

Fig. 5. SEM-EDAX micro-analysis before (1) and after (2) LTA treatment
Source: Own calculation.

In contrast to the micromorphological observation and despite of the very spread blackish features (which could suggest high quantities of Mn), the SEM-EDAX micro-analysis had been detected only few percent of Mn: 7.03% before LTA and 8.33% after LTA (Fig. 5).

The results showed that the combined use of the intelligent tools (LTA and SEM-EDAX) proved to be a valuable technique for *in-situ* investigation (on thin sections) of the amorphous redox features generated under aquic conditions.

CONCLUSIONS

The use of intelligent tools for the study of the characteristic features of a Gleysol concluded:

The applied LTA new technique was useful to study *in situ* on thin sections the amorphous organic matter (having the same optical characteristics as Mn and some Fe oxihydroxides).

Biological activity plays an essential role in the formation of the redoximorphic features (by digging channels that control the soil solution circulation and concequently drained the soil, and melanized organic matter).

The Gleysol biodiversity activity generated redoximorphic features and provided important ecosystem services as regulation of the nutrients and their uptake, as well as C sequestration.

The complex study using intelligent tools (micromorphology → LTA → SEM-EDAX) proved to be useful in the qualitative and quantitative study of the soil specific characteristics as redox features generated by aquic conditions.

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