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Use of micromorphology for humus characterization and classification in some mediterranean calcareous soils

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A B S T R A C T

A micromorphological approach is potentially useful in the classification of humus systems. However, the systematic description of organic material found in thin sections of humus profiles is poorly developed in comparison to already existing guides for mineral soils. This study presents the use of thin section microscopical analyses combined with digital images in order to set the highly detailed method of qualitative description and classification of some Mediterranean humus forms. Three forests and one meadow were selected for topsoil sampling in the Catalan Pre-Pyrenean mountain region. Fourteen thin sections were prepared, scanned and analyzed using the petrographic microscope. This resulted in the description of seven micromorphological fabric units based on their amount, shape, color, size, distribution and degree of decomposition. Digital images from thin section scans helped to classify three Amphi (Pachy-, Eumacro-, Eumesoamphi), and two Mull (Oligo-, Eumull) humus forms.

1. Introduction

The development of any humus form is controlled by soil-forming factors such as climate, topography, soil parent material, organisms (autotrophs and heterotrophs) and human activity (Barratt, 1969). The successive transformation stages of litter under the different levels of faunal and microbial performance lead to the formation of definite horizons of a particular humus form. The morphological differences between diverse humus forms reveal information not only about the efficiency of soil organic matter (SOM) transformation but also about the reaction of forest ecosystem to management practices and growth cycle (Bernier and Ponge, 1994; Ponge, 2013). In this sense, they are thought to be the fastest and the cheapest way of indicating the level of nutrient cycling in ecosystems (Ponge, 2003; Andreetta et al., 2011).

Humus forms rich in biological activity may well correspond to wide range of pH and performance of enzymes (Andreetta et al., 2013).

As it is not quite clear why different humus forms have the same C/N ratios and SOM contents (Brethes et al., 1995) and yet different rates of biological activity, it is important to apply micromorphology to humus profiles.

The first investigations on humus micromorphology were related to soil zoology (Kubiëna, 1955; Zachariae, 1964, 1965; Babel, 1968; Bal, 1970; Pawluk, 1987). At the same time, the decomposition of different plant rests and tissues in the horizons of humus forms and the formation of microfabrics were described in studies of Barratt (1964, 1967). Scanned thin sections and micromorphology were also used by a few researchers to characterize humus types and faunal activity in relation to soil structure (Ciarkowska and Niemyska-Łukaszuk, 2002; Davidson et al., 2002, 2016). Finally, the most common humus components and fabric types of several humus forms found in Central Europe were summarized in "Monographs in Soil Science" (Babel, 1975).

The description of organic materials has not been taken into account at the same level as that of mineral soil materials. In fact, many of the basic concepts established by Bullock et al. (1985) and later by Stoops (2003) such as the coarse/fine parameters, b-fabric, or even pedofeatures, cannot be applied or are irrelevant when describing thin sections of organic horizons. Even if we have information about the types of organic components and the changes they undergo in soils (Babel, 1968; Stoops, 2003; Stolt et al., 2010; Kooistra, 2016) we are still missing a systematics of description of organic materials, as we already have for mineral ones.

In classical works on humus morphology (Müller, 1878) the three main humus forms Mull, Moder and Mor are described. However, the European reference base of humus forms (Zanella et al., 2011) also mentions Amphi, which seems to be typical for Mediterranean environment (Andreetta et al., 2011, 2016; De Nicola et al., 2014). In contrast, some authors emphasize that Amphi is a Xeromoder which overlies a macrostructured A horizon of Mull (Bottner et al., 2000) and is also found in southern part of Alps (Graefe, 2007) and in Belgian forests (Ponge, 1999).

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A previous work by the authors explored the differences between Amphi and Mull humus forms in Mediterranean mountain soils based on micromorphological, physical and chemical observations, and found that it is possible to significantly assign a given set of micromorphological features to the studied humus types (Zaiets and Poch, 2016). The aim of the present study is to show with higher detail these micromorphological tools in order to set a method of qualitative description of humus profiles that could be useful for the study of soil organic matter dynamics.

2. Materials and methods

2.1. Study sites

The study area is situated in the Pre-Pyrenean mountain region in the north-east of the Iberian Peninsula. The relief is tabular sometimes with steep slopes over 20%. The altitude is 800–1100 m asl. The area is covered mainly by pine and oak forests developed on stony calcareous soils. The climate is typical Mediterranean with transition to a subalpine type of climate on higher altitudes. Four habitats within the area were selected for topsoil sampling: holm oak forest (T: Torra), pine brook forest (CAN: Canalda), mixed pine forest (CO: Cogulers shaded; CS: Cogulers sunny) and high meadow (P: Prat). At each site organic, organo-mineral and mineral horizons were simultaneously sampled and humus forms (Table 1) were classified according to the European Humus Forms Reference Base (Zanella et al., 2011).

2.2. Micromorphology

Fourteen thin sections (5 × 13 cm) of topsoil from the study sites were prepared following the methods of Benyarku and Stoops (2005). All thin sections depicted several organic horizons at once except of those prepared from mineral (Bw) horizons. All thin sections were analyzed through an Olympus petrographic microscope (BX51) using 2 x magnification in order to identify and describe fabric units. The thin sectionś true color scans were made with a high-resolution Epson scanner in order to explore simpler method of topsoil investigation. Each image had around 2 MB.

The guidelines of Stoops (2003) were followed for general fabric description (as shape, distribution, orientation, abundance among others). Observed plant residues were grouped in classes according to their morphological changes during their decomposition (Tian and Takeda, 1997; Blazejewski et al., 2005). Descriptions of the different evolution patterns of organic materials followed Kooistra (2016).

A special feature class "organic fine matter" refers to amorphous organic material and organic material that does not have recognizable origin and organic pigment in the inorganic micromass (Stoops, 2003).

The proposed qualitative description of the humus profiles is based on both microscope and scan images and is enlarged from the one proposed by Stoops (2003):

2.2.1. Structure and porosity

The terms to be applied are the same as in mineral horizons for the pedal material, although this is not the most frequent situation for organic materials. For the apedal material (soil particles not assembled in higher units), the structure should be described according to the dominant fabric or c/f related distribution: for instance, massive (sapric densely packed material), layered (flat components with the longer axis parallel to the soil surface) or single grain (monic c/f related distribution, no fine material, loosely packed organic components).

2.2.2. C/f limit, c/f ratio, c/f related distribution

Although these parameters are very important in mineral materials, they do not have a very high relevance in most of the organic materials. The definition of c/f limit (the lowest size of a mineral particle we can identify by optical mineralogy) cannot be applied to organic components, since the lowest size of any organic particle could be that of a phytolith, a cell or an amorphous humus particle, which have very different origins. Nevertheless, it could be relevant in some cases (i.e. sapric materials with some recognizable organic tissues).

2.2.3. Coarse (organic) components

This is the most important and significant part of the description, since the identification of these components determines to a large extent the nature and behaviour of the organic material. The description (Table 2) from organs to amorphous organic material follows the four degrees of organic matter decomposition that can be recognized. Indeed, the different transformation paths of organic components (Kooistra, 2016) are closely related to the ecological conditions of the humus forms.

2.2.4. Pedofeatures

Pedofeatures, often used as indicators of pedogenesis in mineral horizons, are not as meaningful in organic materials. Nevertheless, it is important to record any possible pedofeature in the mineral components, as well as evidences of redoximorphic or textural features (cappings, coatings of mineral material).

3. Results

3.1. Field description of humus forms

According to humus forms classification in the field, one Amphi and two Mulls were observed. The litter horizon (OL) of the Pachyamphi (CAN) consisted of partly bleached pine needles, twigs, pieces of wood, grass residues and moss. The OF horizon had lightly decomposed wood and other plant rests with numerous fungal hyphae. The underlying OH horizon was twice as thin than the previous one and of darker color with thin roots. The organo-mineral A horizon had a biomesostructure.

The litter horizon of the Eumesoamphi (CS) was much poorer and consisted of fresh and old pine needles, twigs, bark, wood and grass rests. An OF horizon was present, whereas the OH was discontinuous. The A horizon had a biomesostructure.

Table 1
Study sites characteristics (from Zaiets and Poch 2016).

Site code	Canalda (C)	Cogulers O (shaded aspect) (CO)	Cogulers S (sunny aspect) (CS)	Torra (T)	Prat (P)
Number of samples and horizons	4 OL, OF + OH, A, Bw	4 OL, OF + OH, A, Bw	4 OL, OF + OH, A, Bw	4 OLv, OF, A, Bw	2 A, Bw
Vegetation	Natural riparian *Pinus nigra* forest	Natural not managed *Pinus nigra* and *Pinus sylvestris* mixed forest	Natural not managed *Pinus nigra* and *Pinus sylvestris* mixed forest	Natural not managed *Quercus ilex* forest	*Thymus vulgaris* high meadow
Altitude, m asl	800	800	800	900	1100
Soil type (SSS, 2014/ IUSS 2014)	Typic Ustifluvent/ Orthofluvic Fluvisol	Typic Ustorthent/Calcaric Regosol	Typic Calciustept/Leptic Calcisol	Typic Calciustept/Leptic Calcisol	Typic Haplustept/Leptic Calcaric Cambisol
Humus form (ERB, 2011)	Pachyamphi	Eumacroamphi	Eumesoamphi	Oligomull	Eumull