

Micromorphological identification of selected lithogenic features in soils developed from Lower Triassic deposits in the Holy Cross Mountains (S Poland)

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Abstract

Areas with red soils developed from Lower Triassic (Buntsandstein) deposits cover about 500 km² of the Holy Cross Mountains area (S Poland). Application of modern techniques such as microscopic studies and computer image analysis allow us to identify the lithogenic features of these soils and establish their systematic position. Micromorphological analysis revealed the occurrence of such lithogenic soil substrate features as the presence of hematite and muscovite in the microskeleton, diagenetic features of the quartz grains or fissuring. Based on these data the soils were classified as Leptosols or Cambisols.

Key Words

pedogenesis, lithogenesis, sandstones, siltstones, clays

Introduction

One of the most crucial problems in soil science is the determination of mutual relationships between such factors as the geological origin of the parent rock, the pedogenic process and the soil properties. This issue is particularly significant in cases when the parent material is represented by deposits with specific or variable mineralogical-petrographic properties. In present-day research trends, the most objective indicators of the *in situ* soil environment are micropedological methods. Based on analysis of unchanged soil samples using microscopic and ultramicroscopic techniques, these methods allow us to identify various elements of the soil environment, determining their mutual relationships in space (pedons), as well as indicating their succession in time (Zaniewski, Van der Meer, 2005; Todisco, Bhiry, 2008). In case of micromorphological studies, the application of optic microscopy methods in polarized transmitted and reflected light allows the observation of many features and properties of the soil substrate that are imperceptible to the naked eye (e.g. size, shape and distribution of coarse grains, distribution of fine elements and pores, presence of organic remains), and which compose the soil microstructure (soil fabrics; Brewer, 1976). Detailed recognition of the microstructure elements allows to evaluate the transformations taking place in the parent material under pedogenic processes. Determination of the scale of these transformations, e.g. based on the analysis of lithorelicts, may have crucial significance in interpreting soil properties and origin (Fitz Patrick, 1993; Stoops 2003). Application of digital registration of micromorphological images and advanced computer software for data processing allow an objective evaluation of the determined features and phenomena (Zaniewski, Van der Meer, 2005; Eliot, Heck, 2007).

The present studies were focused on recognition and quantification of characteristic lithogenic elements in the substrate of soils developed from the Lower Triassic (Buntsandstein) sandstone-clay sediments of the Holy Cross Mountains (S Poland). The obtained results allowed to verify macroscopic data on the range and course of pedogenic processes, origin of some soil horizons and explanation of the specific properties of these soils. They were also an important factor used in classifying the studied soils.

Material and methods

The Holy Cross Mountains are a hilly area in southern Poland. Palaeozoic folds surrounded by Mesozoic strata were exposed after tectonic uplift in Tertiary times (Mizerski, 1995). A large variety of rocks resulted in the complexity of the spatial distribution of many soil types. The Lower Triassic Buntsandstein deposits occur in the Holy Cross Mountains in an area of about 500 km² and are developed as clays, sandstones and conglomerates (Senkowiczowa, 1970). Soils developed from these sediments have unique features and properties, unknown in other genetically and typologically similar rocks. One of the dominating features is the characteristic red colour, resulting from the presence of hematite in the substrate (Szafranek, 1989; Zagórski, Kaczorek, 2002). The study area was located in the Holy Cross Mountains near Wrzosey, Skrzelczyce, Osiny and on Brzuśnica Hill. Profiles of soils developed from Lower Triassic Buntsandstein conglomerates, sandstones, clays and siltstones were made. The micromorphological studies were made on

thin sections from all genetic horizons with application of the Olympus BX-41 polarized microscope. The terminology applied for micromorphological features is after Stoops (2003) and Bullock (Bullock *et al.*, 1985). Image analysis was made with AxioVision 4.5 software with Auto Measure module; each thin section was covered with 8 photographs made at identical light exposure and magnification, which were next combined into an entire thin section (Zaniewski, Van Der Meer, 2005).

Discussion of results

In soils located near Brzuśnica Hill the crucial problem was to explain whether the specific gravel-clay horizons at 50-90 cm are illuvial horizons Bt or lithogenic horizons C or R. Microscopic analysis of thin sections indicated that many micromorphological features of the soil substrate from these horizons show similarities to the petrographic-lithological features of Lower Triassic conglomerates. The main microskeleton elements $c_{(>1\text{ mm})}$ are rather well rounded clasts of various rocks – sandstones, quartzites and siltstones. Rarer are fine quartz grains $c_{(1-0.01\text{ mm})}$ and muscovite plates. Fine elements $f_{(<0.01\text{ mm})}$ comprise clay minerals and they generally fill up voids between the grains (Figure 1). The micromorphological features of this fraction indicate that it is of lithogenic character and represents the primary matrix-type component. The characteristic red colour indicates the presence of hematite, which evidences its relationship with the Triassic clay rocks (Bullock *et al.*, 1985; Zagórski, Kaczorek 2002; Tawornpruek *et al.*, 2006). The analysis of clay concentrations did not reveal the presence of specific incrustations pointing to processes of clay fraction translocation. Thus, eluvial-illuvial processes responsible for the formation of horizon Bt are not present. Based on these results the soils were assigned to Cambisols.

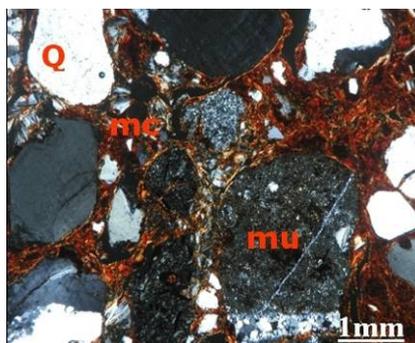


Figure 1. Mikroskeleton differentiated with size of grains and mineral composition; Q – quartz, mc – muscovite, mu - mudstone. Brzuśnica Hill profile, gravel-clay horizon (XPL).

In soils developed from sandstones (Skrzelczyce profile), an important issue was the small thickness of the soil profile. The location of soils in the topmost parts of the hills showed the possibility of erosional processes as factors influencing their formation. Micromorphological analysis showed that most quartz grains derive from the weathering sandstones. This is evidenced by their small size $c_{(1-0.01\text{ mm})}$ and lack of rounding (Figure 2A). The lithogenic origin of the quartz grains is indicated also by the fact that a large number of grains showed characteristic optical features e.g. microsegment relief (Figure 2B) and regeneration rims. These are typical diagenetic features of the Lower Triassic sandstones (Barczuk, 1979). The obtained results unequivocally indicate that the soils developed from Lower Triassic sandstones are shallow soils, and their soil material is not the result of accumulation (glacial, eolian) processes but is formed in situ due to weathering of rocks. Thus the soils were classified as Leptosols.

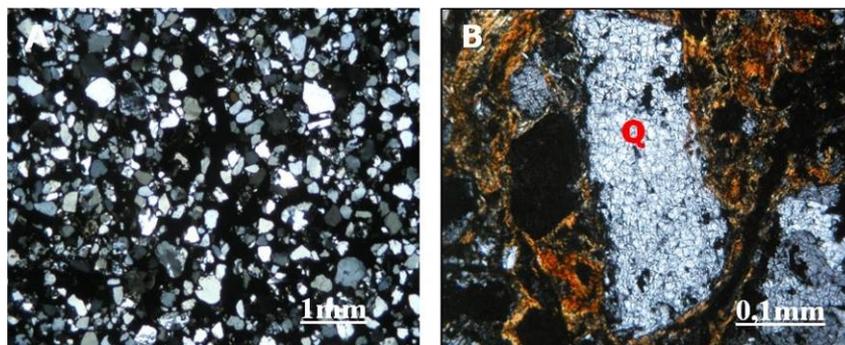


Figure 2. A – unrounded quartz grains in mikroskeleton; B - mikrosegment relief of quartz grain. Skrzelczyce profile (XPL).

In soils developed from siltstones (Wrzosi profile), micromorphological analysis of the lithogenic features allowed us to distinguish the lower range of the pedogenic processes. The specific character of these soils (fine-grained soil substrate and uniform red colour) caused difficulties in macroscopic distinguishing of the genetic horizons. Microscopic analysis of thin sections in subsequent samples allowed to determine that the prevalence of lithogenic features is evident below 80 cm of the soil substrate. The small diameter of the microskeleton grains $c_{(0.1 - 0.01 \text{ mm})}$ directly corresponds to the siltstone fraction and comprises unrounded quartz grains and small muscovite plates (Figure 3). The most important lithogenic indicator is the characteristic red colour of the fine elements $f_{(<0.01 \text{ mm})}$ comprising the clay fraction. It occurs in form of laminas (or forms zonal concentrations), what evidences the preservation of sedimentary features of the deposit. Deep table of the parent rock allows to classify these soils as Cambisols.

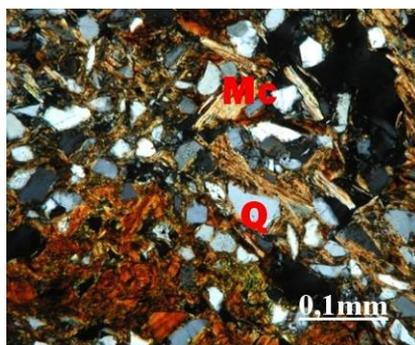


Figure 3. Microskeleton with unrounded quartz grains and small muscovite plates. Wrzosi profile, depth 80cm (XPL).

In soils developed from clays (Osiny profile), an important issue was the presence of a characteristic structure in the middle and lower part of the soil profile. The soil substrate was disintegrated into sharp-edged prisms. This is probably a lithogenic feature. Microscopic analysis showed that the clay soil substrate is sub-divided by numerous fissures (cracks structure; Bullock *et al.*, 1985), whereas voids in form of channels and chambers are absent. A characteristic feature is the lack of changes in the organization of clay domains near the fissures (vosepic structure; Brewer, 1976). Detailed measurements of the microscopic images was made with application of computer image analysis. It showed that the fissures occurring in the soil substrate are 200-400 μm long and organized in a network with meshes approximately at 90° (Figure 4). The fissures are of secondary character, typical of the Lower Triassic clays from the Holy Cross Mountains area and interpreted as the result of post-diagenetic relaxation of the clay sediment (Barczuk 1979). The presented lithogenic features testify for the assignment of these soils to Cambisols.

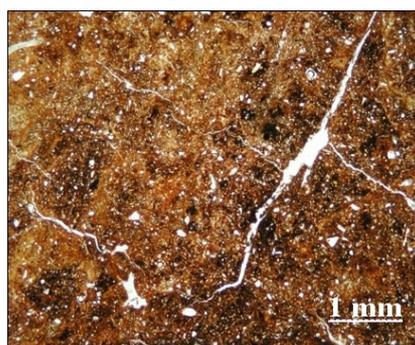


Figure 4. The fissures organized in a network with meshes approximately at 90°. Osiny profile (PPL).

Summary

Micromorphological studies have shown that soils may preserve the lithogenic features of the parent substrate. They include: the presence of hematite and muscovite in the mineralogical-petrographic microskeleton and soil plasma, the diagenetic regeneration rims on quartz grains as well as secondary fissuring. The identification of these features allowed a precise determination of the systematic position of the studied soils: Leptosols in the case of the Skrzelczyce profile and Cambisols in the case of the Wrzosi, Osiny and Brzuśnica Hill profiles.

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