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MICROMORPHOLOGICAL STUDY OF PEDOLOGICAL SOIL FEATURES : A REVIEW

G.W. Ageeb[1], A.S. Taalab[2], Hanan S. Siam[2] and Safaa A. Mahmoud[2]

[1]Soil and Water Use Dept and. [2]Plant Nutrition Dept., Agriculture and Biological Research Division, National Research Centre, 33 El Buhouth St., 12622, Dokki , Giza, Egypt.

Abstract

Micromorphology is the branch of earth science that describes, interprets, and measures the components, features and fabrics of soils materials, and prehistoric/historic artifacts at the microscopic levels. Undisturbed samples are required to see the relationship and arrangement of components or individual soil particles as mineral and organic materials as they occur in nature. Sampling will affect what is observed in the thin section and may cause erroneous conclusions to be made about the soil material being studied. Studies of soil genesis require samples be collected from each horizon, in contrast to studies of soil crusting focus only on the upper few millimeters of soil. Single sample will not represent the variation in structure, voids, or numbers of features present in the object of interest. Many soil features change with the seasons. At various times during the year, soluble minerals can crystallize or dissolve, structural cracks can be open or closed and organic materials can undergo various stages of decomposition. Accordingly, the investigator must anticipate the potential seasonal changes in the features of interest to select the most appropriate sampling time, although sampling in two different periods can provide much information regarding soil dynamics. Micromorphology is can be used simply as a descriptive tool, or as a quantitative one when descriptions are backed by morphological measurements or mineralogical and chemical analyses.

Introduction

Micromorphology is the branch of earth science that describes, interprets, and measures the components, features and fabrics of soils regolith materials, and prehistoric/historic artifacts at the microscopic and submicroscopic levels (Stoops, 2003). Undisturbed samples are required to see the arrangement and relationship of individual soil particles or components as they occur in nature. Both mineral and organic materials are considered. The magnifications used for observation range from that obtained with a simple hand lens to the high magnifications produced by transmission electron microscopes. Micromorpholgical concepts can also be applied using the naked eye. This has been done in the case of hydraulic soil field indicators (USDA-NRCS, 2002) and also with redoximorphic features that are used in the soil classification system *Soil Taxonomy* (Soil Survey Staff, 1999). Microscopic examinations are usually performed on thin sections at magnifications beginning at 10x (for examination of microstructure) and followed by increasingly higher magnifications. Thin sections are slices of soil or sediment that have been impregnated with a resin, fixed to a glass microscope slide, and then ground to a precise thickness so that the optical properties of minerals and pedological features are evident.

Applications of Micromorphology

Micromorphology is now an established analytical tool that provides unique information for any discipline where soil particles, pores and organisms play a role. It can be used simply as a descriptive tool, or as a quantitative one when descriptions are Supported by chemical and mineralogical analyses or morphological measurements.

Soil genesis : Micromorphology was used to develop the definitions of Cambic, Oxic, Spodic, and Argillic diagnostic horizons in Soil Taxonomy (Soil Survey Staff, 1999). Recent studies related to soil genesis can be found in the work of Ageeb *et al.* (2008); Nordt *et al.* (2004), Fauzi and Stoops (2004), Driese *et al.* (2004), and Scareiglia *et al.* (2005). Micromorphology also contributed to studies of duripan genesis and fragipan degradation (Lindbo *et al.,* 2000), gypsum in soils (Ageeb *et al.* 2015, Artieda and Herrero, 2003: Dultz and Kuhn, 2005; Herrero and Porta, 2000), interpretation of paleosols (Alonso *et al.,* 2004), and clay movement (Holliday and Rawling, 2006; Khormali *et al.,* 2003). The varied depositional forms of Fe in soils are documented in studies involving ortstein (Kaczorek *et al.,* 2004: Horbe *et al.,* 2004).

Soil microstructure : Micromorphology used to describe soil microstructure, normally by evaluating the sizes and shapes of soil pores. For example, thin sections show how wheel compaction reduced the number of macro-pores in trafficked compared with non-trafficked rows. Pachepsky and Ravils (2003) evaluated the influence of soil microstructure on water retention, and concluded that future research requires quantitative characterization of soil microstructure.

Surface crusts : Surface crusts reducing both seedling emergence and soil water infiltration. Two kinds of crusts have been identified, structural crusts and depositional crusts. Structural crusts form by water drops striking and modifying bare soil, causing a destruction of aggregates (Fox *et al.,* 2004; Lado and Ben-Hur, 2004). Depositional crusts develop from a build-up of translocated fine particles carried onto the surface by flowing water. Numerous studies have shown that crust characteristics are influenced by a variety of soil properties, including texture, mineralogy, degree of aggregation of the soil (Lado and Ben-Hur, 2004). For example, in soils that are easily dispersed, fine particles that are stripped off coarse particles or aggregates are washed into soil and plug pores.

Archaeological studies : Archaeologists use micromorphology as well (Kooistra and Kooistra, 2003; Arpin and Goldberg, 2004). Pottery fragments, charcoal, coprolite, or bone can be identified through thin section examination, and the effects of burning and physical disturbance can be seen as well. Pottery and ceramics develop unique microstructural patterns and minerals at high temperature, and these features can be used in archaeological studies as indicators of furnace firing and also to understand how raw materials were prepared for building (Sakarya *et al.,* 2004). Micromorphology has also been used to integrate interpretations among artifacts, climate, geomorphology, and soils excavated in archaeological sites (Courty *et al.,* 2004; Mermut *et al.,* 2004). The depositional history of the sediments covering the floors of caves can often reveal if and approximately when humans (or animals) occupied the site, as well as the amount of activity (Angelucci, 2003). Human and animal activity is revealed by the presence of bone, fecal material, or other artifacts (Schiegl *et al.,* 2003; Shahack-Gross *et al.,* 2004). In thinly bedded sediments, the history of the site can sometimes be reconstructed by identifying sedimentary layers and comparing them the surrounding geological materials. Lima *et al.* (2002) studied a toposequence of anthropogenically influenced soils in western Amazonia and combined total elemental analysis, mineralogy, particle size, and micromorphological data to evaluate origins of soil material, pottery, and to estimate population density in the precolonial era.

Biological materials in soil : Jongmans *et al.* (2003) and Pulleman *et al.* (2005) quantified the effects of earthworm activity on aggregation, compaction, soil structure, and decalcification, and documented the abundance of earthworm activity by identification of calcite spheroids, fecal pellets, and worm-worked groundmass in thin sections. Bruneau *et al.* (2004) used image analysis of stained thin sections to quantity bacterial populations and void space in grassland soils.

Hydraulic conductivity and water movement in soil : Hydraulic conductivity and water movement can be estimate through soil materials using micromorphology. The water-conducting pores in the soil can be easily seen with dyes or fluorescence microspheres (Driese and McKay, 2004). This technique has been used to determine whether quartz veins in saprolite conduct water rapidly. Saprolite, or weathered bedrock, can contain quartz veins that are planar-shaped bodies of quartz gravels. They appear capable of conducting water and wastewater quickly. Septic system drainlines that are placed over quartz veins could cause untreated sewage to flow quickly to groundwater and contaminate it. McKay *et al.* (2005) found decreases in saturated hydraulic conductivity related to macro-pore infilling and concluded this relationship was a common feature in many saprolites found in humid, temperate regions.

Relationships between field and microscopic observations

Micromorphological studies span the range between morphological observations in the field and observations of the same fabric at the microscopic level (Scarciglia *et al.,* 2005).

- **Fabric of Vertisols**: Fig. 1 show the fabric of Vertisols where, dominant clay mineral is montmorilonite and swelling and shrinking of the clayey soil results in cracks (Fig. 1,a), stress orientation around a large grain (Fig. 1,b), orientation of plasma on slikenside surface (Fig. 1, c) and striations of plasma(Fig. 1,d) . A characteristics feature of the soil is slickenside, which arranged in a curvi-linear manner.
- **Fabric of aridisols:** Fig.2 show Aridisols with cambic horizon, have a general uniform matrix (Fig. 2,a). Those with an argillic horizon (Fig. 2,b) show some thin cutans (Fig. 2,c). Those with a gypsic horizon (Fig. 2, c) dispersed over the matrix. All Aridisols are enriched with calcium carbonate or calcite.
- **Fabric of Entisols:** Being soils formed on recent sediments, Entisols show the original stertification of the sediment. Other features are present in Entisols as the present of early stages of many formations. Fig.3. show beginning stage of nodule formation (a), while (b) show another young soil, composed of fresh, rather unaltered, primary minerals.
- **Special minerals features** :

1- **Gibbsite**: This minerals found in highly weathered soils such as Oxisols and Ultisols. The aluminum oxyhydrate ($AlO\text{-}OH_3$) crystallizes at soil pH>5.5 and the most common mineral is gibbsite. Boehmite the mono-hydrate is rare. Fig.4, (a) show a gibbsite nodule(X50) with whitish gibbsite crystals and with well defined crystals at X5,000 (Fig.4, b) and (c) is an insitu alteration of feldspar directly to large gibbsite crystals (Fig.4, d) X5,000.

2- **Goethite**: Iron crystallizes in soil as goethite ($FeOOH_3$), hematite (Fe_2O_3) and each with different shapes or habit. Goethite is the most common in soils. Two different habit of goethite seen in void coating (Fig. 10, a) or concretions of wet soils (Fig. 5, b). In well drained soils (Fig. 5, c) or in laterites a lenticular habit (Fig. 5,d) may be observed.

3- **Manganese:** In thin section manganese minerals appear as black, diffuse nodules (Fig. 6, a). A number of minerals may be present in soils depending on conditions in the soil. Manganite (Fig. 6, b) is a common mineral in most well drained soils. In some soils developed on basalts, nsutit (Fig. 6, c) and lithophorite (Fig. 6, d) may occur.

3- **Gypsum:** Is a common mineral in Aridisols. It has several habits. The most common is lenticular (Fig. 7, a, b, c). Occasionally in Egypt as a fibrous habit (Fig. 7, d).

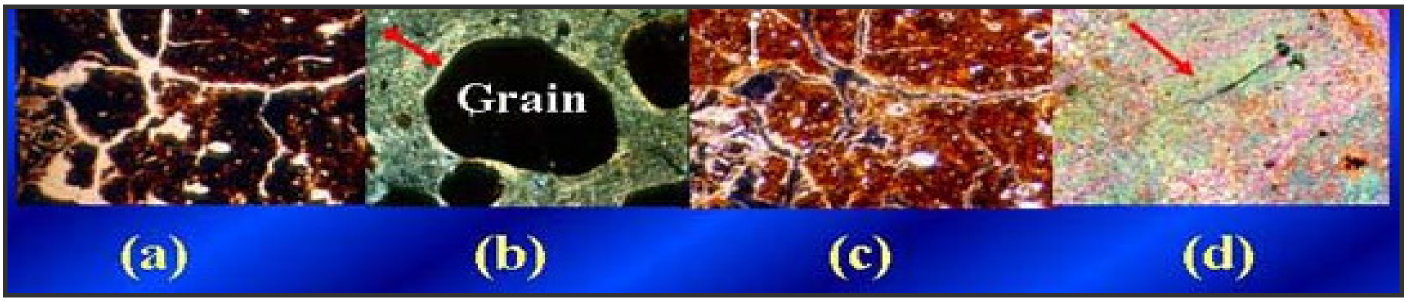

Fig. 1 : The fabric of Vertisols

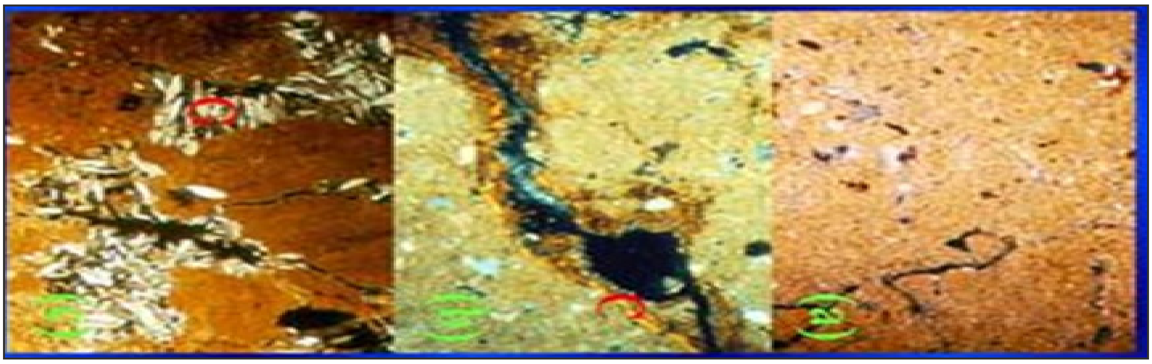

Fig. 2 : The fabric of Aridisols

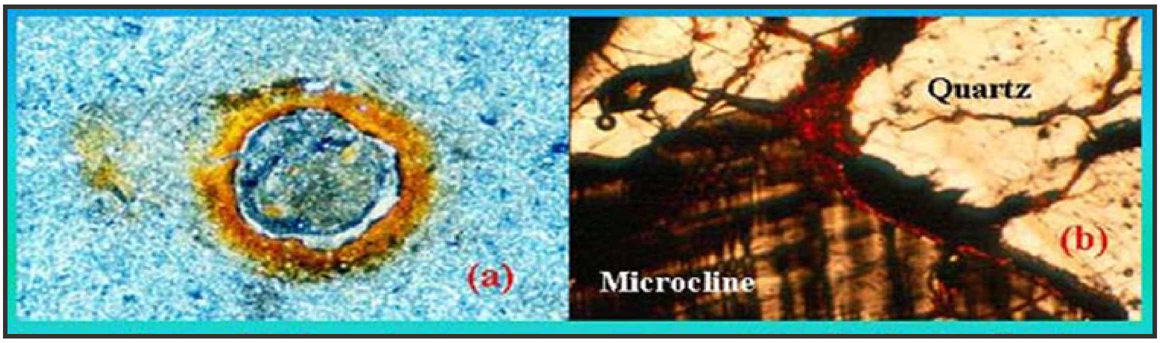

Fig. 3 : The fabric of Entisols

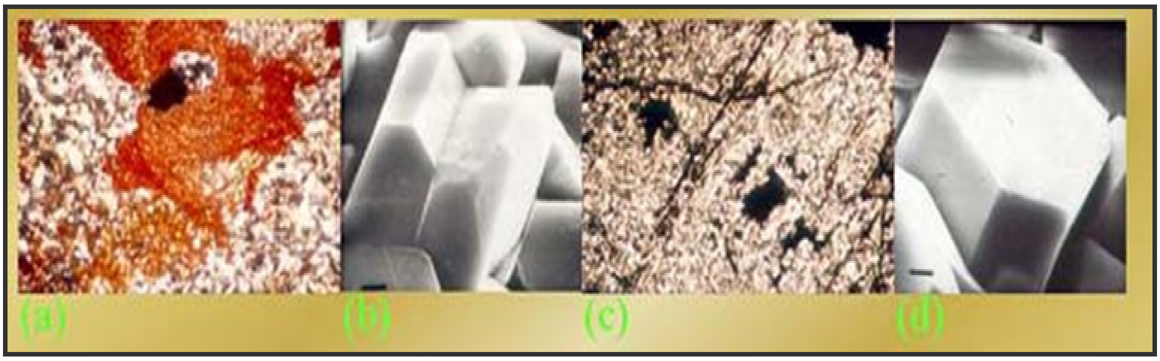

Fig. 4 : Different shapes of gibbsite minerals

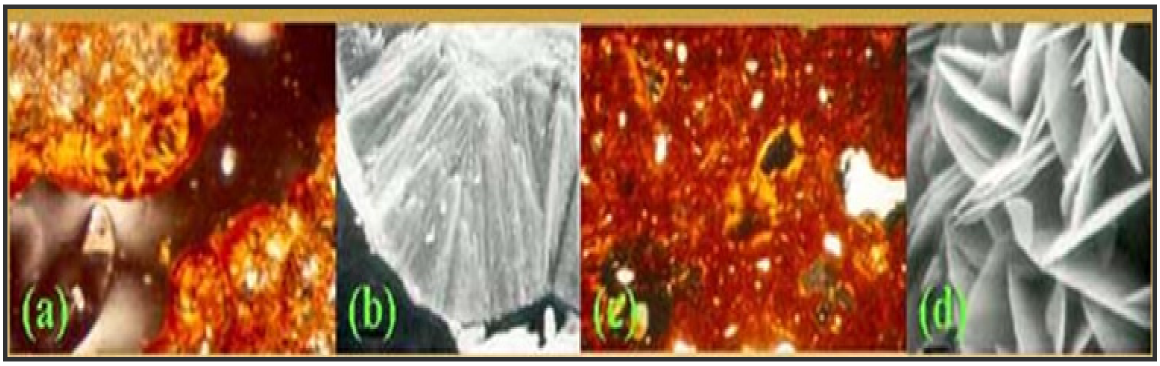

Fig. 5 : Different habit of goethite minerals

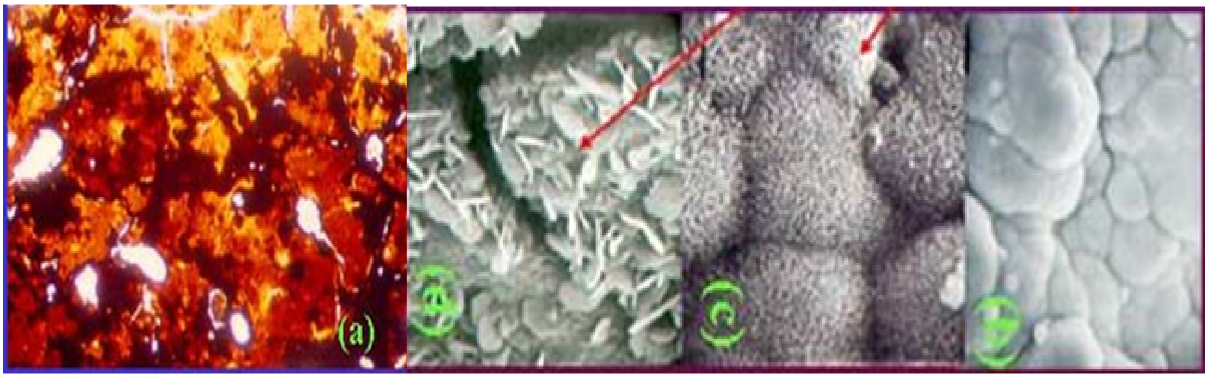

Fig. 6 : Different habit of manganese minerals in soils depending on soil conditions

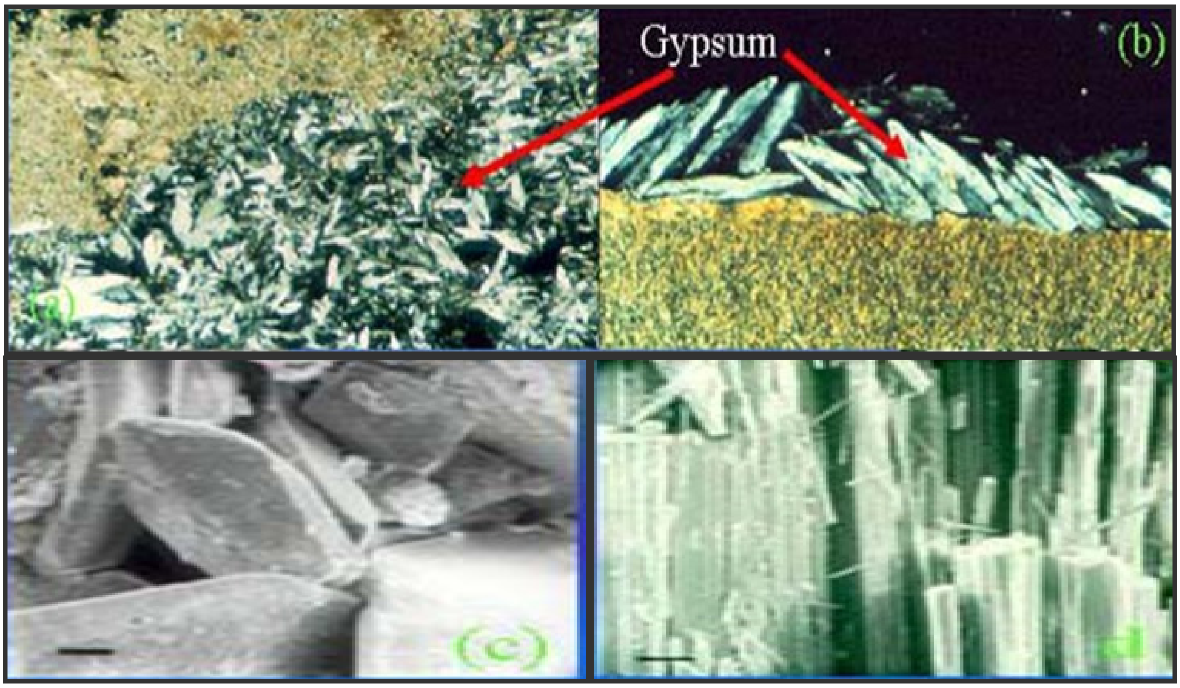

Fig. 7 : Different habit of gypsum minerals in soil.

Too often gaps exist between observations made in the field and those made under the microscope, with little attempt to bridge these gaps. Field descriptions of, for example, particle-size distribution, structure, mottles, and features of pedogenic origin can also be observed in detail in thin sections. In addition, laboratory analysis of bulk samples of soil materials provides additional data that will increase the understanding of microscopic observations. To help bridge the gap between the field and microscope, a detailed field (site and pedon) description should be made at the time the soil is sampled so the context of the soil fabric samples can be understood. It is important that the field description of the site and soil, including the supporting laboratory analyses, be available to the micromorphologist when the thin sections are examined.

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