MORPHOLOGY OF MINERAL WEATHERING AND NEOFORMATION. II NEOFORMATIONS*

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ABSTRACT

Micromorphology is a unique technique for the study of mineral newformations and transformations in soils, as it allows the identification of the spacial relations between newformations and other soil features, including porosity.

A systematic review is given of the pedogenetic minerals recognizable in thin sections with optical methods. Their habits are frequently related to specific environmental conditions.

1 INTRODUCTION

Soil mineralogy is becoming more and more restricted to the study of the colloidal fraction of the soil, its identification, genesis and behaviour. Not sufficient attention is given, in our opinion, to the study of larger newformed minerals, such as the more soluble species in saline soils and the different iron compounds in wet soils.

Relatively large pedogenic minerals are found essentially in three different environments: (i) in arid and semi-arid areas, where precipitation is not sufficient to leach the soil; (ii) in more or less closed systems of wet soils, where leaching of constituents is hindered, and (iii) in strongly leached soils, where essentially residual elements, mainly sesquioxides, tend to individualize. The occurrence of some pedogenic minerals such as pyrite and thenardite, is restricted to one of these environments, whereas some others such as calcite and goethite, can be found in quite contrasting situations. Minerals formed under different conditions can usually be distinguished by their habit and their paragenesis.

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Few information is available on the habit of the different pedogenic minerals in relation to their environment, as it is the case for most rock forming minerals in relation to their geological environments (e.g. Kostov, 1977). A better understanding of the habits of pedogenetic minerals might be very useful to detect subtle changes in pedogenetic processes and environments. Very little is known also about the formation of pseudomorphs. Furthermore, the concept of mineral paragenesis (i.e. the genetic association of a group of minerals) is practically not developed in soil science.

It is the aim of the authors to discuss some of these mineral newformations in relation to their pedogenetic environment. The discussion will be mainly restricted to features observed with the petrographic microscope.

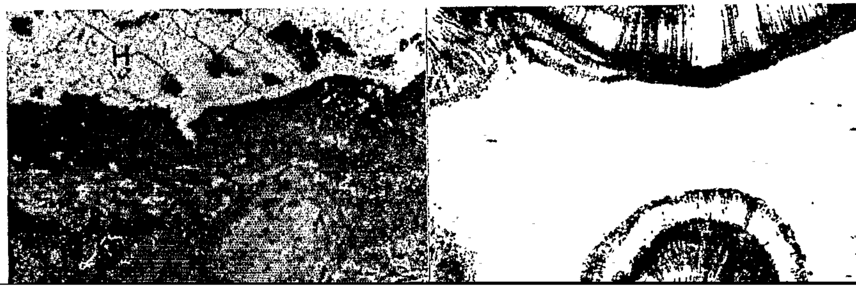
Thin section studies on the more soluble salts in arid soils are lacking, although their submicroscopic aspect has been treated in several papers (Eswaran et al. 1980, Vergouwen, 1981) Some of the most soluble components tend to disappear during impregnation, especially when they are present in relative small amounts. The type of polyester and diluant used is expected to play an important role. Also with regard to unstable wet soils our knowledge is

looked in thin sections because of its low relief and isotropic nature. Only larger, natural crystals with an orthogonal cleavage pattern (Fig. 1) are noticed in thin sections, as the acicular or threadlike efflorescences tend to disappear during impregnation (Hanna and Stoops 1976). Halite has been observed together with gypsum, thenardite, burkeite etc. (Tursina et al. 1980, Vergouwen, 1981); this does not mean however that these associations are in equilibrium.

2.4 Oxides and hydroxides

Pedogenic oxide minerals are practically always microcrystalline, and therefore not recognizable as individual crystals in thin sections. This is the case for hematite, maghemite, anatase and the Mn-oxides. Also many hydroxides, such as the Mn-hydroxides, boehmite, diaspore, lepidocrocite etc. are known as microcrystalline features in the soil. Goethite and gibbsite however can form relatively large crystals.

Gibbsite forms coatings of silt to fine sand sized, short prismatic crystals (pseudohexagonal, according to SEM-observations, Eswaran et al. 1977), or pure xenotopic nodules. These features are most probably the result of a crystallization from the soil



to calcite (in winter) or to monohydrocalcite first and then over aragonite to calcite (in summer) (Dupuis et al., 1984). Very quick crystallization gives rise to microcrystalline (micritic) calcite. Most probably the Mg content of both the calcite and the soil solution will play also a role (Watts, 1980).

Although since long reference was made to a relation between soil fauna, flora and calcite precipitation, only recently detailed studies were made. The *occurrence of polyconcave* calcite crystals (fine sand size) with a fan like extinction pattern in root residues or root channels, surounded by a decalcified hypocoating was

Fig. 3 : Bassanite pseudomorph after lenticular gypsum in an alluvial soil from Egypt. PPL.

Fig. 4 : Idem, XPL. Note the internal fabric of the pseudomorphs.

Trona ($NaHCO_3$ $Na_2CO_3.2H_2O$) forms radiating, tree-like aggregates of slender prismatic crystals with high interference colours. **Burkeite** ($Na_6CO_3(SO_4)_2$) was observed in salt crusts, associated with trona and thenardite, as short prismatic crystals forming coatings on pores, or as loose long prismatic crystals in the salty groundmass.

2.6 Sulphates

soils gypsum practically only occurs as lenticular crystals, as

the gypsum, mainly parallel to the cleavage, this is not the case for the replacement by calcite. Pedogenic anhydrite with a dendritic habit has been observed only in one Egyptian desert soil. Nests of slender prismatic crystallites of **celestite** ($SrSO_4$) (Fig. 5) associated to large gypsum concentrations, were described by Barzanji and Stoops (1974).

In semi arid conditions, gypsum mostly occurs as coarse xenotopic pore infillings. In acid conditions (e.g. in acid sulphate soils, peat) gypsum is found mainly as pseudohexagonal crystals (in the matrix), or as spheroidal aggregates of acicular crystals in voids.

Thenardite ($NaSO_4$), when formed as a result of rapid evaporation in the pore system (e.g. efflorescences),invariably has an acicular habit; the needles are grouped in semi-spheroidal aggregates. In the groundmass, where crystallization is slower, lenticular crystals are formed, similar to gypsum crystals, except for the absence of cleavages (Fig. 1). Very fragile chrysantemum-like thenardite aggregates result from the dehydration of mirabilite (Tursina et al. 1980). Mirabilite has never been observed in thin sections as it dehydrates during preparation. Thenardite is associated with gypsum, halite, trona and mirabilite

Other sulphate minerals (e.g. bloedite, hexahydrite, leonardtite) have been observed in salt crusts (Vergouwen 1981), but no thin section data are available.

All the above mentioned sulphate minerals are essentially found in dry to very dry areas, however, **barite** ($BaSO_4$) was mainly observed in relatively wet environments. It occurs in the groundmass as nests of small, short prismatic, sometimes slightly lathshaped crystals, in a range of soils (e.g. Ultisol, Alfisol, Vertisol) that have slightly saline groundwaters (Stoops and Zavaleta, 1978).

Jarosite, formed in acid sulphate soils, occurs as masses of crystallites, not individually recognizable with the optical microscope (Miedema et al, 1974), and therefore not further discussed here.

2.7 Phosphates

Only one pedogenetic phosphate mineral has been described in thin sections, namely **vivianite** ($Fe_3(PO_4)_2.8H_2O$). In fact, not the colourless vivianite, but the deep blue oxivivianite is observed in thin sections, as a quick oxidation of part of the divalent iron takes place during sampling and preparation. It occurs essentially

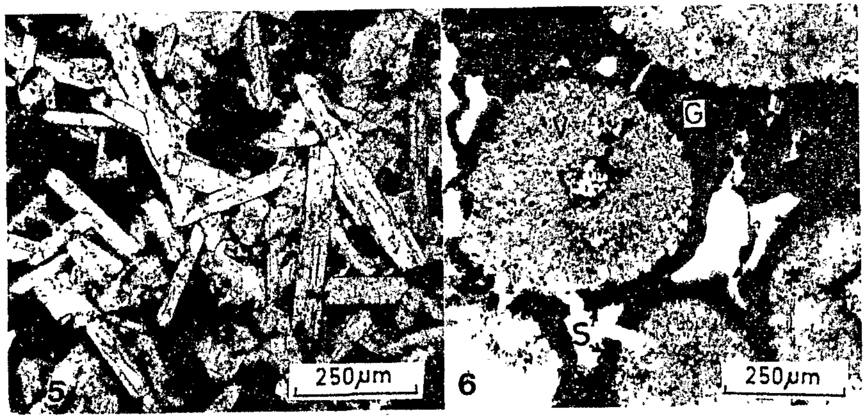


Fig. 5 : Accumulation of prismatic crystals of celestite in a gypsiferous soil from Morocco. PPL.

Fig. 6 : Rootchannels filled with granular vivianite (V) and surrounded by siderite (S) coating, with some interstitial goethite (G) in a bog ore from Belgium. PPL.

as relatively large lath-shaped minerals, both as single crystals or radial aggregates, or as granular, microcrystalline aggregates (Fig. 6) or coatings. It is characterized by its blue colour and strong pleochroism (Stoops 1983). Transformation of vivianite to an isotropic, yellowish substance through complete oxidation has been observed in several cases.

2.8 <u>Silicates</u>

Most pedogenetic silicate minerals are phyllosilicates and seldom have a sufficient large size to be visible, as individuals, in thin sections. Newformed **kaolinite** can form small, worm-like crystals (elongated normal to the cleavage direction) in the

rapidly in pore spaces (e.g. calcite, thenardite, halite, gypsum). Spheroidal aggregates of acicular crystals are more common in moist environments (e.g. goethite, siderite, vivianite).

- many crystals do not form in the groundmass, but preferentially crystallize in pore spaces (e.g. thenardite, halite); their crystallizing force is probably not sufficiently large to remove mechanically the groundmass; others (e.g. celestite, barite, siderite) are formed essentially in the groundmass. When formation takes place both in the groundmass and in the pore space, a different habit is to be expected.
- minerals crystallizing in different environments display generally also different habits (e.g. calcite, gypsum, goethite).
- physicochemical conditions in soils are changing frequently and relatively quickly (compared to geology) so that equilibrium situations are seldomly reached. Therefore only mineral associations are easy to identify while real mineral paragenesis seldom occur.

4 ACKNOWLEDGEMENT

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AMPHIBOLE ALTERATION TO VERMICULITE IN A WEATHERING PROFILE OF GABBRO-DIORITE

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ABSTRACT

Amphibole weathering to vermiculite in ferromagnesian sandy grains of saprolite and C horizon of a Typic Rhodoxeralf from southern Portugal is studied. Minerals identification and alteration studies were accomplished by X-ray diffraction, optical and electron (scanning and transmission) microscopy and electron microprobe analysis. Vermiculite replaces amphibole along planes which are parallel to the cleavage planes (110) of the primary silicate. In this process the contents of Si, Ca and Mg decrease whereas Fe content remains approximately constant during the initial stage of weathering. On the basis of lattice coherence between a chain silicate and a 2:1 layer silicate, a solid state transformation of amphibole into vermiculite with no intervening non-crystalline phase is proposed.

1 INTRODUCTION

Vermiculite, an interstratified vermiculite-smectite, goethite and hematite were reported as weathering products of a gabbro-diorite consisting mostly of amphiboles and plagioclase feldspars in different stages of alteration to scapolite (Abreu, 1986).

Preliminary studies using optical microscopy and X-ray diffraction analysis indicate a progressive replacement of amphibole by a yellow-brown 2:1 layer silicate during the rock weathering. These preliminary results appear to be similar to those firstly reported by Barshad and Fawzy (1969) and, more recently, by Eggleton (1975,1984,1986), Eggleton and Boland (1982), Eggleton and Smith (1983) and Cole and Lancucki (1976) to explain the weathering mechanisms of some ferromagnesian silicates.

This paper examines the alteration of amphibole during weathering of a gabbro-diorite in the south of Tagus river, Portugal, by thin sections studies, electron microprobe analysis, X-ray diffraction and scanning electron microscopy (SEM). The alteration mechanism is evidenced by means of transmission electron microscopy (TEM).