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SOIL MICRO-MORPHOLOGY: A BASIC AND APPLIED SCIENCE

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PEDOGENIC MICROLAMINATED CLAY IN PALEOGENE SEDIMENTS.

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ABSTRACT

Fifty-eight layers from three sections lying from N to S in the Puy-en-Velay Tertiary basin (Massif Central, France) have been studied micromorphologically. The base of the sequence has been attributed to the Late Eocene. The sediments have undergone an early diagenesis but have never experienced a burial diagenesis.

Soil micromorphology methods have enabled the differences between pedological features and other diagenetic features to be determined. Highly abundant pure or speckled clay, both microlaminated and oriented (argillans), coating tubular and planar pores prove the translocation of clay in a subaerial environment. Parallel-striated and cross-striated b-fabrics in some layers suggest their past vertic behaviour. Large impregnative micrite nodules barely mask the clay groundmass and the numerous textural and pedoturbation features. The ordering of pedological features enables the chronological succession of sedimentary, pedological and other diagenetic processes.

As all the layers show the same micromorphological pattern, we are able to infer their aggradative pedological origin and the relative stability of the environment during the formation of the sequence.

1. INTRODUCTION

The Puy-en-Velay basin in the French Massif Central is filled by Paleogene continental sediments which have only undergone a slight diagenesis. The are made up of three main sequences (Larqué and Weber, 1978). The first consists of arkoses of Middle Eocene age. The second or intermediate sequence attributed to the Ludian (Late Eocene) is formed by a series of clayey sands overlain by a series of illitic clays (Gabis, 1963). In the third sequence of Early Oligocene age, two different paleosols were identified, providing evidence of past ecosystems (Larqué et al., 1980; Larqué and Weber, 1985).

The petrographic study of the clayey series in the second sequence, has also identified pedological features. As such features could have a possible paleoenvironmental significance, a systematic study has been undertaken using techniques of soil micromorphology. The first results are presented.

2. MATERIALS AND METHODS

The clayey series can be observed in the three sections at Rosières, Brives-Charensac and Orzilhac, respectively in the north, middle and south of the Puy-en-Velay basin. The clays are mainly illitic (from 60% to 100%) and somewhat kaolinitic (from 0% to 40%); only traces of smectite have been detected in a few layers. The three sections possess somewhat different morphological facies. As an example, the Rosières section has: light red and green sandy clays at the base, alternating reddish blue and light brown clays with calcareous nodules to the top, all forming a 55 m thick stratigraphical section. Slickensides are frequently observed. The Brives-Charensac section is 150 m thick and the layers are rich in Characea (an algae typical of humid environments).

Thin sections from 58 layers from the three locations were described following the method of Bullock et al. (1985).

3. MICROMORPHOLOGICAL FEATURES

Most of the layers contain the features described below. Only their different proportions mark the different layers. A clayey groundmass is ubiquitous.

As a result of the diagenetic processes, the material is quite consolidated and pore-like features (vesicular and planar) are completely filled by calcite. Consequently, the present material is completely "apedal". Nevertheless, the identification of aggregates welded together, along with the occurrence of other features of pedological origin, reveal that the material once had a developed pedality.

Most of the layers do not have or only have scarce amounts of coarse mineral grains. The coarse/fine ratio C/F is smaller than 1/20. When present, the grains are mainly quartz and K feldspars with some muscovite and plagioclases. Only the sandy base of the northern and central series has a C/F = 9, with coarse mineral grains of the same type as stated above. Quartz shows some degree of border corrosion by micritic and microsparitic calcite. Plagioclases and K feldspars are somewhat seritized.

Groundmasses are almost completely clayey, formed by dusty and impure clay in which the relatively coarser particles are usually smaller than 5um. The C/F = 1/10. A variety of b-fabrics are found: from undifferentiated and speckled in rounded micromasses of sand size, which are quite abundant, to striated (parallel-, cross-, crescent-, grano-) related or not to fissures, specially developed in the northern and southerns sections (figs. 1,2,3). No strial b-fabric is observed in any layer. In some layers, groundmasses are entirely formed by more or less rounded fragments of oriented clay pedofeatures (papules), giving a mosaic-speckled b-fabric. In others, a partial or total impregnation of micrite gives a crystallitic b-fabric in which clayey groundmass and clayey pedofeatures, while veiled by micrite, can still be recognized (fig. 4).

Textural pedofeatures, either undisturbed, partially eroded or fragmented,

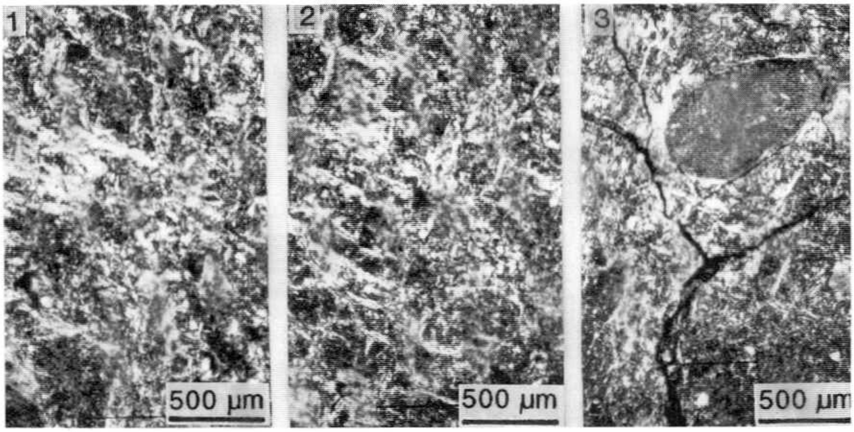

Fig. 1: Parallel-striated b-fabric. XPL.

Fig. 2: Cross-striated b-fabric. XPL.

Fig. 3: Grano-striated b-fabric. XPL.

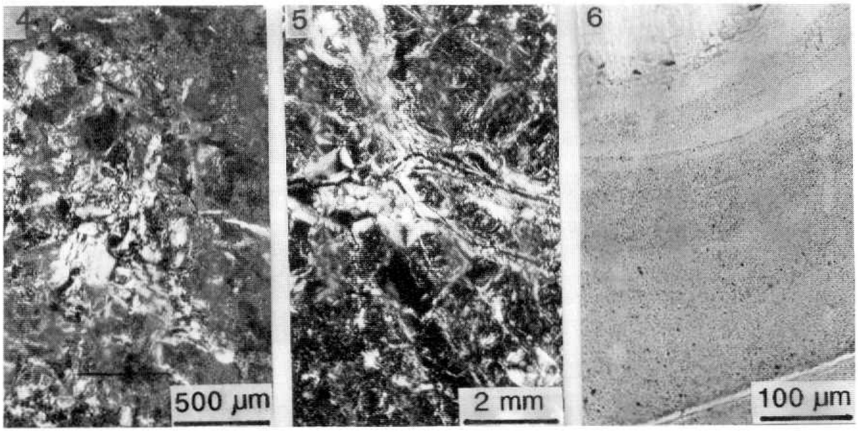

Fig. 4: Clayey groundmass and clay coatings barely veiled by an impregnative nodule of micritic calcite. XPL.

Fig. 5: Cross-juxtaposed clay coatings and fragmented clay coatings. XPL.

Fig. 6: Microlaminated oriented clay coating a macrochannel (1 mm wide), also infilled by sparite visible in the top left corner. PPL.

are quite abundant and can account for more than 50% of some slides (fig. 5). They are found as typic coatings in planar voids and as crescent or typic coatings in tubular voids (figs. 6,7). They are frequently cross-juxtaposed, following two main generations of planar voids (fissures) crossing one another at angles of between 50° and 90°. As fragments (papules) they are found randomly distributed, forming up to 50% of the groundmass. All of them are pale yellow, clayey, from limpid to impure, and from non-laminated to highly microlaminated. Interference colours go from yellow to light grey; extinction bands are usually sharp.

Calcitic pedofeatures are quite abundant and diversified. The most frequent are micritic nodules (fig. 8); in some layers the degree of impregnation by micrite can dominate the whole groundmass. Vesicles interconnected by planar voids and channels can be both completely infilled by microsparite or sparite crystals. In some cases the sparitization can reach 80% of the slide. A kind of calcitic feature described by geologists such as the "cone-in-cone structure" is also present in some layers, occupying most of the slide and leaving small patches of clayey groundmass (fig. 9).

Ferroginous pedofeatures are only found in a layer near the base of the Brives-Charensac section. They consist of mottles with a low degree of impregnation by iron, yellow-red and brown-red in colour, between a millimetre and a centimetre in size, covering about 50% of the slide. Mottles are separated by the regular pale-yellow groundmass.

Pedofaunal features are inferred from crescent and bow-like fabric arrangements. Except in the case of well developed striotubules of millimetre size (fig. 10), other faunal features are only visible under crossed nicols; they include passages and rounded aggregates.

4. SEDIMENTOGENIC AND PEDOGENIC INTERPRETATIONS

The oriented domains of the groundmass do not seem to have been much affected by the burial stresses. Otherwise, clay reorientation would show strial b-fabrics instead of the observed ones. This observation supports the interpretation of an early diagenesis instead of a burial one. Cross-striated b-fabrics are thought to be due to the stresses created upon shrink-swell processes (Brewer, 1964). The nature and abundance of oriented domains in some layers seem to confirm some vertic behaviour of the material. Such behaviour is nos exclusive of Vertisols or smectite-bearing soils; it rather indicates an alternate cycling of wetness and dryness in highly clayey materials. In the hypothetical case of smectite clays being present in such an environment, a mechanism of low-temperature pre-burial illitization should then be the most likely postulated cause. Laboratory experiments indicate that illitization

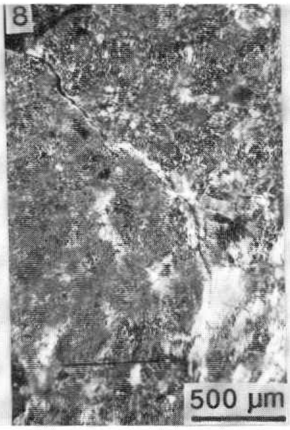

Fig. 7: Microlaminated oriented clay coating a macrochannel (1 mm wide), also infilled by sparite in the top left corner. Same as Fig. 6. XPL.

Fig. 8: Impregnative micritic nodule. XPL.

Fig. 9: Calcite crystals forming a "cone-in-cone" structure. PPL.

Fig. 10: Striotubule. PPL.

can take place at surface temperatures during alternate wetting and drying of smectites in the presence of K bearing minerals (Srodon, 1987). This last possibility, however hypothetical, cannot be disregarded.

Microlaminated clay with sharp extinction bands, both as tubular and planar pore coatings, is regarded as having formed by the progressive deposition of clay particles (Brewer, 1964). Also known as argillans, they typically form in argillic horizons. Even if it has been considered that when a whole horizon is composed entirely of intertwining clay coatings, as in some of our layers, their origin may be a combination of in situ weathering and reorganization (Fitzpatrick, 1984), the different composition of micro-laminae seems to suggest a rather depositional (illuvial) origin. Experimental work performed to ascertain the mechanism of argillan formation has demonstrated that layering requires multiple sequential depositions of colloid materials of different composition (Theocharopoulos and Dalrymple, 1987). These authors also state that the drying down of the clay suspensions from an air-water interface, determines the uniformity of microlaminated clay coatings; nevertheless, layering occurs even when clay suspensions are added to the wet surface of previous clay coatings. Quite similar features, though with not such sharp extinction bands and alternating with coarser layers, have been found completely filling agricultural drainpipes 40 years old in a vertisol under an almost permanent water-table in Marais-de-Boucé, France (Solé-Benet, 1979).

It is well known that vertic processes disrupt clay coatings. Nevertheless, cutans become progressively less disturbed with depth and can maintain their complete form (Holzhey et al., 1974).

It is suggested that such textural features could be produced in the deep horizons of a clayey soil (pelosol or vertisol?) under a climate favouring bisiallitization and temporarily (period unknown) submitted to waterlogging and dryness. A palustrine environment, as suggested by the sedimentological study (Larqué et al., 1980), seems to agree with this interpretation.

Micritization is found in a variety of soil environments, from arid to warm Mediterranean, and is probably related to biological activity (bacterial) either in a soil or in a burial environment. Esparite infillings seem to be of diagenetic origin. Cone-in-cone structures appear to be due to crystalline growth of calcite in a microbial gel substratum induced by a pH gradient (Gisbert et al., 1987).

Pedoturbation by burrowing fauna (especially striotubules) and rubefied layers are also indicative of pedologic processes, the latter related to a fluctuating water-table.

CONCLUSIONS

Although there is no contemporary soil which fits exactly the micromorphological characteristics being described, most, if not all features may be interpreted in terms of contemporary pedological processes. A general sequence of development can be given from the evidence of micromorphological features.

Deposition of a clayey sediment was followed by the initiation of soil formation through bioturbation and shrink-swell processes. The subsequent accumulation of more clays would have buried the edaphized layer which would then be subjected to illuviation through seasonally open cracks. Under a permanent water-table, clays become deferrified and only a possible fast burial would preserve the features from the fluctuating water-table (mottled layer).

Once the history of accumulation of the whole clayey series has been stablished, with some indication of its paleo-environment, further research is neeeded to ascertain the evolution of the basin. Accurate quantification of pedological features through the three sections in the basin will possibly contribute to the paleogeographical and sedimentological development of the Puy-en-Velay basin during this particular period of the Late Eocene.

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