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MINERALOGICAL AND TEXTURAL CHANGES IN FRENCH GUYANA OXISOLS AND THEIR RELATION WITH MICROAGGREGATION

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The T.E.M. has been used on undisturbed samples embedded with an expoxy resin. The results show modifications of the fabric from the bottom to the top of the soil sequence. In the deep horizons, the fabric is continuous and muscovite crystals are transformed into large kaolinite crystals. Iron oxide is located on kaolinite basal surfaces. In the upper part of the sequence, kaolinite crystals become smaller and oxides are completly diffused into the clay matrix forming micropeds which in turn determine physical properties. A model for soil pedogenesis is proposed in these oxisols.

1 INTRODUCTION

In many of the soils located to the north of Kourou in french Guyana, oxisols are found which have a particular behavior in response to water dynamics (Fritsh and Sarrailh, 1986). The typical oxisols are located in the upper part of soil sequence as shown Fig.1. Their surface horizons (M) are brown, micro-aggregated, thick and very permeable, hence water movement is mainly vertical. Further down the soil toposequence, the surface horizons become massive. Under these conditions, water dynamics is becoming lateral and mainly superficial. These two types of horizons are respectively named in this paper surface (S) and deep (D) horizons. The results presented in this article aim at a better understanding of the role of the constituent mineralogy and their inter-relationships in the genesis of the soil organization and consequently in the water dynamics of these oxisols.

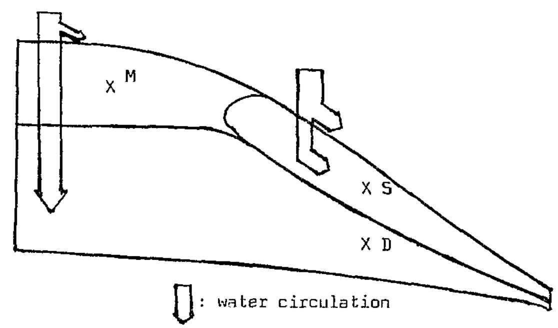

Fig.1 : Diagrammatic representation of the toposequence

2 MATERIALS AND METHODS

The materials studied were sampled in a microaggregated oxisol (M : 50-55 cm) and in a weathered oxisol in surficial horizons (S : 20-40 cm) and in deeper horizons (D : > 70 cm) respectively. Main soil sample data are reported Table 1.

In addition, undisturbed aggregates, 2-3 mm in size, were stored at soil humidity, then prepared as described by Tessier (1984). The sample prepared at 0.032 bar matric potential, is placed in a porous container. Its water content is progressively replaced by different solvents : methanol, propylen oxide and a very fluid epoxy resin (Spürr, 1969). Once hardened the samples were cut using an ultramicrotome Reichert equiped with a diamond knife Diatome. The Philips 420 transmission electron microscope (T.E.M.) at low magnifications (1000) allowed observation of the micrometric organization of the material ; high resolution transmission electron microscopy (H.R.T.E.M.) was used to characterize the nature, crystal structure and intercrystal relationships. Mercury injection measurements were made on dried samples using a Carlo Erba apparatus.

Table 1. Principal soil characteristics of the sequence

Horizons	M	S	D
pH	4.7	5.3	5.1
Colour	10YR 5/6	10YR 6/6	2.5YR 6/8
< 2 µm %	64	29	34
Kaolinite %	24	16	43
Gibbsite %	22	3	-
Goethite %	undetectable by X-rays	5	14

3 RESULTS

3.1 Low magnification T.E.M. micrographs

The deeper horizon (D) consists of adjacent domains of large particles set approximately face-to-face (Fig.2a). The particles are flat and can reach 10 µm in size. In the horizons just above the preceding (S), there is a reduction in the average size of the particles, however, some large particles subsist (Fig 2b). In any case the arrangement remains continuous. Therefore no other level of organization other than that due to the clay particles themselves is possible. In the upper horizons (M, Fig.2c), the particles are very small in size and are gathered into dense spherical clusters of 30 to 40 µm. These are partially visible on the T.E.M. micrograph.

Thus, the horizons of these soils are clearly individualized at low T.E.M. magnification by their texture and the organization of their constituents, and

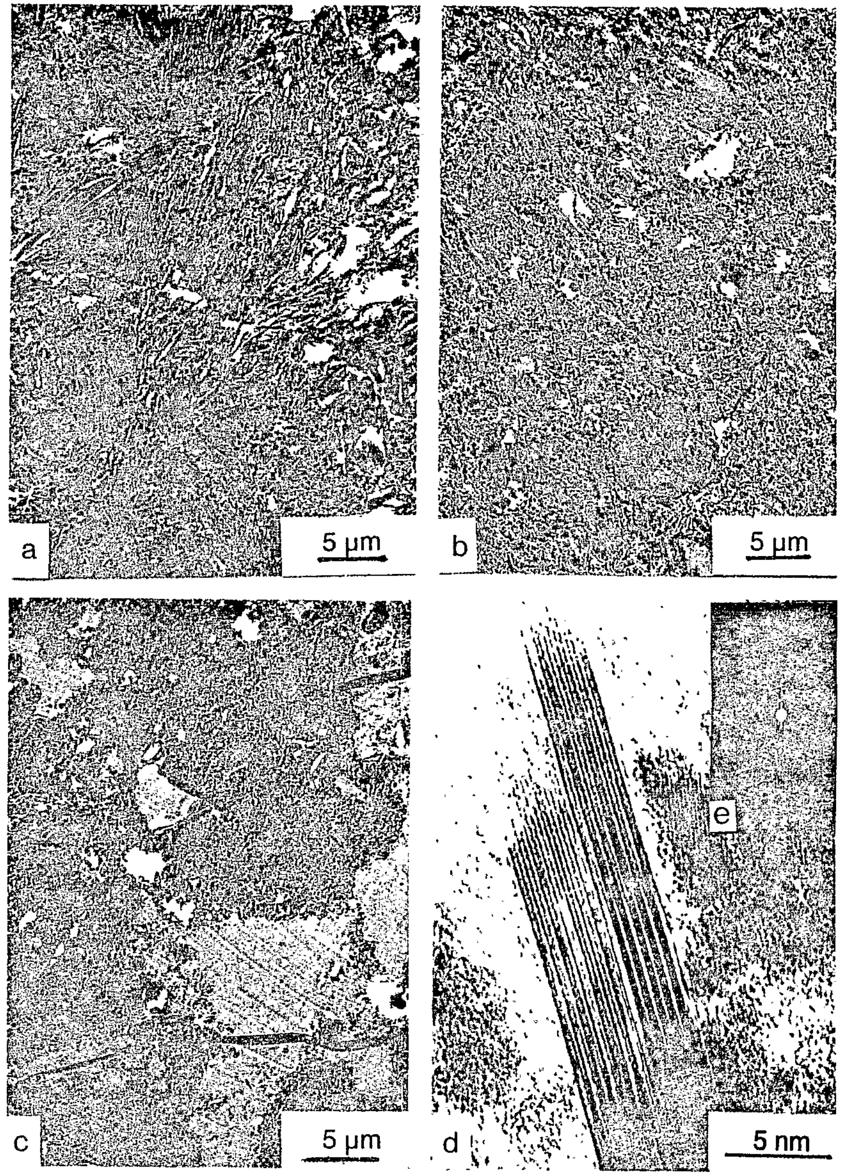

Fig.2 : T.E.M. microphotographs. (a) Deeper horizon (D) ; (b) Surface horizon (S) ; (c) Microaggregated horizon (M) ; (d) Muscovite crystal with diffraction pattern (e)

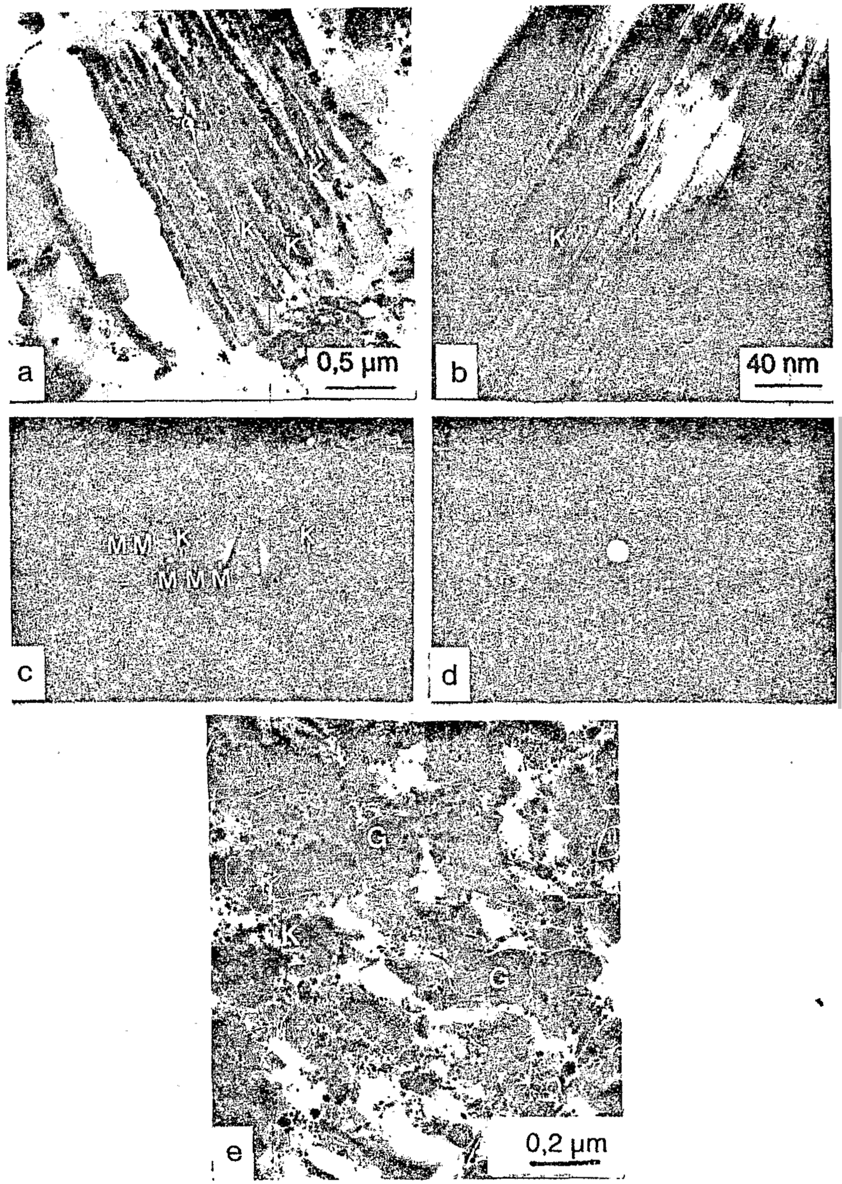

Fig.3 : T.E.M. micrographs. (a) Geothite sandwiched between kaolinite (D horizon) ; (b) Interstratified kaolinite-muscovite crystal with diffraction pattern (c) ; (d) Diffraction pattern of goethite (See Fig.3a) ; (e) Particle arrangement of the microaggragated horizon

consequently by their porosity.

3.2 Medium and H.R.T.E.M. micrographs

In the deep horizons of the soil, muscovite can be observed at high resolution showing the high electronic density areas of the mica layers i.e. octahedrons and tetrahedrons (Fig.2d): Microdiffraction proves it to be pure muscovite (2e). Further up the profile, mainly kaolinites (K) are present with iron oxides (Go) sandwiched between the basal surfaces (Fig.3a). Microphotographs and diffraction patterns indicate that muscovite can be interstratified with kaolinite (Fig.3b and 3c) and that iron oxide is goethite (Fig.3d). Under the electron beam, kaolinites are partly degraded in spite of a rapid exposure (< 30 seconds). This type of organization is typical of that found in horizons of muscovite weathering. In the microaggregated horizon (M, Fig.3e) goethite is no longer visible except in very small crystals or crystal aggregates and, the presence of gibbsite (G) in an ovoid form, can be seen next to the kaolinite (K). Gibbsite has the peculiarity of shrinking under the electron beam. The entire organization is very fine structured, and is in the form of dense clusters where the different constituents are very closely associated. Few pores are visible and their size does not exceed 0.1 µm.

3.3 Mercury injection curves

Figure 4 clearly shows porous spectrum changes from microaggregated (M) to massive (S and D) horizons. The microaggregated horizon exhibits a bimodal pore size distribution corresponding to interparticle pores (3.1 to 31 nm) and intercluster (or interpedic) pores (> 1 µm) respectively. The massive B horizon shows only an monomodal pore size distribution.

4 DISCUSSION

Based on studies conducted on three horizons, the results obtained by T.E.M. show the pedogenetical interactionships existing in these oxisols.

The first evolution is mineralogical. In the deeper horizon (D), unweathered pure muscovite is found. Above this, muscovite crystals are interstratified with kaolinite layers, showing a progressive weathering of the parent material. The final stage of muscovite weathering is reached when muscovite is entirely transformed into kaolinite. In this case, goethite crystals are sandwiched between large kaolinite crystals and their genesis is certainly due to the release of iron from the muscovite during weathering. The typical arrangement of goethite around kaolinite crystals disappears in the microaggregated horizon once the amount of gibbsite reaches about 10 %.

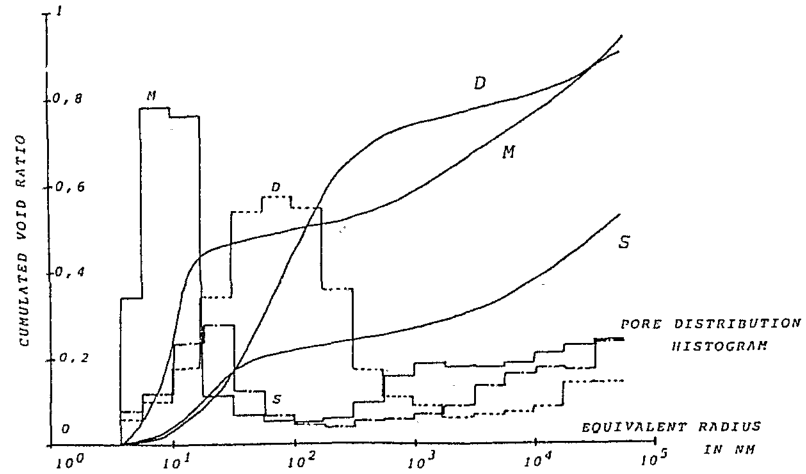

Fig.4 : Mercury injection curves of the three horizons

These observations show that the lateral evolution observed is due to weathering mechanisms in the broad sense of the term. The pedological data reflect the effect of a long term process which has led to an advanced pedogenesis. Here we recall the results of Young and Stephen (1965), Segalen (1973) and Herbillon (1980) on mineralogical evolution, representing different stages of desilisification :

muscovite -> kaolinite -> gibbsite

Apart from the lateral mineralogical evolution, this sequence also exhibits a similar clay textural variation. The first stage of weathering allowed the formation of very large kaolinite crystals which are about 5 µm in size. Consequently, the < 2 µm fraction in these horizons is low. Textural changes only occur when the muscovite has been completely transformed into kaolinite. The entire system becomes very fine structured and the constituents are very closely associated. These observations show that weathering in these oxisols has a step by step mechanism with which the reduction of particle size and changes in their arrangement are among the most important consequences of the soil evolution, if not the most important consequences.

From both fabric and textural changes revealed by T.E.M., macroscopic consequences can be deduced. The microaggregated horizons are characterised by a bimodal pore size distribution, while the deeper coarse clayed horizons exhibit a monomodal pore size distribution. Thus a very good agreement between low magnification T.E.M. observations and mercury injection curves exists. We

conclude that only inter-aggregate pores are capable of maintaining vertical water dynamics in these oxisols. On the contrary, even with coarse clay particles, the vertical drainage cannot be insured by porosity resulting from their arrangement alone.

These data allow us to suggest a pedological model for this toposequence. Due to the presence of deep weathered horizons in sommit position, vertical weathering may be analogous with M, S and D horizons identified along this sequence. The presence of less strongly weathered horizons on the slopes can explain a particular soil genesis. The first weathering step corresponds to the formation of the microaggregated mantle. The disappearance of this microaggregated mantle along the slope gives way to the deeper horizons with a continuous structure. It is concluded that two mechanisms contribute to evolution of these oxisols :

- a vertical evolution, i.e. a classical weathering
- a lateral evolution resulting from erosion and probably lexiviation. The loss of soil material exceeds the rate of weathering.

5 CONCLUSIONS

Low and high resolution T.E.M. on undisturbed soil samples, permits observations of arrangement, texture and crystalline structure of the clay minerals of the soils. It gives information concerning their different levels of genesis and organization. The parallel use of electron microscopy and physical measurements (pore size distribution), gives the relation-ship between properties at the crystal level and the macroscopic properties of the soil. However mercury injection help to confirm T.E.M. data.

Pore size distribution curves and low magnification T.E.M. observations permit a better understanding of water dynamics in these oxisols. Because in massive structured soils the large interparticle pores are small and homogeneous, drainage is mainly superficial and lateral. On the contrary, in the case of microaggregated soils, both very fine crystals and pores are associated with stable micropeds.

The origine of these micropeds is not clearly certain. They could have developped out of micro and micro-organism activity (Eschenbrenner, 1988) or by more bonding between the clay organic matter and iron oxides (Chauvel et al.,1978 ; Follet, 1965).

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PROPERTIES OF SILICEOUS CEMENTS IN SOME AUSTRALIAN SOILS AND SAPROLITES

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ABSTRACT

The cementing agents in siliceous hardpans, granitic saprolites and hard-setting Alfisol E horizons were examined using micromorphological, SEM/EDXRA, TEM/EDXRA and EMPA methods. Siliceous glaebules and silans were observed in the hardpan samples and in clay enriched bands in saprolite. Alfisol E horizon samples have a dense silasepic fabric, common fine grainy cutans and a few, somewhat isotropic, clay/silt bridges between quartz grains. SEM/EDXRA observations show that the hardpan cements are highly siliceous and have a low aluminium content. Grain bridging structures in the Alfisol E horizons have Si/Al ratios of 3:1 to 15:1 suggesting the presence of silica-rich phases. TEM/EDXRA analyses indicated that in all the samples, mixtures of discrete particles of crystalline clay minerals and amorphous silica occur. Amorphous silica was clearly the major cementing agent in both the hardpan and the saprolite samples examined. In the Alfisol E horizons the results indicate that soluble silica and possibly precipitated aluminosilicates may play some role in hard-setting, although there are not enough of these materials present to overcome slaking processes on wetting.

INTRODUCTION

The properties and development of siliceous cements in silcretes have been studied in Australia in considerable detail (Langford Smith, 1979; Milnes and Twidale, 1983), but less is known about the nature and properties of cements in silica hardpans (duripans), soils with hard-setting A and E horizons, and saprolites. Soils with silica hardpans are generally restricted in their occurrence to areas with less than 250 mm rainfall. They are classified as Durargids (Soil Survey Staff, 1975) or as red and brown hardpan soils in the Australian Great Soil Group classification of Stace *et al.* (1968). Hard-setting is a common phenomenon in many Australian soils with a textural contrast between coarser A/E and finer-textured B horizons (Alfisols, Ultisols). It is characterised by the development of a compact and apparently apedal condition of the A horizon on periodic (usually seasonal) desiccation of the soil (Northcote, 1979). However, field observations indicate that a similar condition is also common in many E horizons. Also included in this study were samples of granitic saprolite, which also appeared to have undergone partial cementation during the weathering process. Samples investigated and their field occurrence are listed in Table 1. The aim of this paper is to elucidate the role of chemical cementing agents in these materials.