TRANSFERS, ACCUMULATION MODES, MINERALOGICAL TRANSFORMATIONS AND COMPLEXITY OF HISTORICAL DEVELOPMENT IN LATERITIC PROFILES

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ABSTRACT

Using petrological analyses of several African lateritic profiles, accumulation mechanisms have been characterized during lateritisation. Absolute accumulations, by transfer, occur before and after weathering. Relative accumulations, by weathering, concern parent rock minerals in alterite then secondary minerals in lateritic horizons. Part of these two mechanisms is estimated quantitatively in a bauxitic profile developed on a granite.

INTRODUCTION

Petrological analyses, recently realised on lateritic profiles in Congo (Muller et al., 1981), Ivory Coast (Nahon et al., 1977, Boulange, 1983) and Cameroon (Sarazin et al., 1982, Rosello et al., 1982) have described some mechanisms which occur during lateritisation.

These mechanisms, which are more particularly at the origin of iron and aluminium oxihydroxides accumulations, are classed in two categories according to the terminology proposed by D'Hoore in 1954:

Transfer and deposit mechanisms, at the origin of accumulations so-called "absolute" because they correspond to gains of material.

Mineralogical transformation mechanisms which, by associated losses of material, are at the origin of residual products accumulations, so-called "relative accumulations".

To show how these two types of mechanisms can occur during the development of lateritic profiles, this study regroups a certain number of petrographical, microchemical and mineralogical data issued from these different works. And, it presents then (Fig. 1) according to their localisation in the three successive unities which constitute lateritic profiles: unweathered parent rock, alterite, looser or lateritic indurated upper horizons.

ABSOLUTE ACCUMULATIONS PRIOR TO WEATHERING OF ROCK

At the lower part of one bauxitic profile in Ivory Coast, in the parent rock which is a two micas granite, Boulange (1983) indicates that some transmineral fissures, crossing as well as quartz and unweathered feldspars (photo 1), contain amorphous aluminosilicated deposits which crystallize in halloysite. These halloysite

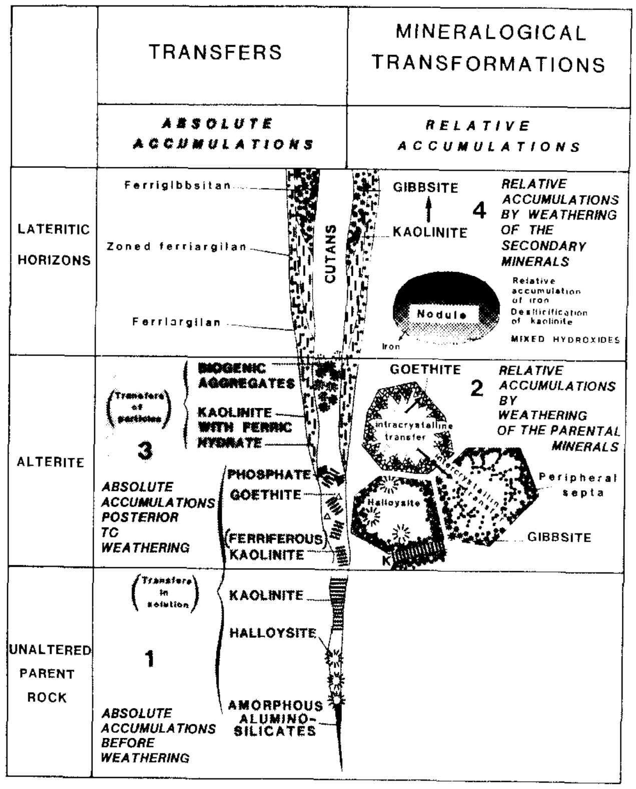

FIG. 1. Schematic localisation of relative and absolute accumulations mechanisms in a lateritic profile.

neogeneses (photo 2) covering unaltered surface of quartz or microcline are very independant of substratum and are anterior to their weathering.

In the same way, at the scale of a single mineral, between an unaltered biotite flakes as microprobe analyses demonstrate it, one can see neogeneses of kaolinite. Using SEM, in photo 3, these kaolinite crystallizations are perpendicular to unaltered biotite flakes of which they are so independant and anterior to their weathering.

We can consequently see that, prior to the weathering of rock or of one mineral, transfer of successive deposits of amorphous products, halloysite and kaolinite can be realised. They precipitate from solutions originated in alterite or upper horizons.

These absolute accumulations, anterior to the weathering represent, in this bauxite profile from Ivory Coast, augmentation of 2 to 5 percent of the aluminium concentration in the granite.

RELATIVE ACCUMULATIONS DURING WEATHERING OF PARENT ROCK MINERALS

In alterites, one can see (Delvigne, 1965) that during mineralogical transformations of parent rock minerals, residual metallic oxihydroxides accumulate at the periphery of parent rock mineral relicts to constitute "septa", either aluminous: gibbsitic from feldspars (photo 4 and 6), either ferruginous: goethitic from garnets for example (photo 5). And, these septa, formed by relative accumulation, realize pseudomorphs of some parent rock minerals and fix preservation of structures or else textures of parent rock.

One specify more, by scanning electron microscopy, as in the weathering of hornblende (photo 7), that iron might be displaced a little few from parent relict (photo 8) to form a peripheral goethite septum (photo 9). Some intracrystalline transfer of iron (Fig. 1) consequently occurs and constitutes this relative accumulation in peripheral septum form.

Aluminium hydroxides accumulate also relatively during weathering of this hornblende and two cases can be observed: either direct crystallization of gibbsite strictly at the contact of hornblende relict (photo 8) either, after disappearing of parent relicts, crystallizations of gibbsite which take place and concentrate only in some cells of the network formed by goethitic septa (photo 9). This late case necessites an aluminium redistribution and transfer between parental relicts or else between adjointing minerals.

Such aluminium intercrystalline transfers occur also (Boulange, 1983) during differential weathering of microcline and plagioclases: indeed, during weathering of microcline anterior to this of plagioclases, intercrystalline transfers and aluminium concentrations occur in some voids of plagioclase pseudomorphs.

So, during their accumulation in alterites, residual products of weathering in parent rock minerals can be redistributed either in the limits of original crystal (intracrystalline transfer), either between adjointing minerals (intercrystalline transfers) (Fig. 1).

ABSOLUTE ACCUMULATIONS POSTERIOR TO THE WEATHERING OF PARENT ROCK MINERALS

Always in alterite and posterior to the relative accumulations caused by weathering of primary minerals, take place a succession of different deposits (absolute accumulation) which settle (Fig. 1):

In intracrystalline porosity, caused by weathering, and especially in cavities formed by dissolution of parent relicts and limited by peripheral septa. These are, for example, neogeneses of halloysite which, subsequently to hornblende pseudomorph by iron and aluminium oxihydroxides (photo 10) cover as well as over goethite septa than gibbsite (photo 12). These are also kaolinite neogeneses which crystallize perpendicularly to the wall of gibbsite septa in a former feldspar (photo 11).

In original fissural porosity or in tubular porosity of biological source crossing structures of laterite. In an alterite from Congo (D. Muller et al., 1981), the presence of three successive accumulations has been observed. Firstly crystallizations of automorphous kaolinite vermiforms (photo 13). These ones can be moreover ferriferous kaolinite (Rengasamy et al., 1975, Herbillon et al., 1976, Mendelovici et al., 1979) characterized by low substitution rate (1%) (Fayolle, 1979, Bonnin et al., 1982) determined by several mineralogical data, including electron paramagnetic resonance.

Then, subsequently to neogenesis of these kaolinitic vermiforms, two other ultimate crystallizations can overlay them. These are frequently goethite like rosettes, only settled on the surface of kaolinitic flakes (photo 14). At last, on the surface of kaolinitic flakes, exceptionnally crystallizations of calcium phosphate have been determined by microprobe analyses and have yet been noted by several authors (Nahon, 1976, Wilhelm et al., 1979) as ultimate accumulations of supergene apatite.

All accumulations, which had been described, are crystallizations caused by solution transfers and occur, more often than not, in the lower part of alterites. But in the upper part of alterites, these accumulations are overlayed then relayed by other accumulations caused by transfers of particles (Fig. 1). These are very frequent cutans, generally made up of kaolinite and ferric hydrates (photo 16). These ferriargilans (Brewer, 1964) can be themselves overlayed by ultimate products, which are aggregates of biological source and form pedotubules (Brewer, 1964).

All these absolute accumulations, caused by solution and or particular deposits, can be estimated quantitatively by isovolumetric method (Millot and Bonifas, 1955), when structures and volumes of parent rock are undisturbed in alterite ("isalterite", Chatelin and Martin, 1972). So, in a granitic isalterite from Ivory Coast, Boulange (1983) shows that the whole of these deposits can represent about 40% of gains in aluminium.

RELATIVE ACCUMULATIONS DURING WEATHERING OF SECONDARY MINERALS

In upper lateritic horizons, indurated or not, new mineralogical transformations occur and affect this time secondary minerals. Two cases have been yet more particularly studied in Ivory Coast and in Congo. They concern transformations in secondary minerals after their concentration like either cutans or nodules.

Transformation of ferriargilans. Microprobe analyses through zoned ferriargilans (Bocquier and Nalovic, 1972) show that the more kaolinitic external rim undergoes a desilicification. Aluminium accumulates relatively and precipitates as gibbsite (Boulange et al., 1975). This transformation can be also shown petrographically by lateral and continuous passage, in a same deposit, of kaolinite to gibbsite (photo 17).

Such relative accumulations of gibbsite, caused by transformation of former kaolinitic deposits, are very frequent in some bauxite horizons (photo 18), where they superimpose themselves to former gibbsite relative accumulation caused by weathering of primary minerals (cf. § 2). They often represent more than half of the concentrations of aluminium in bauxite.

Transformation of hematitic and kaolinitic nodules. Studying cortification of some nodules in a laterite from Cong, Muller et al. (1981) have shown that these hematitic and kaolinitic nodules present, in their periphery, two types of transformations (Fig. 1).

At the top of the nodules, iron accumulates relatively because quartz dissolves and kaolinite is destabilized. Aluminium released by this desilification of kaolinite does not precipitate as gibbsite (like in ferrigibbsitans), but it forms with iron a mixed hydroxide: aluminous goethite, with 15 to 20% $Fe^{3+} \rightleftarrows Al$ substitution (Norrish and Taylor, 1961, Nahon et al., 1977).

At the lower part of the nodule, geochemical transformations are opposite (Nahon, 1976): kaolinite remains unaltered as quartz, and it is hematitic iron which is solubilized.

So, all these transformations, which in lateritic horizons concern secondary aluminosilicated or ferruginous minerals, form relative accumulations of less soluble metallic compounds. They conduce like this to the increasing of metallic concentrations in pisolites or in lateritic duricrusts.

But these transformations conduce also to solutions which are transfered to the lower part of profiles where they will create deposits (absolute accumulations) by precipitation of amorphous aluminosilicated products and by crystallization of halloysite, kaolinite (ferriferous), goethite ... (Cf. § 1 and 3).

CONCLUSION

It can be possible to precise quantitatively how take place these two mechanisms of accumulation (relative by weathering and absolute by transfer) in the development of a lateritic profile.

This quantitative estimate has been made in a bauxite profile developed on a granite in Ivory Coast (Fig. 2), on the basis of isovolumetric method in the lower part of the

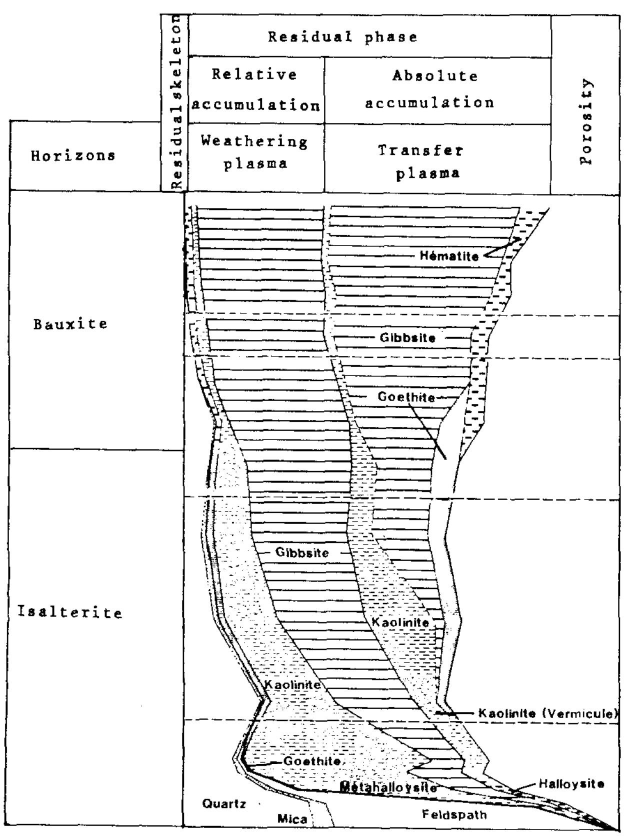

FIGURE 2

Quantitative estimate of the weathering and transfer plasmas in a lateritic bauxite on Ivory Coast granite (Boulange, 1983).

profile where rock structure is unaltered and selecting collapsing factor in lateritic horizons (Boulange, 1983).

It shows that the part of absolute accumulations increases notably from the lower part of the top of profile where it exceeds 50%. It shows also two chief stages of gibbsite formation, by weathering of primary minerals in the lower part of the alterite and by weathering of secondary minerals transfered or not, like kaolinite, from the top of the alterite.

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PLATE I - LEGEND

Photo 1. Thim section micrograph (crossed nicols)

Transmineral fissure (TF) crossing plagioclase (Pl), microcline (Mi) and quartz (Q), in an unweathered granite.

Photo 2. Scanning electron micrograph (SEM)

Absolute accumulation in a transmineral fissure: on the quartz surface (Q), amorphous aluminosilicated deposit (am) which crystallizes in halloysite (Ha).

Photo 3. SEM

Absolute accumulation in an unweathered mineral: neogenesis of kaolinite (Ka), crystallizing perpendicularly to unweathered biotite flakes (Bi.F).

Photo 4. Thin section micrograph (crossed nicols)

Relative accumulation of aluminium during orthose weathering: gibbsitic septum (Gi.s), crystallizes in the periphery of orthose relict (Or).

Photo 5. Thin section microcraph (plain light)

Relative accumulation of iron by weathering of garnet: septa network of goethite (Go.s) delimits dissolution voids (V) and pseudomorphs a former garnet.

Photo 6. Thin section micrograph (crossed nicols)

Relative accumulation of aluminium by weathering of microcline: septa network of gibbsite (Gi.s) pseudomorphs a former microcline. Absolute accumulation of kaolinite (Ka) between septa (cf. Photo 11).

Plate I

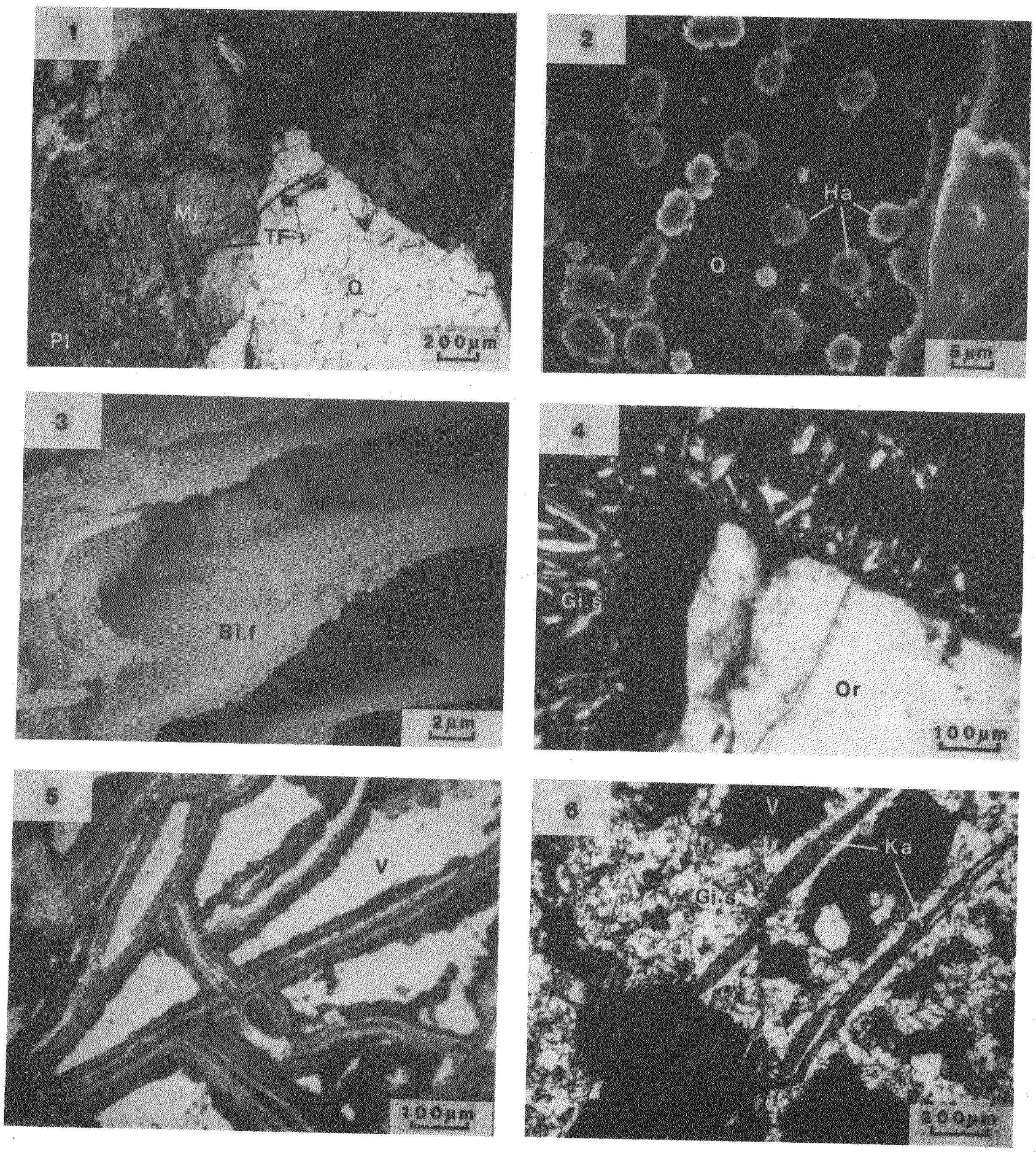

1
Mi
TF
Q
Pl
200µm
2
Ha
Q
5µm
3
Ka
Bi.f
2µm
4
Gi.s
Or
100µm
5
V
100µm
6
V
Ka
Gi.s
200µm

PLATE II - LEGEND

Photo 7. SEM

Relative accumulation of iron during hornblende weathering: formation of goethitic septum (Go.s) in the periphery of amphibole crystal (Am) being weathered.

Photo 8. SEM

Relative accumulation of iron and aluminium during hornblende weathering: direct crystallization of gibbsite strictly at the contact of hornblende relict (r.Am) and goethitic septa (Go.s) forms by little displacement of iron from relict (transmineral transfer).

Photo 9. SEM

Relative accumulations of iron and aluminium during hornblende weathering: goethitic septa network (Go.s), with in some cells crystallization of gibbsite (Gi).

Photo 10. SEM

Absolute accumulation posterior to weathering: neogenesis of halloysite (Ha) overlays as well as goethite septa (Go.s) than gibbsite (Gi).

Photo 11. SEM

Absolute accumulation posterior to weathering: neogenesis of kaolinite (Ka) which crystallizes perpendicularly to the wall of gibbsitic septa (Gi.s).

Photo 12. SEM

Absolute accumulation posterior to weathering. Detail of Photo 10: neogenesis of halloysite (Ha) overlaying gibbsite.

Plate II

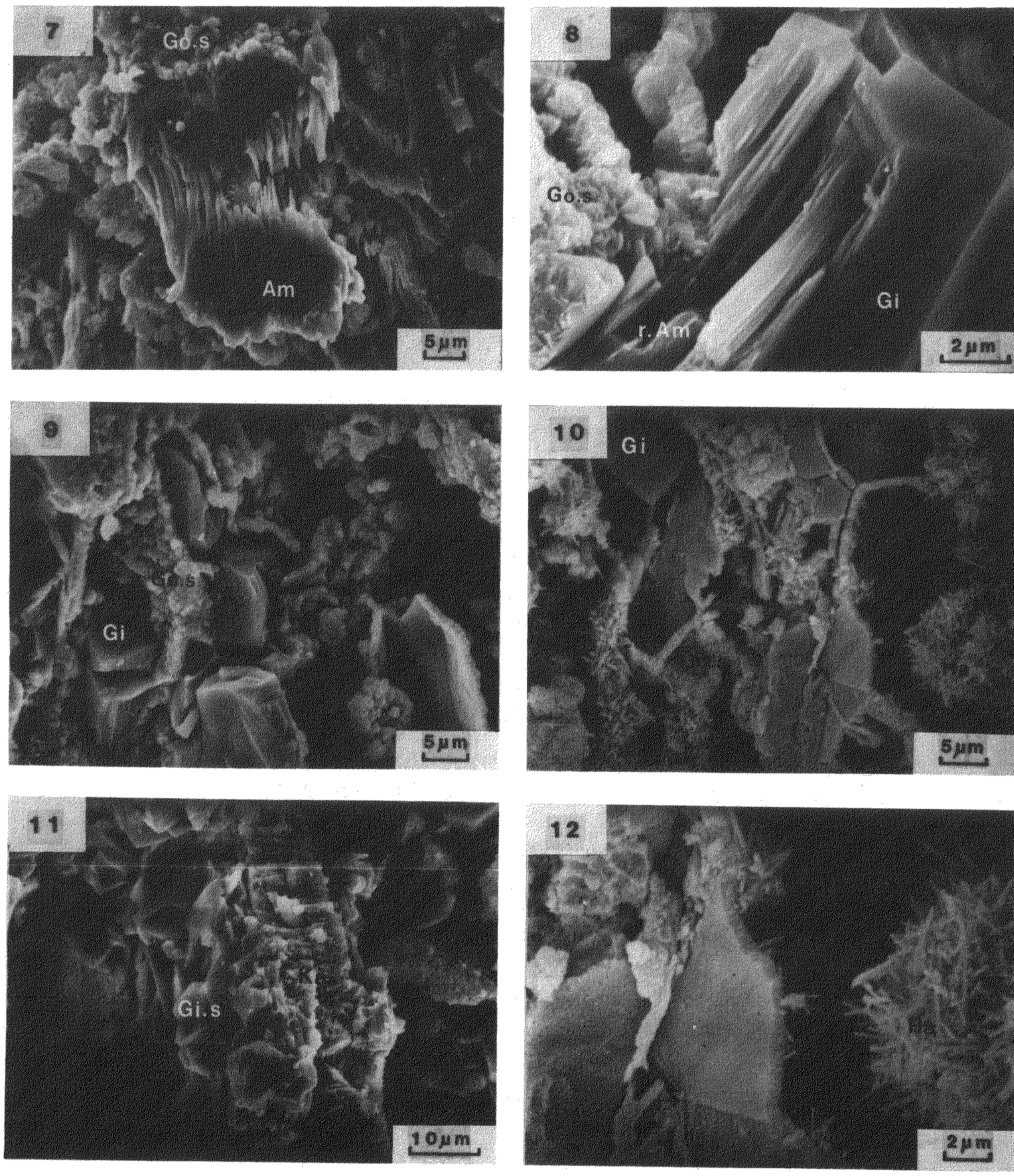


PLATE III - LEGEND

Photo 13. SEM

Absolute accumulation posterior to weathering. Automorphous crystallization of kaolinite vermiforms (Ka.V).

Photo 14. SEM

Ultimate absolute accumulations: crystallization of goethite like rosettes (Go.r) on the surface of kaolinitic flakes (Ka).

Photo 15. SEM

Ultimate absolute accumulations crystallization of calcium phosphate (ca.Ph) on the surface of kaolinite neogenesis flakes (Ka).

Photo 16. Thin section micrograph (plain light).

Absolute accumulations by particles transfer: kaolinite and ferric hydrates cutans (F.arg.) and filling by biological aggregates (b.ag.).

Photo 17. Thin section micrographs (plain light).

Transformation of ferriargilans: in a ferriargilan, continuous lateral passage corresponding to the transformation of kaolinite (Ka) to gibbsite (Gi).

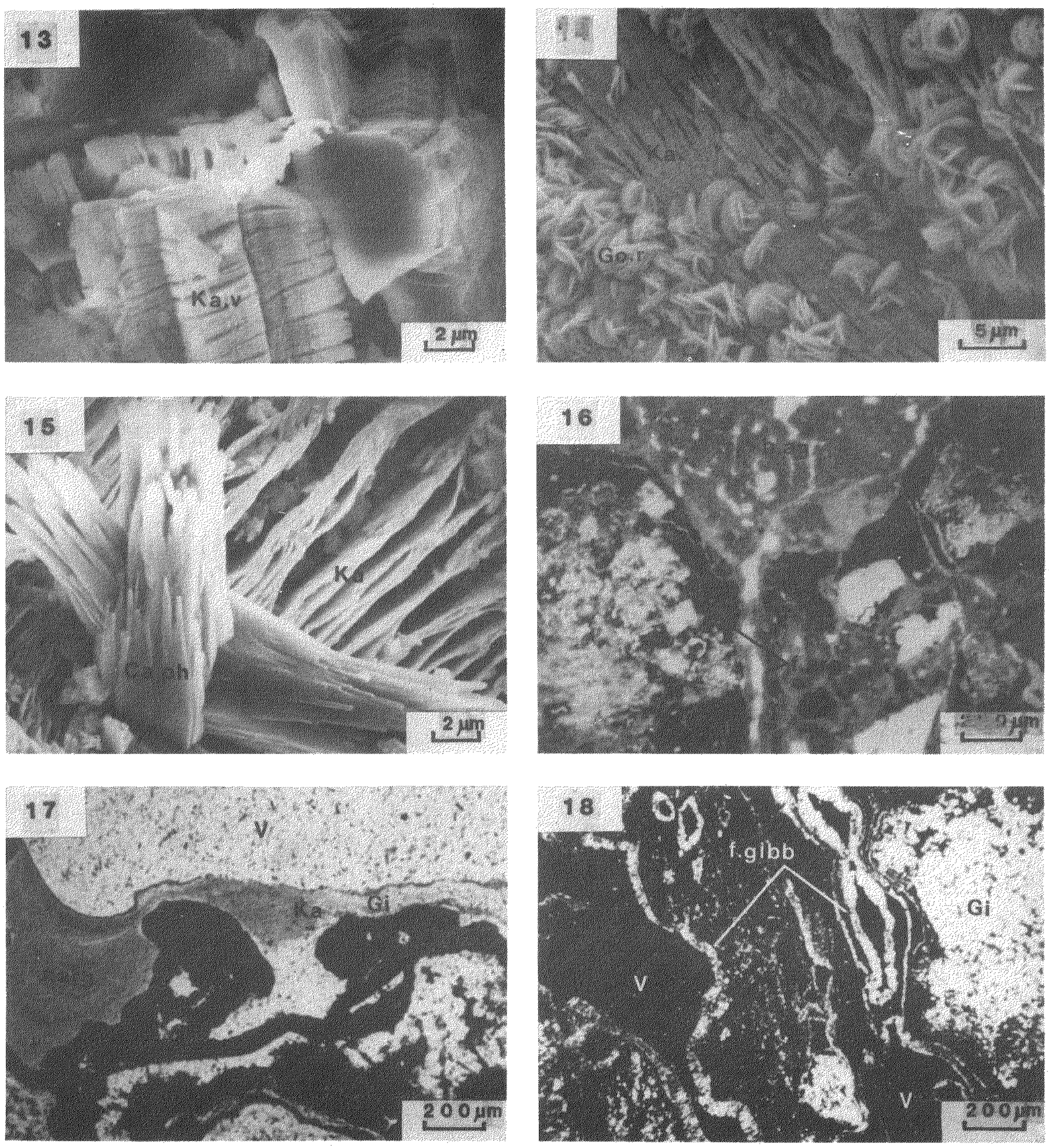
Photo 18. Thin section micrograph (crossed nicols)

Relative accumulation in a bauxite from Ivory Coast:

. Gibbsitic feldspar pseudomorph (Gi): first relative accumulation of aluminium during weathering.

. Gibbsite in ferrigibbsitan (F.Gibb.): second relative accumulations of aluminium caused by transformation of a ferriargilan (cf. Photo 17).

Plate III



LATERITISATION PROCESSES

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