LITHODEPENDENCE AND HOMOGENIZATION OF MINERALOGICAL AND CHEMICAL COMPOSITION OF FERRICRETES

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In Western and Central Africa, the lateritic weathering mantle is very thick, widespread, and, in many cases, capped by old and widely developed ferricretes.

Ferricretes consist of relative accumulations of poorly mobile major elements such as iron, aluminum and silicon, minor or trace elements such as vanadium, chromium, phosphorus, and insoluble minerals such as quartz, ilmenite, tourmaline and zircon. These elements and minerals may concentrate in situ or may be transported over short distances either in solution in the percolating waters or mechanically in bioturbation products. Most of them are autochthonous. The most soluble minerals are dissolved, and moderately or highly mobile elements are leached in solution and removed from lateritic landscapes. Beside the resistant primary minerals (mainly quartz), ferricretes are generally composed of a fairly constant secondary assemblage made of hematite, goethite, kaolinite and sometimes gibbsite.

Despite their apparent homogeneity, ferricretes show a large diversity of mineralogical and chemical compositions, related to their age, their degree of evolution and the nature of the parent rock from which they derive. Some very immature and recent ferricretes retain the mineralogical and the chemical signature of their parent rock; they are called lithodependent. In others, older and more mature, mineralogical and chemical compositions are homogenized and the composition of the parent rock is almost totally modified. These can be called lithoindependent.

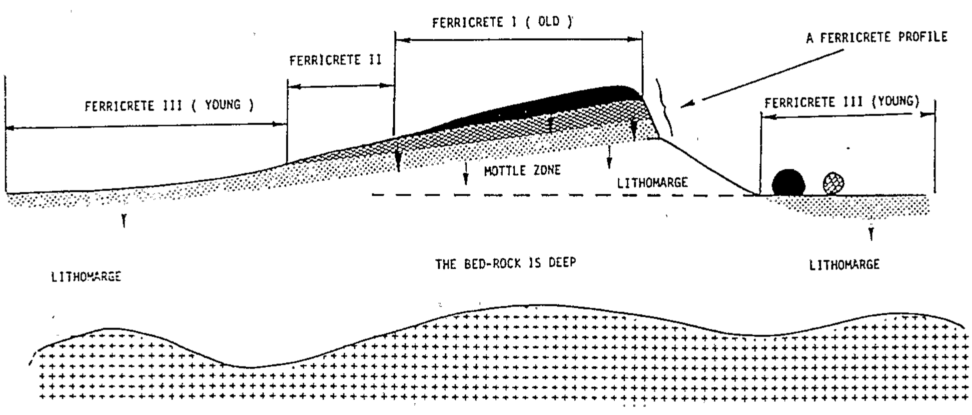


Figure 1. Lateral distribution of lateritic facies in a tropical landscape shaped by erosion and subsequent

Mineralogical and geochemical diversity of the lateritic facies

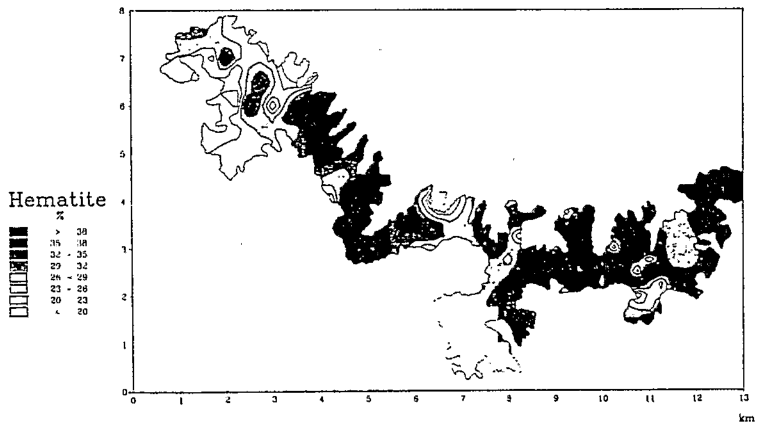
At different scales of observation, from regional to local, laterites outcrop as patchworks of a high degree of mineralogical and chemical diversity.

At a regional scale (20 km) a ferricrete lateritic landscape consists generally of a myriad of plateaus capped by iron duricrusts (carapaces, cuirasses, gritty layers) and separated by depressions or thalwegs, in which there are outcrops of the lower horizons such as mottled zones, lithomarges, saprolites and sometimes parent rocks (Fig. 1). In a given system, for example the "haut glacis" of Michel (1973), all plateaus were supposed to lie on the same morphological level and were supposed to exhibit the same characteristics. In fact, they do not show the same mineralogical and chemical composition and consequently the same degree of evolution (Mazaltarim, 1989).

The same kind of heterogeneity is also observable on a local scale in a set of ferricrete samples collected at the surface of a given morphological unit of a plateau system, covered by a continuous ferricrete (Fig.2) (Mazaltarim, 1989; Roquin *et al.*, 1989; Freyssinet, 1990).

At each scale of observation, the heterogeneity of outcropping facies has received different interpretations. Some authors invoke climatic differences (Michel, 1973). Others claim that tectonics plays an important part in differentiating the altitudes of peneplanation (McFarlane, 1973). Yet others have looked at the heterogeneity as being due to variations in chemical compositions of parent rock (Leprun, 1979), or to lateral variations of facies due to lateral migration of elements (Fe, Al, Si) within profiles (Nahon, 1976). A systematic mapping of ferricrete plateaus located in Mali (Kangaba) in Burkina Faso (Gaoua) and Centrafrica (Zemio) (Mazaltarim, 1989; Freyssinet, 1990) shows that the surficial heterogeneity can be explained by a differential surface erosion process. The erosion leads in different places and at different times to an exposure of subsurface horizons younger and less evolved than other ones, located close by and not eroded. After erosion, all the outcropping young and old facies are submitted to continuous weathering under similar conditions.

A continuous ferricrete covering a given morphological surface appears in fact as a patchwork; of petrographical, mineralogical and chemical facies differing in age and degree of evolution (Figs. 1 and 2). This can be regarded as a consequence of the



Plateau de Banankoro (Sud Mali)

Figure 2. Patchworks of different petrographical, mineralogical and geochemical facies of ferricrete, due to differential erosion over a given morphological surface. The soil surface was permanently submitted to a contrasted tropical climate and outcropping ferricretes are of different ages and degrees of evolution (Mazaltarim, 1989; Freyssinet, 1990).

differential erosion which finally involves all the ferricrete surfaces.

Allochthony or autochthony of ferricretes

The diversity of the petrographic facies or of the mineralogical and chemical compositions of the outcropping ferricrete samples makes the interpretation of the surficial geochemistry difficult. For many years the question of the allochthony or autochthony of ferricretes has been debated. Are they the result of lateral transportation of iron in solution precipitating in a lithodependent host saprolite (Maignien, 1958; Michel, 1973; McFarlane, 1976) or are they formed from long distance mechanically transported materials, so that they are entirely independent of the surrounding rocks? Should we consider the lateritic mantles as masks without any relationship with the underlying rocks or as skins developed from the underlying parent materials (Millot, Bocquier and Paquet, 1976)?

During these last 10 years, evidences of the ferricrete autochthony were accumulated. In most cases, quartz and resistant minerals as well as iron and some trace elements reflect the composition of the underlying rocks. The lithodependence of ferricretes is now generally admitted.

Lithodependence of young duricrusts and chemical homogenization of old ferricretes

Ferricretes of different degrees of evolution and age, overlying parent rocks of differentcompositions are clearly lithodependent in young and poorly evolved systems while they arelitho-independent in old and highly evolved facies, which are chemically homogenized. A set of samplesincluding acid and basic parent rocks and their associated ferricretes collected in the region of Gaoua (Burkina Faso), have been classified as a function of their iron content (Fe_2O_3 %). Diagrams of evolutive trends for some elements are shown in Fig. 3.

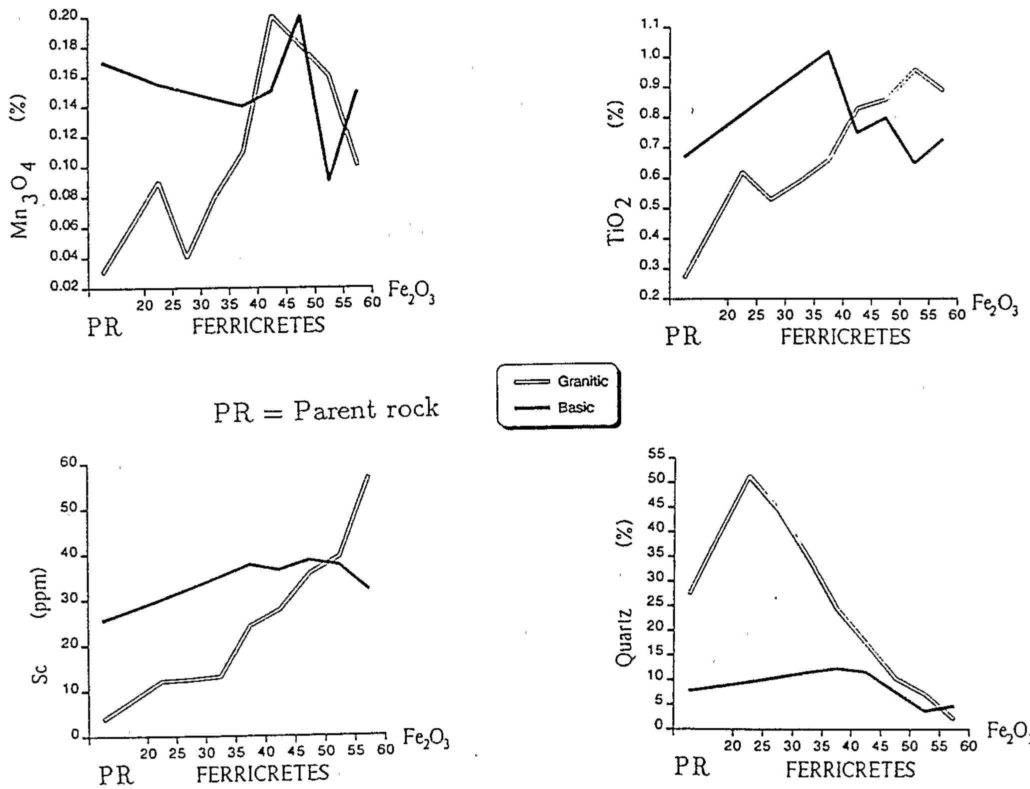


Figure 3. An example of the mineralogical and chemical composition of ferricretes of Gaoua (Burkina Faso), located on different basic or granitic parent rocks (PR). For low Fe_2O_3 contents, compositions are distinct: ferricretes are lithodependent. For high Fe_2O_3 contents, compositions are homogenized : ferricretes seem to be lithoindependent (from Tardy *et al.*, 1988).

Poor in iron (30-40 %, Fe_2O_3), the nature of the parent rock still can be detected, while in ferricretes rich in iron (55-60 %) mineralogical and chemical compositions are almost totally homogenized. In old and highly evolved ferricretes, the nature of parent rocks is not recognizable and there is no way to separate those which are formed either on granites, gneiss, schists, amphibolites, gabbros, sedimentary or volcanic rocks. Independently of the nature of parent rocks from which they derive, the final composition is the same : poor in quartz (5 %) and mostly made of kaolinite (30 %), goethite (35 %) and hematite (30 %). When aging, ferricretes become richer in iron and in hematite relatively to goethite and poorer in quartz. Kaolinite content remains almost constant. Trace elements which are originally located in heavy and resistant primary minerals such as zircon, ilmenite, cassiterite ct cetera are progressively redistributed : either leached out, incorporated into or adsorbed on to, goethite, hematite and kaolinite (Tardy *et al.*, 1988; Mazaltarim, 1989; Boeglin, 1990;

Conclusion

Most of the ferricretes develop through a downward vertical movements of iron and resistant minerals (quartz, zircon, etc...) accompanying the lowering of the landscape surface. They occur as litho- dependent autochthonous relicts; at a landscape scale they are autochthonous and do not result from a large lateral transport. Therefore, the litho- dependence principle refers only to the column of parent rock previously located above, which is in most cases similar to the unweathered material located below. The degree of lithodependence decreases with age and degree of evolution. Along the progress of alteration a chemical homogenization takes place and after a long period of maturation under the same climatic conditions, all the ferricretes of different origin become similar.

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REFERENCES

FREYSSINET PH., 1990. Géochimie et minéralogie des latérites du Sud-Mali. Evolution des paysages. Prospection géochimique de l'or. Thèse de l'Université Louis Pasteur, Strasbourg, (in preparation).

LEPRUN J.C., 1979. Les cuirasses ferrugineuses des pays cristallins de l'Afrique Occidentale sèche. Génèse-Transformation- Dégradation. Sci. Géol. Mém., Strasbourg, 58, 224

MAGNIEN R., 1966. Compte-rendu de recherches sur les latérites. In: Recherches sur les ressources naturelles, 4, U.N.E.S.C.O., Paris, 4, 155 pp.

MAZZALTARIM D., 1989. Géochimie des cuirasses ferrugineuses et bauxitiques de l'Afrique Occidentale et Centrale. Thèse Univ. Louis Pasteur, Strasbourg, 263 pp.

McFARLANE M.J., 1973. Laterite and topography in Buganda. Uganda J., 36: 9-23.

McFARLANE M.J., 1976. Laterite and landscape. Acad. Press Inc., London, 151 pp.

MIHEL P., 1973. Les bassins des fleuves Sénégal et Gambie. Etude géomorphologique. Th. Sci. Strasbourg, Mém. ORSTOM, 63, 3 vol., 752 pp.

MILLOT G., BOCQUIER G. and PAQUET H., 1976. Géochimie des paysages tropicaux. La Recherche, Paris, 7, 65: 236-244.

NAHON D., 1976. Cuirasses ferrugineuses et encroûtements calcaires au Sénégal Occidental et en Mauritanie, systèmes évolutifs : géochimie, structures, relais et coexistence. Sci. Géol. Mém., 44, 232 pp.

ROQUIN C., DANDJINOU T., FREYSSINET PH. and PION J.C., 1989. The correlation between geochemical data and SPOT satellite imagery of lateritic terrain in southern Mali. In: S.E. Jenness (Editor) Geochemical Exploration 1987. J. Geochem. Explor., 32: 149-168.

TARDY Y., MAZALTARIM D., BOEGLIN J.L., ROQUIN C., PION J.C., PAQUET H. and MILLOT G., 1988. Lithodépendance et homogénéisation de la composition minéralogique et chimique des cuirasses ferrugineuses latéritiques. C. R. Acad. Sci., Paris, 307, série II, 1988: 1765-1772.