INFLUENCE OF PERIATLANTIC CLIMATES AND PALEOCLIMATES ON THE DISTRIBUTION AND MINERALOGICAL COMPOSITION OF BAUXITES AND FERRICRETES.

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Since the Jurassic, parts of the Brazilian and the African shields have been subjected either to equatorial, humid tropical, or to arid tropical climates. Both are covered by a thick and widely distributed lateritic mantle, the age, the nature and the mineralogical composition of which vary from one region to another. Bauxites form under hot and humid equatorial climates (25°C and rainfall > 1800 mm/yr), while ferricretes develop under seasonally contrasted tropical climates (30°C and rainfall between 1300 mm/yr and 1700 mm/yr). Since the Jurassic and the opening of the Atlantic ocean, Africa and America have been moving northwards so that equator and tropics positions were progressively shifted towards the south. Consequently the surface of the periatlantic continents were covered by laterites of different kinds and of different ages.

BAUXITES AND FERRICRETES IN THE SOUTHERN HEMISPHERE

In the southern hemisphere, and particularly in Brazil, and in South- and South-East Africa, ferricretes are not widespread, either because they were previously formed under contrasted tropical climates and later dismantled under equatorial climates or because paleoclimates were never sufficiently hot and contrasted or because contrasted paleoclimates did not operate during a long enough time (Tardy *et al.*, 1988). In Brazil, for example, scattered hematitic ferricretes were described in the Nordeste, Goias and Matto Grosso and seem to be preserved in these semi-humid regions. Ferricretes also outcrop in several parts of Amazonia but appear to have been dismantled under the rain forest equatorial climate (Melfi *et al.*, 1979; Tardy *et al.*, 1988; Nahon *et al.*, 1989).

Ferricretes are also present in South Africa, (Milnes *et al.*, 1987; Milnes and Fitzpatrick, 1987; Fitzpatrick, 1988). However, they have not the same extent and the same development as in the northern hemisphere. Particularly, in Western and Central Africa, hematitic nodular or pisolitic ferricretes are widely developed (Maignien, 1958; Michel, 1973; Nahon, 1976; McFarlane, 1976; Leprun, 1979; Petit, 1985). Bauxites are widespread in Guinea, Ivoly Coast, Nigeria and Cameroon. Some bauxites are very old and seem to have been formed since the Jurassic and through the Cretaceous and the Eocene in near equatorial conditions (Michel, 1973; Boulangé *et al.*, 1973; Hieronymus, 1973; Boulangé, 1984; Valeton and Beissner, 1986). In South America bauxites may be very old (Jurassic) or younger (Miocene) (Dennen and Norton, 1977; Aleva, 1981; Truckenbrodt and Kotschoubey, 1981; Kronberg *et al.*, 1982; Grocke *et al.*, 1982; Lemos and Villas, 1983; Trescases and Melfi, 1985); in South-East Africa, they are reported to be essentially Eocene (Grubb, 1973; Parrish and Curtis, 1982; Parrish *et al.*, 1982; Fitzpatrick, 1983; Patterson *et al.*, 1986; Fitzpatrick, 1988). In both areas, for million years climates have been continuously humid and paleoclimates have been evolving from arid to humid and in both areas, bauxites are dominantly gibbsitic and generally show massive structures with no pisolite development nor boehmite formation (Fig. 1), (Tardy *et al.*, 1988; Kobilsek, 1990).

BAUXITES AND FERRICRETES IN WESTERN AND CENTRAL AFRICA

The remaining old bauxitic laterites which are

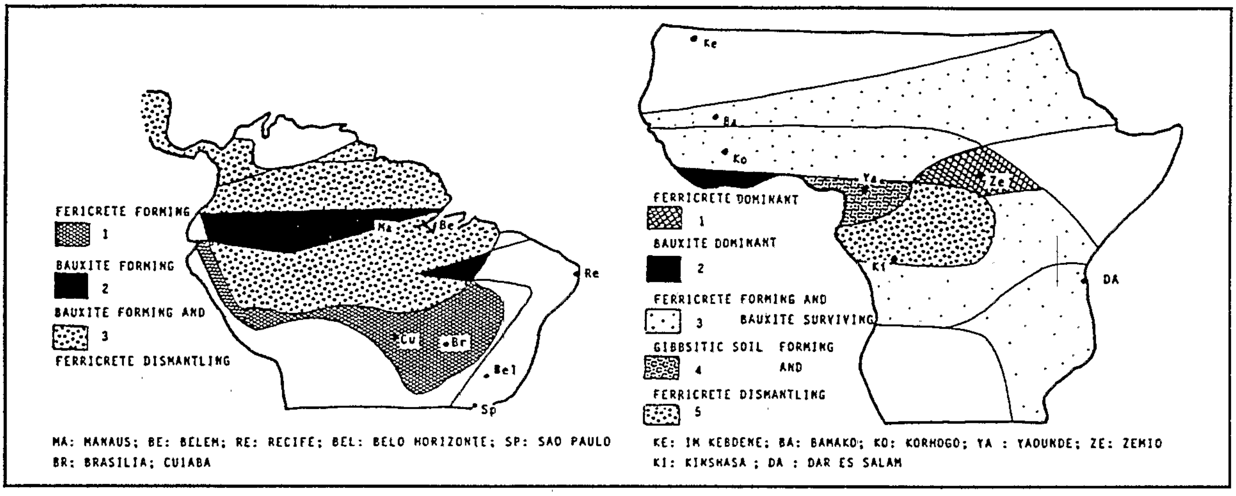

Fig. 3. Paleoclimates and succession of potential lateritic domains in Africa and in Brazil : (1) Domain submitted to contrasted tropical climate and probably continuously covered by ferricretes since the Cretaceous (100 Ma) or the Eocene (50 Ma); (2) Exclusively bauxites : equatorial domain covered by bauxites since the Cretaceous (100 Ma); (3) Bauxite transformation and ferricrete formation domain previously submitted to equatorial climate and later exposed to contrasted tropical climates; previously covered by bauxites and later by ferricretes; (4) Ferricretes dismantling and bauxite formation, in domains previously covered by ferricretes and presently evolving under the rainforest equatorial climates.

abundant in Mali and in Burkina Faso located at the edges of Sahara yield mainly gibbsite but also boehmite formed later together with a secondary development of pisolites. In these regions, probably at the end of the Eocene or since the Miocene, under contrasted tropical climates, gibbsitic bauxites ceased to form and hematitic and kaolinitic ferricretes began to develop. The secondary formation of boehmite and pisolites in bauxites is probably contemporaneous with the extension of the ferricrete, occurring when equatorial climates were replaced by tropical, as the Sahara progressively moves southwards (Tardy *et al.*, 1988). Thus on a continental scale, regions in which gibbsitic bauxites were formed continuously or over a long period of time do not show a wide development of ferricretes, while those which exhibit boehmitic and pisolitic bauxites are covered by a large mantle of surficial iron accumulation. This is particularly the case in Western and Central Africa, where ferricrete may have been formed since the end of the Cretaceous (McFarlane, 1976; Tardy *et al.*, 1988).

In the present-day equatorial regions covered by rain forest, gibbsitic and goethitic soils are now forming. However ferricretes that are being dismantled, are also outcropping (Novikoff, 1974; Volkoff, 1985). It is clear that some, if not all, of the hematitic nodular red soils or nodular stone lines may result from a secondary transformation of ancient ferricretes formed earlier under seasonally contrasted climates and presently submitted to humid equatorial conditions. This is clearly the case in a large part of the Congo and the Amazon basins (Nahon *et al.*, 1989).

The relative stability of goethite compared to hematite, and gibbsite compared to boehmite, is controlled by two thermodynamic and climatic factors, that is, temperature (T) and water activity (a_w). Thermodynamic activity of water is a parameter equivalent to the relative humidity of the air ($a_w = p/p° = 100$ HR (%)) which characterizes the dryness or the humidity of the climates. An increase of temperature and a decrease of the water activity, can both lead to the formation of dehydrated minerals in laterites (Tardy and Nahon, 1985; Trolard and Tardy, 1987). Consequently, tropical climates such as those prevailing South of the Sahara, characterized by a mean annual temperature of about 30°C and by a dry season of several months duling which the relative humidity of the air becomes lower than 70 %, favour the formation of hematite and kaolinite in iron accumulations and of secondaly boehmite in gibbsitic bauxites, previously formed.

CONCLUSIONS

During the last 100 Ma and due to the slow drift of continents, climatic zones have progressively shifted. During the Jurassic, equator was located on what is now Mauretania and Northern Venezuela. Then, Africa rotated and the two continents were displaced northwards, shifting the equator in a more southward position (Parrish *et al.*, 1982). Both Brazil and SE Africa, initially more arid, have been moving to become progressively more humid. By contrast, West and Central Africa, more humid to begin with, later became dryer and less humid. Western and Central Africa on one hand, and SE Africa and Central Brazil on the other, during the Cretaceous and the Tertiary, were subjected to climates which, independently of global fluctuations, have been changing in an opposite way. Consequently, some climatic contrasts, which today separate the first from the second group of continental regions, might have also operated in the past.

Finally, the spatial and temporal distribution as well as the observed mineralogical composition of bauxites and ferricretes, in Brazil and in Africa, do not only result from the diversity of the present-day climates but reflect also the paleoclimatic evolution of each continent since the latest Jurassic and the Atlantic opening.

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