

# GEOCHEMICAL CHARACTERISTICS OF AFRICAN AND BRAZILIAN BAUXITES DEPOSITS : $\text{SiO}_2$ - $\text{Al}_2\text{O}_3$ - $\text{Fe}_2\text{O}_3$ SYSTEM and Ti, Cr, V and $\text{Fe}_2\text{O}_3$ RELATIONS

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## INTRODUCTION

West Africa and Brazil are known to be the most important world lateritic bauxite reserves. The studies carried out in these fields have given analytical data concerning different ore deposits with respect to the nature of the parent rock, the geomorphological setting and the composition of the secondary products.

In Brazil, these bauxitic formations consist of four types of deposits with distinct lithologies located in four main areas : 1) the northern area (Amazon) where the deposits develop mainly from clastic sedimentary rocks (ex. Porto Trombetas); 2) the "Quadrilátero Ferrífero" where the deposits occur on precambrian sediments; 3) the southeast area (Minas Gerais) where the deposits form at the expense of granulitic and charnokitic precambrian rocks; 4) the southeastern area where bauxite deposits develop from alkaline rocks (Melfi *et al.*, 1988; Boulangé and Carvalho, 1988).

In West Africa, the bauxitic ore deposits are located preferentially along each side of the uplift axis of the west-african shield (Boulangé and Millot, 1988). The southern belt runs along the Guinea gulf coast submitted to an humid tropical climate. The ore deposits develop in situ from crystalline rocks (schists, amphibolites, granites...). In the northern belt, the bauxitic deposits consist of very evolved weathering profiles.

Petrological, mineralogical and geochemical analysis allow to define the genetic relationships between the different facies and to establish the history of every type of deposit. In fact, there are

two main bauxitic types. The first, directly or indirectly formed by weathering of parental rock, called "original bauxites". The second, called "degraded bauxites", develops from the original bauxites by deferruginization processes. This last type includes pseudobrecciated, nodular and pisolitic facies (Boulangé, 1984). Sometimes, the resilication of bauxite can lead to kaolinitic facies. The evolution from the original bauxites to these degraded or kaolinitic facies is always accompanied with a deferruginization process.

With respect to the parent rocks, we can consider three groups of deposits : 1) bauxites from felsic rocks (granite, syenite, phonolite), 2) bauxites from mafic rocks (amphibolite, basalt), 3) bauxites from sedimentary and metamorphic rocks (gneiss, phyllites, sandy clay sediments). According to geochemical data, it is possible to distinguish the deposits related to the parent rocks, to understand their evolution and to establish some elements correlation.

## BAUXITES RELATED TO FELSIC ROCKS

The examples are taken in Ivory Coast, deposits from granite (Lakota) (Boulangé, 1984), and in Brazil, deposits from syenite (Passa Quatro) (Sigolo and Boulangé, 1987). In both cases the profiles, resulting from direct transformation by weathering of the parent rocks, are constituted, from the bottom to the top by a massive saprolitic bauxite, a fragmentary saprolitic bauxite and a fragmentary

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alumino-ferruginous crust. These facies, with textures and structures preserved, are original facies.

The geochemical data shown a strong positive correlation between  $\text{Fe}_2\text{O}_3$  and Ti, Cr, V. Whereas  $\text{Fe}_2\text{O}_3$  content increases from 1% in the parent rock to 15-20% in the bauxite, Ti increases from 0.2%-0.5% to 1%-2%, Cr from 10 ppm to 600 ppm, and V from 20 to 200 ppm.

Only the deposits from granite (Lakota) show profiles with degraded bauxites. These pisolitic facies, rich in aluminium and poor in iron, are also characterized by a higher Ti content (2.5%). The evolution resulting from a deferruginization process promotes also depletion of Cr and V. Indeed, the positive correlation between  $\text{Fe}_2\text{O}_3$  and Cr or V is kept. So it seems that Cr and V follow the iron in this process.

### BAUXITES RELATED TO MAFIC ROCKS

The Orumbo Bocca deposit develop from amphibolite (Ivory Coast) (Boulangé, 1984) and Lages deposit from basalt (Brazil) (Dani, 1988) are the examples shown in this group. In these profiles we can observe a succession of original facies, and degraded facies (only for Orumbo Bocca). The original facies result from direct or indirect transformations of parent rocks. The geochemical data allow to distinguish these two ways. During the weathering processes the  $\text{Fe}_2\text{O}_3$  contents increase from 12%-15% in the parent rocks to 45% in the bauxitic facies from amphibolite, and 30% from basalt. Ti increases from 0.5%-1.5% to 2.5%-3.5% and V from 200-300 ppm to 1000 ppm. Cr contents are different for amphibolite (from 200 ppm to 2000 ppm) and for basalt (from <15 ppm to 100 ppm).

In the Orumbo Bocca profile, degraded facies (nodular) result from a separation of iron and aluminium. The more ferruginous facies are characterized by very low Ti content (<0.3%) and the more aluminous facies by high Ti content (2.5 to 3%). As in the previous group, Cr and V remain in a positive correlation with iron and follow the iron during this step of deferruginization.

In the Lages deposit, it seems that resilication process occurs at the lower part of the bauxite profile. The derived kaolinitic facies are characterized by high Ti contents (4 to 6%). Cr and V remain in a positive correlation with iron.

### BAUXITES RELATED TO SEDIMENTARY AND METAMORPHIC ROCKS

In this group we place three types of bauxite

deposits in Brazil : from gneiss in Cataguase (Lopes, 1987), from phyllites in Quadrilatero Ferrífero area (Varajão *et al.*, 1989), and from sandy clay sediments in Porto Trombetas (Amazonas) (Boulangé and Carvalho, 1989).

The heterogeneity of the gneisses in the Cataguases deposits makes difficulties to define the evolutive series of the facies. Out of the resilicated facies in the lower part of the profile, it seems that only original facies occur. The  $\text{Fe}_2\text{O}_3$  content about 10% in the parent rock increases to 20% in the bauxite. At the same time Ti increases from 0.5% to 3%, Cr from 20 to 300 ppm and V from 100 to 500 ppm. In the lower clayey facies the Ti contents reach 4 to 6%, but Cr and V remain in a positive correlation with iron.

In Quadrilatero Ferrífero area, it was not possible to find the unaltered parent rock. On the base of iron contents, it is possible to distinguish three types of deposits : i) plateau deposits (25%  $\text{Fe}_2\text{O}_3$ ), ii) slope deposits (30-40%), iii) slope deposits with enclosing itabirites (40-50%). For all types, the Ti, Cr and V contents are respectively between 1.5% to 3%, 80 to 400 ppm and 80 to 500 ppm. In the down slope deposits, bauxite is deferruginized, and in this particular bauxitic facies, the Ti content reaches 4%. The Ti content in iron-crust formed in other place from this remobilized iron reaches to only 0.3%. In other hand, the resilication processes are frequently observed in the lower part of bauxitic profiles, and the derived kaolinitic facies are rich in Ti (4%).

In Porto Trombetas deposits, the profile developed from sediments, present : i) a basal kaolinitic layer, ii) a bauxite layer capped by iii) a ferruginous crust with aluminium rich zone (nodular bauxite), and iiiii) upper kaolinitic layer. It is shown that the upper part of the basal kaolinitic layer is formed by resilication from the bauxitic layer. The geochemical data shown that the  $\text{Fe}_2\text{O}_3$  content varies between 2% and 35% in the bauxitic layer, Ti remains about 1%, Cr between 40 and 300 ppm, V between 90 and 600 ppm. In the basal kaolinitic layer the Ti content increases from 1% in the bauxite, to 5%. In the upper kaolinitic layer the Ti content also increases to 3%. Thus, it is possible to consider that the upper kaolinitic layer is formed by degradation processes (deferruginization and resilication) of old bauxitic and kaolinitic profile. In the both cases, as in the previous types, Cr and V remain in the same positive correlation with iron.

In conclusion, the bauxitization process require an important aluminium accumulation

(relative and absolute). But this process is always jointed with an important iron accumulation. Elements as Ti, Cr, V have the same behaviour that iron in this accumulation process. But, during the deferruginization evolution, chromium and vanadium are depleted in hydromorphic environment and remain in a positive correlation with iron. Whereas in degraded bauxite facies formed by deferruginization and/or resilication process, the titanium contents increase two or three times in relation to the original bauxite. In the other hand, Ti, Cr and V contents keep a clear relation with the three groups of the parent rocks (felsic, mafic and sedimentary) and can be thus considered as a good geochemical memory of the parent rock.

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