THE BAUXITE OF THE QUADRILÁTERO FERRÍFERO

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The "Quadrilátero Ferrífero", located in the central part of Minas Gerais state, Southeast Brazil, covers an area of nearly 7,000 km^2. It is a mountainous Precambrian region, with altitudes from 650 to 2,000 m. The bauxite reserves of this region are estimated to 10 million tons, distributed in 24 small deposits, which ranges from 150 to 1,500 thousands of tons. Considering both the geomorphological aspects and the geological situation, the deposit types have been interpreted differently in the various studies carried out in the region. The majority of the studies (Guimarães, 1945; Vaz, 1945; Lacourt, 1947; Dorr, 1969; Moore, 1969; Maxwell, 1972) suggested for the bauxites an autochthonous evolution from clayey phyllites and dolomites, while in a few others (Fleischer et al., 1968; Fleischer & Oliveira, 1969), the deposits were considered as allochthonous. On the other hand, in all these studies, it was mentioned the presence of a discontinuity between the substratum and the mineralized layers, which has been explained as a result of bauxitisation of either lacustrine clayey sediments inside depressions (Varella & Rosales, 1977; Büchi et al., 1982), or volcanic acid rocks (Dorr, 1969).

I. Regional aspects

The "Quadrilátero Ferrífero" forms the southern end of the folded belt of São Francisco Shield (Fig. V.1). The stratigraphic series overly a granite-gneissic basement that is the central outcrop in the southern part of the "Quadrilátero Ferrífero". These series are constituted by 3 great lithostratigraphic units (Harder & Chamberlin, 1915; Dorr, 1969; Ladeira, 1980):

- *Rio das Velhas Supergroup* forming a greenstone belt that includes the phyllitic and quartzitic formations of Nova Lima and Maquiné groups, the ultramaphic rocks on the eastern border and the bearing gold greenschists on the south.

- *Minas and Itacolomi Supergroups* formed by thick units of Proterozoic metasedimentary rocks. The Minas Supergroup has the most important deposits of iron, manganese and aluminum. The general metamorphic grade is lower than the greenschist facies, increasing from west to east.

The bauxite deposits are generally associated with the Itabira Group, included in the Minas Supergroup, and containing two units: Cauê and Gandarela formations. The main constituent of Cauê formation are the itabirites, associated with dolomitic and amphibolitic facies, intercalated with phyllites and marble. The Gandarela formation is constituted by dolomites, dolomitic phyllites, dolomitic itabirites and phyllites. Pires (1979) postulated that the base of Gandarela Formation would be formed by a magnetite-chlorite-schist, originated from mafic volcanic rocks, and by dolomitic lens, suggesting an environment similar to the recent reefs. It has to be remarked that the presence of volcanic rocks in the Minas Supergroup has been mentioned quite often (Guimarães, 1935, 1951, 1964; Guild, 1957; Simmons, 1958; Johnson, 1962; Dorr, 1969).

On the other hand, the occurrence of sedimentary deposit of Tertiary or Quaternary age has been reported in the "Quadrilátero Ferrífero". They constitute the lacustrine basins of Gandarela and Fonseca. Other sedimentary deposits occur as well in other regions, especially in Gandarela, Macacos and Rio Acima Quadrangles.

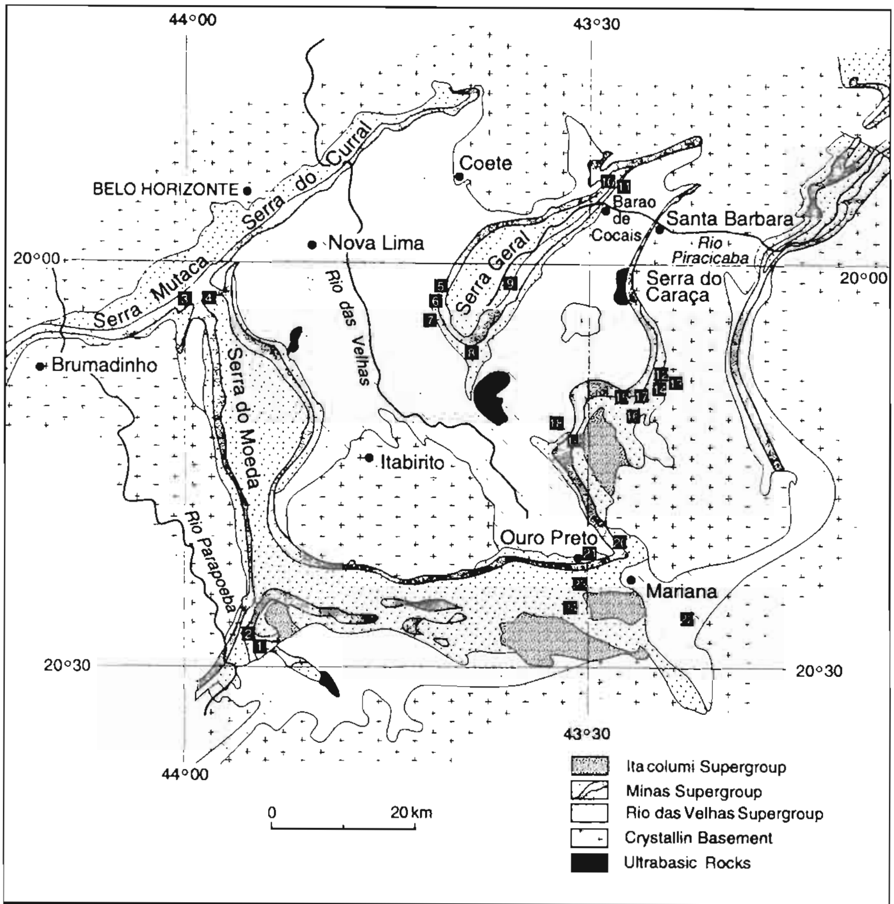
The geological structure pattern in this iron rich region results of a complex tectonic, having three main trends (north, east and south) and being constituted of three orogenetic phases. The first phase (2,700 m.y.) is younger than the deposition of Rio das Velhas Supergroup, while the second and most important one (2,000 m.y.) affected the Minas Supergroup and is equivalent to the Transamazonic Cycle. The last phase (500 - 600 m.y.) corresponds to the Brazilian Cycle (Brito Neves et al., 1979; Cordani et al., 1980; Uhlein et al., 1986).

The hydrological system is superimposed upon the geological structure. The main rivers are the Paraopeba in the west and Velhas in the center, which flows toward the São Francisco river. The Piracicaba and Gualaxo rivers drain the eastern part of the "Quadrilátero Ferrífero".

The present climate is of semi-tropical type. The mean temperatures vary from 14 to 21°C and it is rarely higher than 30°C. The annual mean rainfall ranges from 1,500 to 2,000 mm and increases from northwest to southeast; the months of June and July are completely dry and December and January are the most rainy months.

According to King (1956) and Dorr (1969), the geomorphological evolution of the "Quadrilátero Ferrífero" was characterized by the development of four surfaces placed at different levels, having different ages:

- the Gondwana surface (Lower Cretaceous), with altitudes varying from 1,500 to 1,600 m,
- the Post-Gondwana surface (Upper Cretaceous), between 1,200 and 1,400 m,



1 - Casa da Pedra	9 - Fazenda do Vargem	17 - Cata Preta
2 - Serra da Bandeira	10 - Dois Ircuaos	18 - Batatal
3 - Jardine Canada	11 - Fazenda do Sape	19 - Canta Historia
4 - Vargem dos Oculos	12 - Faria	20 - Serra de Antonio Pereira
5 - Fazenda do Lopes	13 - Macaquinho	21 - Serra da Brigida
6 - Maquiné	14 - Fazendão	22 - Morro do Cruzeiro
7 - Gandorela	15 - Morro da Arataca	23 - Tesoureiro
8 - Vigario da Vara	16 - Morro da Fraga	24 - Moujolo

Figure V.1 - Geological map of the Quadrilátero Ferrífero (modified after Dorr & Barbosa, 1963) and location of the bauxite deposits.

- the Sul-Americana surface (Oligocene-Miocene), with altitudes from 850 to 950 m,
- the Velhas surface (Pliocene), forming the central part of the "Quadrilátero Ferrífero" with an average altitude of 750 m.

From the beginning and up to now, the existence of these surfaces has been a matter of controversy (Varajão, 1988). Braun (1971), just after the proposal of Dorr (1969), has remarked that it would be very unlike that the rest of the Gondwana surface would be preserved after the intense erosional process that happened in the post-Gondwana period. In any case, the idea of a control of the topography by the lithological structure has been well accepted.

With regard to the general morphological features, it is possible to distinguish three units:

- the summits and the upper part of the higher topography, with altitudes over 1,500 m;
- the hill slope, corresponding to the intermediate unit, with altitudes ranging from 800 to 1,400 m;
- the depressions presenting altitudes varying from 1,200 to 1,400 m.

It has to be remarked that some other geomorphological units can be found in the "Quadrilátero Ferrífero". That is the case of a large depression, occurring in its central part, that was cut down by the Rio das Velhas, where the average altitude is about 800 m. The are also, in the external border of the "Quadrilátero Ferrífero" some small plateaus, in a rather low topographic position (about 900 m).

II. Classification of the bauxite deposits

The most part of the studies of the bauxite deposits, that normally followed their exploitation, were carried out taking into consideration particularly the aspects associated with the topographic positions, and consequently, with the erosional surfaces and their ages (Vaz, 1945; Guimarães, 1945; Guimarães & Coelho, 1945; Lacourt, 1947; Fleischer & Oliveira, 1969; Dorr, 1969; Moore, 1969; Maxwell, 1972; Ferreira, 1983). Recently, a study was carried out by Varajão (1988) and despite not presenting a detailed petrographic analysis, it represents a good inventory of the deposits of this region.

Based on the knowledge accumulated so far, a classification of the bauxite deposits of "Quadrilátero Ferrífero" is proposed here, taking into consideration both the geomorphological and geochemical aspects. As concerning the geomorphological aspects it was observed that the deposits were associated to 4 different units: high plateaus; hill slope; depressions and low plateau. The geochemical aspect refers to the average chemical composition of each deposit plotted on ternary diagram SiO_2-Al_2O_3-Fe_2O_3 (Fig. V.2), based on chemical analysis from regional mining companies (Table V.1). It can be observed that the deposits have a tendency to be distributed in 4 groups that correspond to the different morphologies mentioned above.

Thus, based on these two aspects, the bauxite deposits of the "Quadrilátero Ferrífero" were classified in 4 different types: the high plateau bauxites - Type I; the hill slope bauxites - Type II; the depression bauxites - Type III, and the low plateau bauxites - Type IV.

1. Type I - High Plateau Bauxites

These deposits are all situated in a high topographic position,

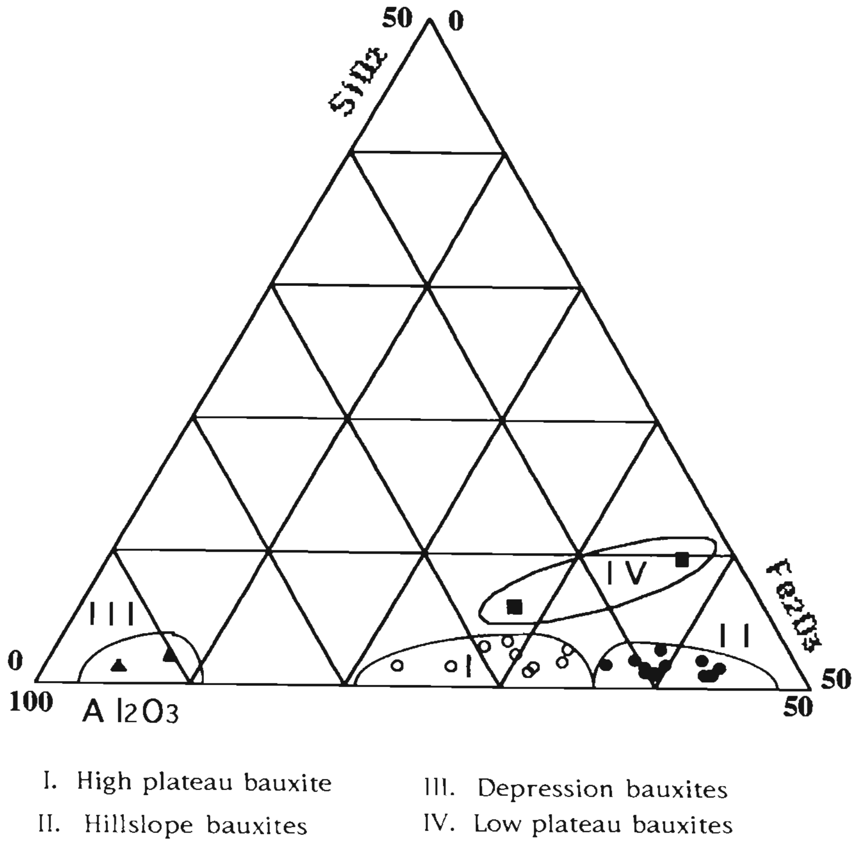


Figure V.2 - Diagram SiO_2 - Al_2O_3 - Fe_2O_3 allowing to range the Quadrilátero Ferrífero bauxite deposits on function of its main chemical components.

forming either the summit of a slightly tilted plateau or a part of a slope of a higher topography:

Serra do Batatal: 1840 m
Gandarela: 1640 m
Maquiné: 1600 m
Conta História: 1550 m
Vigário da Vara: 1510 m
Fazenda do Lopes: 1510 m
Serra da Bandeira: 1500 m
Serra da Brígida: 1490 m

The average chemical composition shows that these bauxites, with 47% Al_2O_3, are very poor in silica (1,5% SiO_2), but have a rather high content of iron (22% Fe_2O_3).

2. Type II - Hillslope Bauxites

These deposits occur in various altitudes and are also distributed on the morphological surfaces, except for the high plateau. They are normally protected by the itabiritic wall (Itabira Group) of the folded series of Minas Super-Group.

Tesoureiro: 1400 m
Jardim Canada: 1350 m
Monjolo: 1070 m
Morro do Arataca: 950 m
Cata Preta: 930 m
Casa da Pedra: 1350 m
Serra Antº. Pereira: 1220 m
Morro do Fraga: 1020 m
Dois Irmãos: 950 m
Fazendão: 890 m
Fazenda do Sapé: 830 m

The average chemical composition shows bauxites with 43% Al_2O_3, very low silica content (< 2% SiO_2) and a high iron content (29% Fe_2O_3).

3. Type III - Depression Bauxites

This type of deposit is quite rare, and up to now only 2 examples are known: Vargem dos Óculos (1350 m) and the foot slope of Morro do Fraga deposit (990 m). The old deposit of Morro do Cruzeiro (1210 m), already completely exploited, considering its description given by Guimarães & Coelho (1945), could be added to this group. But there is no chemical data to do so.

These bauxites contain a very high amount of alumina (56% Al_2O_3), together with 5% Fe_2O_3 and 1,2% SiO_2.

4. Type IV - Low Plateau Bauxites

This type of deposit occurs on the plateaus situated in the external border of the "Quadrilátero Ferrífero", and includes the deposits of

Table V.1 - The bauxite deposit types of the Quadrilátero Ferrífero and its chemical composition.

	Type	N°	Location	SiO2	Al2O3	Fe2O3
		2	Serra da Bandeira	2	43,6	22,3
		5	Fazenda do Lopes	1,1	53,5	16
		6	Maquiné	2,2	48,7	19,3
High		8	Vigario da Vara	1,,3	45,9	23,2
plateau	I	18	Batatal	1,1	46,8	21,9
bauxite		19	Conta Historia	0,7	41,1	31,2
				0,96	43,65	15,68
				0,67	40,5	21,86
				1,09	38,57	23,76
		1	Casa da Pedra	1,5	41,1	25,7
		3	Jardim Canada	1,3	42,6	29
		7	Gandarela	2,9	47,9	20,5
		10	Dois Irmaos	1,2	40,4	31,8
Hillslope		11	Fazenda do Sape	1,6	40,7	30,6
bauxite	II	15	Morro da Arataca	0,7	41,3	31,9
		16	Fraga	0,9	48,9	31,5
				0,7	43,08	19,95
		17	Cata Preta	1,2	48,9	31,5
		20	Serra de A. Pereira	2,2	43,2	28,8
		21	Serra da Brigida	1,8	48,2	21,1
		23	Tesoureiro	1	37,1	31,7
		24	Monjolo	0,7	43,2	28,4
Depression		4	Vargem dos Oculos	1,2	59	5
bauxite	III	16	Fraga	1,1	57,5	3
		22	Morro do Cruzeiro	1,2	44,7	25,8
Low		12	Faria	7,4	40	27,5
plateau	IV	13	Macaquinho	2,4	48,1	20,4
bauxite		14	Fazendao	0,8	43,3	28,6

Faria (920 m) and Macaquinho (920 m) .

These bauxites, with 46% Al_2O_3 and 23% Fe_2O_3, are separated from the other types by the higher silica content (5 to 7% SiO_2).

III. Profiles characteristics

The various bauxite deposits of the "Quadrilátero Ferrífero", as mentioned previously, are distributed in 4 different types, and for each of them, the most typical deposit was selected:

Type I: Batatal deposit

Type II: Morro do Fraga deposit

Type III: Vargem dos Óculos deposit
Type IV: Macaquinho deposit

These various types of bauxite deposits were studied in different degrees of detail, depending on the peculiar characteristics of each one. Thus, the deposit of Vargem dos Óculos (Type IV), presenting a geomorphological setting completely different, as compared to the other deposits, was object of a detailed study (Varajão A., 1988; Varajão et al., 1989; Boulangé & Carvalho, 1991). The bauxite of Morro do Fraga (Type II), considering its abundance and the easy access, was also studied with a certain detail, particularly in its morphological and petrological aspects (Varajão C., 1988). For the rest of the deposits, only a general study, aiming its characterization, was carried out.

1. Type I . High Plateau Bauxite - Batatal Deposit

The deposit of Batatal, being exploited for 10 years, is located in the southern end of Serra Geral, which forms the eastern ridge of the "Quadrilátero Ferrífero" (Fig. V.1). The deposit, with a thickness varying from 5 to 10 m, occurs on a plateau, showing a smooth declivity to the east, with altitudes between 1,840 and 1,820 m, covering an area of 90,000 m^2. According to Maxwell (1972), the bauxite was supposed to lay on the Itabira Group rocks but further prospection seems to indicate that the bauxite could be originated from the phyllites of Batatal formation (Büchi & Menezes, 1982).

Recently, a profile of a shaft located in the upper part of the plateau was observed concerning the morphological and micromorphological aspects. This study (Varajão et al., 1989) allowed to establish the complete profile that shows, from the top to the bottom, the following facies:

Ferruginous massive bauxite (1 m): a red massive alumino-ferruginous crust, with a porous and vacuolar structure. Locally, this crust present a nodular aspect, where the nodules of the crust are embedded in a porous and vacuolar clear matrix. This layer is constituted mainly of gibbsite, hematite, small amount of goethite associated with the matrix, anatase and quartz. As for the chemical composition, this horizon is constituted by 46,5% Al_2O_3, 26,5% Fe_2O_3 and 2,8% TiO_2.

Mottled bauxite (4 m): a hard massive bauxite, made up of dark red volumes with hematite and gibbsite, sometimes nodular, that changes into brown yellow to beige volumes with gibbsite and goethite. This horizon presents an upper part (1 m) richer in Al_2O_3 (54%) with 23% Fe_2O_3 and 2,3% TiO_2, as opposed to the lower part that shows .41% Al_2O_3, 30% Fe_2O_3 and 2,6% TiO_2.

Mottled clay (2 m): an horizon formed by small red bauxite volumes (nodules), with hematite and gibbsite, embedded in a kaolinitic matrix, with a small amount of goethite. It seems that the bauxite nodules are relicts in continuity with the matrix, underlying the resilication process, associated with a strong deferruginisation. The average chemical composition shows 30% Al_2O_3, 14% SiO_2 and 10% Fe_2O_3, with more than 3% TiO_2. The high content of TiO_2 of this clay horizon confirms this transformation, that is followed by a residual Ti accumulation in the form of anatase. This transformation process intensifies the existing discontinuity between this horizon and the basal clay.

Kaolinitic basal clay, where the presence of muscovite and sericite underlines the original phyllite schists.

The micromorphological study of the bauxite profile has shown that it was submitted to several successive phases of reorganization, indicating a very long geological history. Hereby, the original structures were completely removed, resulting in a discontinuity between the bauxite profile and the basal weathered phyllite. As a consequence, it is difficult, in the present step, to precise if the parent rock is the basal phyllite.

2. Type II. Hillslope Bauxites - Morro do Fraga Deposit

The bauxite deposit of Morro do Fraga is located in the eastern border of the "Quadrilátero Ferrífero" (Fig. V.1), 7 km far from Santa Rita Durão District. According to Maxwell (1972), this deposit is situated on the inverted limb of Santa Rita syncline, constituted by the Itabira Group formations. Under the topographical point of view, the deposit is situated on the slope of a small basin, with altitudes between 1050 m and 975 m. This basin is limited by a crest line formed by a subvertical itabirite layer, covered by an iron crust that protects it against the erosion.

According to their position on the above morphology, two different profile types can be distinguished: the profiles situated on the slope and the one situated in the depression. In the profiles on the slope, it was observed that the basal clay is covered, from the bottom upwards, by the following sequence of facies: massive bauxite, alumino-ferruginous crust and nodular horizon (Fig. V.3).

Massive bauxite. It is an homogeneous bauxite with a hard, dark red, porous and vesicular facies, having a thickness of 4 m in the back slope and 8 m in the foot slope. It is formed by dark red volumes constituted by hematite and gibbsite. These irregular volumes are separated from each other by volumes of saccharoid well crystallized gibbsite,

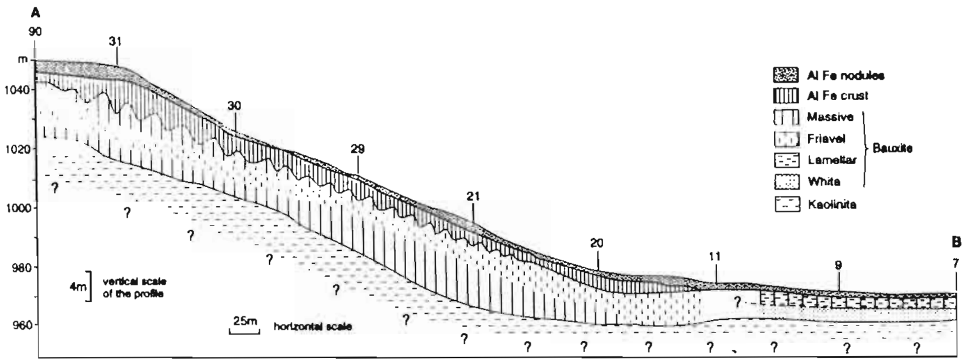


Figure V.3 - Topographic sequence of the Morro do Fraga bauxite deposit.

delimiting voids that are partially or completely invaded by dark ferruginous products. Vertically upwards, the density and the pores size increase and isolate bauxite volumes, resulting in a friable facies. Towards the back slope, close to the itabiritic walls, the pores impregnation by ferruginous products is rather important. The pores and vesicles are partially filled by a gray, argillomorphic and very humid product, that becomes readily dark when exposed (observed in a quarry front). It is a ferrihydrate that changes directly into hematite. In the foot slope, on the contrary, a deferruginisation takes place, underlined by a discoloration of the dark red volumes which are isolated within a light to brownish red matrix, constituted by gibbsite and goethite. This horizon presents Al_2O_3 content varying from 40% in the massive facies to 50% in the friable facies, 20% Fe_2O_3, less than 1% SiO_2 and less than 2% TiO_2.

Alumino-Ferruginous crust. This horizon, having thickness of 1 to 2 m, presents an irregular lower limit with the massive bauxite. This facies presents a goethitic matrix enveloping relicts of massive reindurated bauxite. The alumino-ferruginous horizon differs from the previous one by the porous dimension and the absence of gray ferrihydrate precipitate. The presence of goethite in the matrix is only associated with vertical migration and not with lateral flow coming from the back slope. The chemical composition of this horizon is very similar to the subjacent bauxite (40% Al_2O_3 and 20% Fe_2O_3).

Nodular horizon. This horizon, with a thickness of 0,5 to 1 m, is formed by subspherical nodules of alumino-ferruginous crust, with a diameter of 10 cm. The chemical composition is characterized by an increase of Fe_2O_3 content (25%) and a relative increase of Al_2O_3 (45%).

Towards the back slope the nodules are cemented by a ferruginous product and form locally a pseudobrecciated crust.

In the lower part of the area, in the depression bottom, the nodular horizon and the alumino-ferruginous crust form only one horizon, hardened and rich in Fe_2O_3 (35%), having in the upper part (2 m) goethitic lamellae. These lamellae become less important and disappear completely downwards giving place to a gray to white argillomorphic bauxite horizon (2 m). This gray bauxite is very rich in Al_2O_3 (57%) and has a low content of iron Fe_2O_3(3%). On the other hand, the high value of TiO_2 (4,5%) suggests that this bauxite was submitted to a deferruginisation process and a consequent TiO_2 residual accumulation (Boulangé & Carvalho, 1989). Considering its characteristics, this profile is better classified as type III.

The Morro do Fraga bauxite deposit, situated on a slope, shows various geochemical mechanism according to the geological and morphological condition. Hence, the alteration process affects at the same time the itabirite and the phyllite layer. But, in the former, it progresses slowly and gives origin to a ferruginous crust while in the phyllite it forms bauxite and the process goes deeply. As a consequence of this differential erosion, the topography is reinforced with the itabirites forming the crest line and the bauxites laying on the slope.

A great amount of iron is liberated by the itabirites. It moves down, it is fixed as ferrihydrate and it changes into hematite as soon as the profile is submitted to desiccation. However, this mechanism does not occur in the surface, where the previously formed bauxite is submitted to a breaking down and a nodulation. The fragments were mechanically transported and deposited in the depression. Here, under hydromorphic conditions, the bauxite suffers an intense deferruginisation, giving origin to a gray to white argillomorphic bauxite, with no trace of resilication and rich in residual TiO_2 (4,5%) as anatase.

On the other hand, the amount of iron available in the slope, and get moving, is redistributed as lamellae in the upper part of the profile. This distribution marks well the water table movement in this depression.

3. Type III. Depression Bauxites - Vargem dos Óculos Deposit

Description of facies. The deposit of Vargem dos Óculos are of two types: kaolinite deposit and bauxite deposit. They are located at 15,5 Km of Belo Horizonte in the vicinity of the road leading to Rio de Janeiro, and cover an area about 50 ha (Fig. V.1). They are situated in the Moeda syncline trough, west border of the "Quadrilátero Ferrífero", and are developed on Precambrian Itabira Group rocks. The morphology is very similar to the Morro do Fraga deposit. Thus, an itabiritic crust forms the crest line bordering a large depression, where the deposits of kaolinite and bauxite are situated.

The profiles of kaolinite and bauxite deposits are very similar, their difference being only the thickness of the different facies. The study of the open cut mine samples and drill hole cores leads to establish a typical profile, with three major units (Varajão et al., 1989), that are, from the bottom to the top (Fig. V.4): lower clay unit, middle bauxite unit and covering unit.

The lower clay unit. This facies, not well developed in the bauxite deposit, at least in the exposed area, but very thick in the kaolinite deposit (more than 12 m), is constituted, from the bottom to the top, by two facies, with gradational contacts:

a. Massive kaolinite facies. This facies can be observed only at the bottom of the visible profile in the kaolinite deposit. It occurs as block fragments (50 cm large) bounded by a network of narrow cracks (1 mm) with a red argillo-ferruginous coating. The kaolinitic fragments are compact and are made up by a quartzous skeleton embedded in a kaolinitic matrix. The quartz (less than 5% and smaller than 3 mm) is fractured, showing dissolution features on their edges and sometimes a red ferruginous coating (hematite) in the fissures. The kaolinite matrix is brownish to white, with a better crystallization in the white zones.

b. Kaolinite with ferruginous zonation facies. This facies, with a thickness about 12 m in the kaolinite deposit, is more fragmentary than the previous one and independently of the cracks. Ferruginous zonations are developed in the kaolinitic fragments. This zonation is expressed by the alternation of red ferruginous and white kaolinitic lineations, that develop in a meter scale and are independent of fractures. These lineations are abundant in the upper part and are reduced to scattered spots downwards. The ferruginous zonations give a pink yellow color at the matrix, suggesting that iron is been removed from the present profiles with possible transformation of hematite into goethite.

Transition facies. This facies, with thickness to 3 m in the kaolinite deposit, was observed only in the lower part (0.50 m) of the bauxite deposit. It is characterized by a greater amount of alumino-ferruginous nodules embedded in a kaolinitic and gibbsitic matrix. The nodules are formed by gibbsite, quartz, hematite-gibbsite-quartz association and hematite with ferruginous halos, gradually disappearing into the matrix. The gibbsite shows irregular outline embayments of dissolution that put

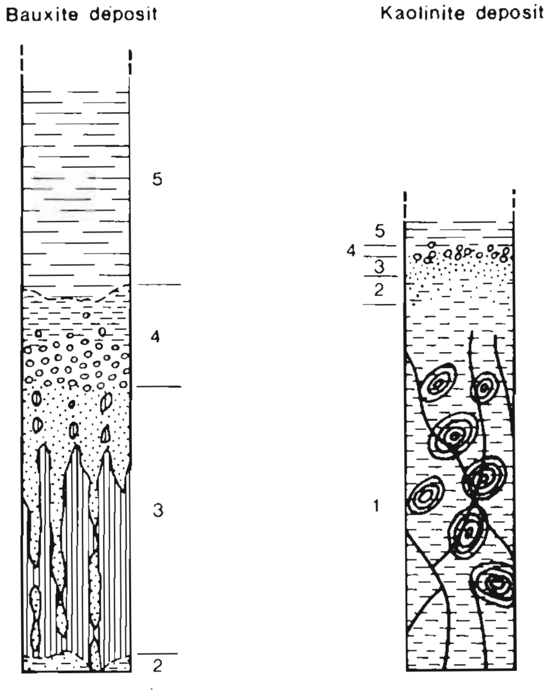


Figure V.4 - Schematic section of the bauxite deposit and kaolinite deposit of Vargem dos Óculos (Quadrilátero Ferrífero).

the gibbsitic and the kaolinitic matrix side by side. These nodules, sometimes with internal voids, could be relicts of an older alumino-ferruginous crust or bauxite. All the nodules show gradual transition with the yellowish brown matrix. Nodules and matrix are also submitted to a new deferruginisation that leads to the formation of kaolinitic matrix with few ferruginous relicts. This unit seems to result from the degradation of an older bauxitic crust that itself was submitted to a great accumulation process of aluminum and iron. The degradation process is characterized by a deferruginisation of the alumino-ferruginous nodules and an iron redistribution in the ferruginous bands and by a resilication observed in the gradual contact between the well crystallized gibbsite and kaolinitic matrix.

Bauxite horizon. Rather thin in the kaolinite (1 m), this unit can reach 3 m thick in the bauxite deposit. In the lower part, it is constituted by an association of red volumes embedded in yellow volumes. Both are cut down by white volumes, appearing as vertical pockets in the middle part and getting coalescent to form wholly the upper part. The red volume is formed by irregular shaped and sometimes coalescent nodules with mainly hematite-gibbsite mineralogical composition; the gibbsite is in close association and indistinguishable from the hematite and also appearing coating cracks and voids. The edges of the nodules show a gradual transition with yellow zones of which the mineralogical composition is mainly goethite and gibbsite. In the middle part, it can be observed a clear contact between the alumino-ferruginous nodules and the white volumes. Under the microscope, at the edges of these vertical pockets, it seems that the white gibbsitic matrix results from the deferruginisation of the alumino-ferruginous nodules that is complete in the upper part. Then the bauxitic facies is formed by small relicts of well crystallized gibbsite embedded in a cryptocrystalline gibbsite.

In the kaolinite deposit, this facies is reduced to a thin horizon of red alumino-ferruginous relict nodules embedded in a white gibbsitic matrix.

Ferruginous nodular facies. This facies, with a thickness varying from 0.5 to 2.5 m in the bauxite deposit, is represented only by some dispersed nodules in the kaolinite deposit. In the bauxite deposit it is characterized by irregular shaped nodules, with variable size (3 to 10 mm), cemented by a red yellow matrix and forming a crust. Some indentations of these crusts go into the subjacent white bauxite, showing a progression of the ferruginisation downwards. The nodules are either a hard, dark red compound, mainly constituted of hematite and gibbsite, or a friable, pink yellow compound with gibbsite, hematite and goethite. These nodules have the same structures as the alumino-ferruginous ones of the bauxitic facies and are surrounded by a goethitic-gibbsitic cortex.

In the upper part, this facies shows relict fragment nodules composed of hematite, goethite, gibbsite and quartz. The middle bauxitic unit is characterized by the presence of relict nodules of an older alumino-ferruginous formation that give evidence of deferruginisation process, going, even, with resilication process, as observed in the kaolinite deposit.

Covering Unit. The unit is barren, presenting clear sedimentary features. Two superimposed layers include nodules of ferruginous crust, bauxite and itabirite, that is oriented parallel to the bedding. It can be observed, in the interstitial voids of these sediments, gibbsite coating that indicates a permanent dependence on the alumino-ferruginous crust situated at the low slope.

Chemical Composition

The deposits of kaolinite and bauxite of Vargem dos Óculos present the same sequence of horizons and so, for the chemical composition, the samples were grouped according to the facies, regardless the type of deposit: I. lower kaolinite, II. lower transitional zone, III. bauxite, IV. ferruginous zone and upper transitional zone. The covering layer, being completely barren, as concerning the mining point of view, is not considered in this discussion. The chemical composition for the different facies are shown in Table V.2.

Major Elements. The diagrams SiO_2-Al_2O_3-Fe_2O_3 (Fig. V.5) and TiO_2/Fe_2O_3 (Fig. V.6) were obtained from the results of the chemical analysis (Table V.2) and give a better idea of the chemical variation for the different facies.

As concerning the low clay (I), analyzed only in the kaolinite deposit, it can be observed that their samples are grouped close together which means that they are very homogeneous.

In the lower transitional zone, in both kaolinite and bauxite deposits, it seems that the points are very scattered. Nevertheless, it can be noticed that some samples are closer to the subjacent clay (Vk5), while other ones are nearer to the bauxites (Vk51b and Vb12-13). In the former, where the petrographic analysis has shown evidences of resilication, an increase of TiO_2 content is observed.

In the bauxite, it can be observed (Fig. V.6) that the TiO_2 amount increases, while the Fe_2O_3 content decreases. This result indicates that the deferruginisation process, identified in the petrographic analysis, led to a residual accumulation of titanium and alumina, probably by a volume reduction.

In the upper part, as observed in the petrographic analysis, the bauxite undergoes a ferruginisation process, that results in a relative decrease of TiO_2 content. This observation is valid for both, the red bauxites, not submitted to deferruginisation, and the TiO_2 rich white bauxites, that underwent deferruginisation.

Thus, the detailed analysis of the major elements variation makes possible to set the various steps of the supergenic history of the deposits. By no means it is possible to assure the affiliation between bauxite and the basal kaolinite. However, the discontinuity, put in evidence in the transitional zone, was masked by the deferruginisation and resilication processes. In any case, considering its relative horizontal settlement, it seems to be of sedimentary origin.

Table V.2 - Chemical analysis of the kaolinite deposit (vk) and bauxite deposit (vb) of Vargem dos Óculos (Quadrilátero Ferrífero).

	Massive kaolinite				Transition facies			Bauxite			Ferruginous nodules			
	VK 1	VK 2	VK 3	VK 4	VK 5	VK 51a	VK 51b	VK 52a	VK 52b	VK 53	VK 54a	VK 54b	VK 55a	VK 55b
SiO2	42.61	43.25	43.17	42.48	40,21	14.55	23.89	8.10	6.15	3.19	5.87	3,57	3.47	2,25
Al2O3	37.83	38.01	37.88	37.43	34.95	22.50	42.89	39.66	59,05	56,86	34.09	22,82	27,22	54,68
Fe2O3	1.02	0,89	0,93	1,21	5.17	46,19	2.91	26,05	2.88	5.82	33.85	50,45	47,73	12,91
TiO2	2,57	2.36	2.60	2.50	2,50	2,31	4,35	3.12	3.92	3,78	2.19	1,45	2.16	2.58
H2O+	13.77	13,97	13,87	13,92	13,90	12.02	20.00	20.35	26,22	26,25	19,55	17,82	16,80	25,02
H2O-	0,55	0.35	0.40	0,42	0.25	0,52	0,20	0.32	0,10	0,15	0,40	0,70	0,87	0.35
Mn	0,01	0.01	0,02	0.01	0,02	0.02	0,03	0,02	0,02	0,02	0,02	0,01	0,02	0.03
Total	98.36	98.84	98.87	97,97	97,00	98,11	94,27	97,62	98.34	96,07	95,97	96,82	98,27	97,82
Cr	314	266	253	259	286	224	274	296	338	352	199	196	191	149
Ni	34	84	79	79	65	29	38	18	18	7	9	10	8	7
Sr	62	108	117	119	111	81	7	113	10	80	72	50	47	7
Ga	71	72	72	71	75	75	75	92	98	97	55	69	43	60
V	139	136	136	165	274	687	126	221	129	138	387	2355	422	140
Zn	30	54	64	59	48	102	28	54	16	18	70	98	87	33
Zr	313	300	319	315	315	264	510	393	492	494	291	320	308	330
Nb	49	39	43	93	40	40	86	58	76	75	40	44	40	49
Y	26	26	28	24	24	18	48	28	49	5	18	17	16	30
La	47	63	70	69	81	52	93	74	68	100	37	32	28	57
Ce	147	150	160	162	160	92	174	129	144	179	62	55	49	110
Nd	43	49	65	58	63	31	56	44	40	50	19	16	14	25
Sm	10,00	11,00	15.00	12,00	13,00	6,00	11,00	8,40	7,80	8,30	3,40	3,20	2,80	5,30
Eu	2,10	2,40	2,80	2.60	2,60	1,00	2,00	1.50	1.50	2,60	0.60	0,60	0,50	1,10
Gd	4,80	6,00	6.20	5,00	4,40	2.60	5,60	3,60	3,90	5,90	1.50	1,30	1,50	3,30
Dy	7.00	9,00	10,00	8,40	7,30	2,80	5,40	4.00	3,90	5,20	1,50	1,50	1,30	3.50
Yb	2,40	2.10	2,30	2,00	2,30	2,30	4,50	3,20	3,20	5,00	1,10	1,10	1.30	3,60

	Transition facies			Bauxite					Ferruginous nodules			
	Vb 14	Vb 13	Vb 12	Vb 1	Vb 2	Vb 3a	Vb 3b	Vb 4	Vb 5a	Vb 5b	Vb 6	Vb 7
SiO2	5,83	9,47	7,49	1,66	1,62	2,05	1,13	1,60	2,16	1,26	4,44	4,17
Al2O3	55,79	47,29	46,55	53,91	54,05	41,68	63,25	62,19	23,13	58,10	22,88	25,90
Fe2O3	8,02	16,67	18,90	14,94	14,72	31,15	2,44	3,35	54,89	8,76	55,11	44,85
TiO2	2.52	2,61	2,92	3,36	3,42	2,54	4,15	3,91	1,18	3,65	1,25	3,10
H2O+	27.02	23,75	23,42	27,00	26,92	22,40	30,05	30,47	17,50	28,45	16,15	19,25
H2O-	2,40	0.27	0.42	0,17	0,15	0,45	0,02	0,01	0,80	0.07	0,72	1,65
Mn	0,01	0.02	0,02	0,02	0,01	0,01	0.01	0,01	0,01	0,01	0.01	0,02
Total	101,59	100,08	99,72	101,06	100,89	100,28	101,05	101,54	99,67	100,30	100,56	98,94
Cr	251	303	319	366	378	348	385	346	312	275	290	291
Ni	2	8	1	1	4	1	1	1	2	1	2	1
Sr	100	103	108	135	128	91	136	109	40	89	44	53
Ga	80	105	110	93	122	118	101	101	105	95	114	150
V	222	268	340	520	323	665	171	208	1510	280	1248	381
Zn	13	22	21	14	13	16	8	8	23	12	25	32
Zr	537	715	556	530	328	440	761	735	624	741	307	560
Nb	47	60	47	45	12	38	71	64	51	69	21	50
Y	41	54	41	40	18	32	56	52	46	56	19	40
La	57	68	67	77	74	51	80	48	28	59	29	36
Ce	104	122	123	140	140	98	142	100	48	110	50	63
Nd	37	44	43	47	45	32	51	29	18	35	16	23
Sm	7.30	8,50	8,44	8,92	8,62	6,44	9,91	5,55	3,60	7,11	4,07	4,82
Eu	1,26	1.50	1,42	1,45	1,50	1,13	1,67	1,06	0,68	1,43	0,72	0,91
Gd	4,19	4,24	4,94	4,97	5,00	3,83	5.80	3,37	2,04	10,70	1,98	4,72
Dy	4,86	4,77	5,79	5,72	5,51	4,51	7,06	4,15	2,30	15,40	2,35	3,33
Yb	3,18	3,50	4,03	4,23	4,00	3,25	4,75	2,60	1,81	11,90	2,16	3,81

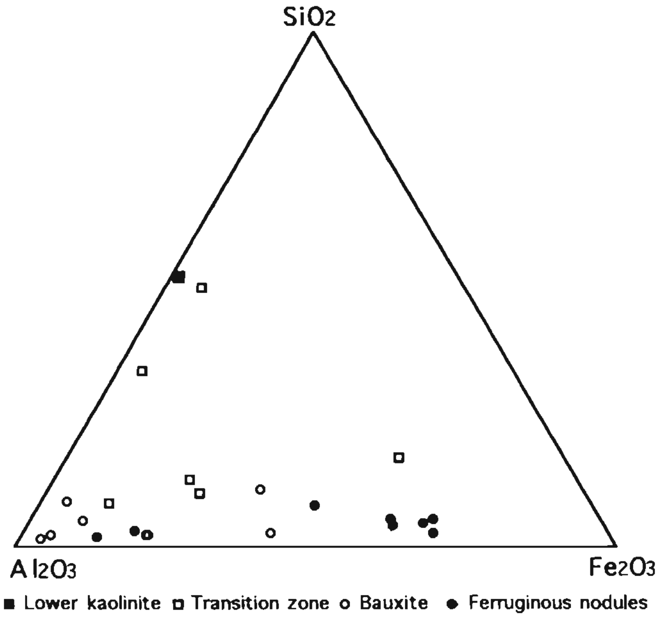


Figure V.5 - Diagram SiO_2 - Al_2O_3 - Fe_2O_3 of the main facies of Vargem dos Óculos deposits.

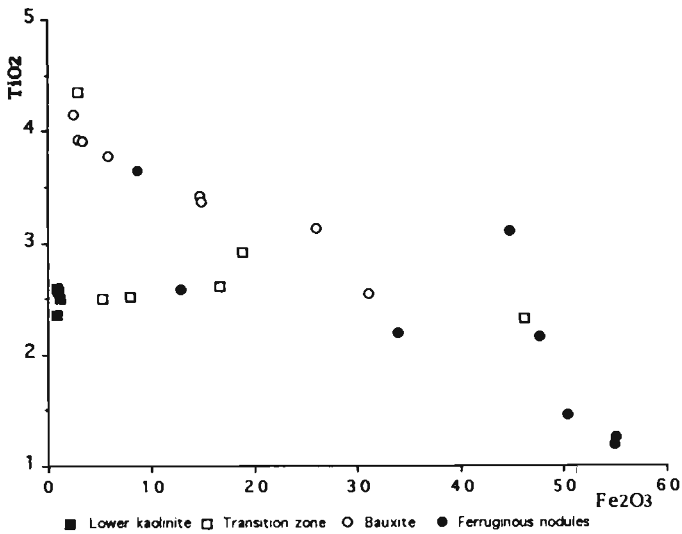


Figure V.6 - Relationship Fe_2O_3 vs TiO_2 of the main facies of Vargem dos Óculos deposits.

Trace elements. The results, concerning the trace elements for the bauxite and kaolinite (Table V.2), show that certain elements (Zr, Nb and Y) present a behavior similar to titanium. Thus, the white argillomorphic bauxite and the transitional clay zone underlying the bauxite horizon, which are richer in titanium, present also a higher content of these elements (up to 760 ppm), that would be submitted to a residual concentration. Despite not having been analyzed, it is known that the zircons contain the analyzed Nb and Y (Murali et al., 1983; Hinton & Hupton, 1991).

The gallium contents follow as well the Ti behavior, but their correlation is not as good as the one for Zr and with a larger difference between the bauxite and the kaolinite deposits.

On the other hand, vanadium and, in a less extension, chromium present a behavior close to the iron one. Thus, the higher values of vanadium correspond to the more ferruginous facies, regardless the deposit type, indicating that V follows iron throughout the different steps of the supergenic cycle.

Rare Earth Elements. The Rare Earth Elements analyses for the bauxite and kaolinite deposits are shown in Table V.2, and the Fig. V.7 presents the diagrams of their distribution, normalized to chondrites. It can be observed that the bauxitic horizons, the subjacent ferruginous nodules and the lower transitional horizon present very similar distribution. For the last two horizons, the REE contents are very close (ΣREE =200 to 300 ppm) with a ratio Lach/Ybch varying from 10 to 15. On the contrary, in the ferruginous nodules, the ΣREE decreases (100 to 200 ppm) and the ratio Lach/Ybch is lower than 10, at least for the bauxite deposit. It is noticed that, during the ferruginisation, there is a slight increase of heavy REE as compared to the light REE.

The distribution of the REE for the low clay, as compared to the overlaying horizons, is rather different, with a higher content (ΣREE about 300 ppm) and with a ratio Lach/Ybch normally over 20. This result point out also the existence of a discontinuity between the lower clay and the bauxite horizons.

As for the parent rock, not identified in the area, the results of the REE distribution in a rhyodacite from the Paraná Basin (Piccirillo & Melfi, 1988) was used for comparison. A good correlation was found, reinforcing the idea of a volcanic origin for the kaolinite and bauxite deposit.

The chemical analysis as a whole, has shown that, in both bauxite and kaolinite deposits, a continuous gradation exists between the

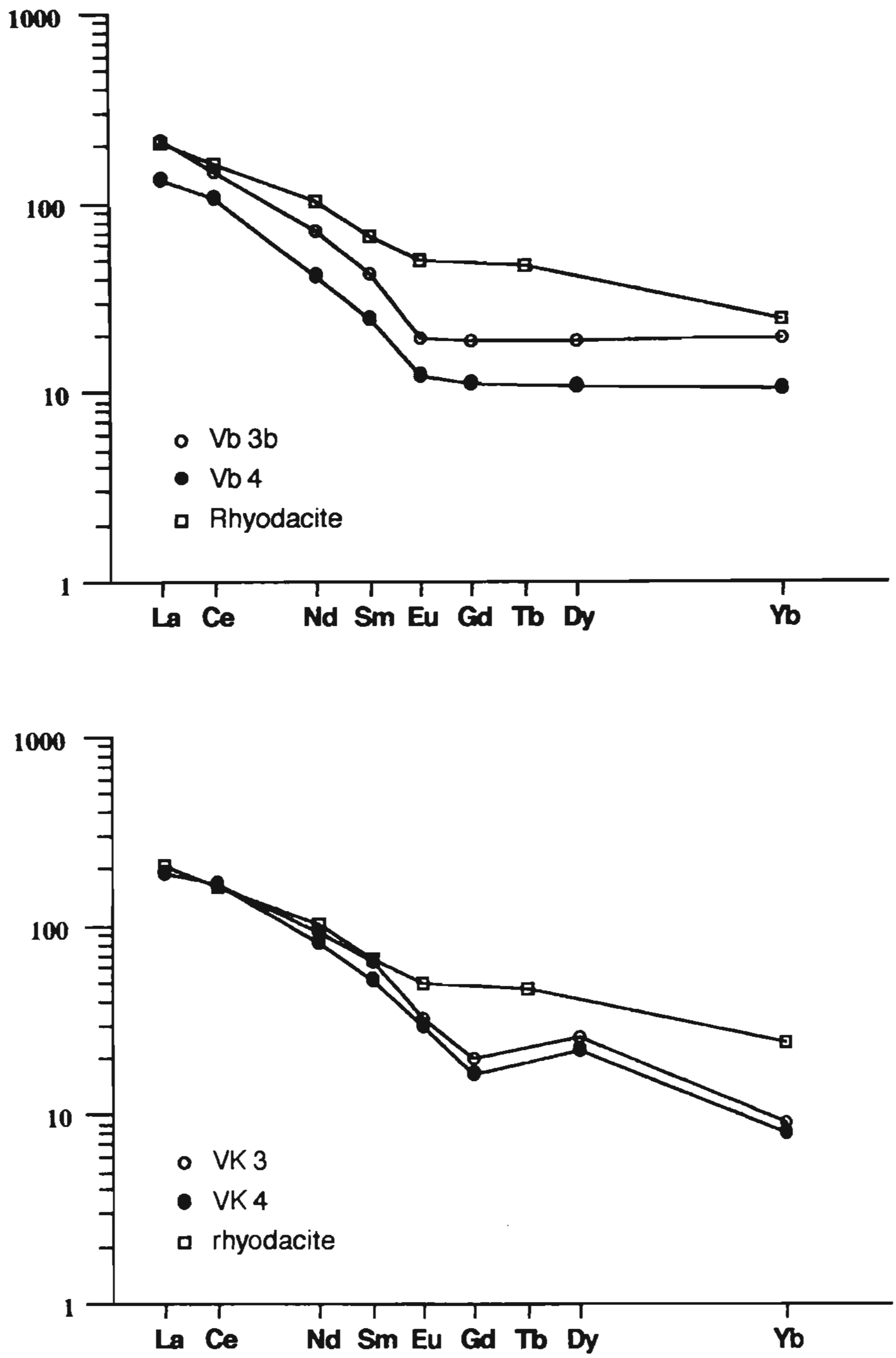


Figure V.7 - Representative chondrite-normalized REE abundances for bauxite deposits (vb) and kaolinite deposit (vk) of Vargem dos Óculos. For comparation, REE abundance for rhyodacite from Piccirillo & Melfi (1988).

bauxite submitted to resilication and the lower transitional clay horizon, as well as, between the bauxite submitted to a strong ferruginisation and the overlaying ferruginous nodules.

On the other hand, it was also shown a discontinuity between the three upper units and the underlying kaolinite.

As considering the REE signature, one can say that both kaolinite and bauxite deposits would be formed by the transformation of a parent rock of volcanic type.

4. Type IV. Low Plateau Bauxite - Macaquinho Deposit

The Macaquinho bauxite deposit is located in the eastern part of the "Quadrilátero Ferrífero", 11 km far from Santa Rita Durão. It is situated in the southern edge of "Chapada do Canga", a large plateau, with altitude of 900 m, capped by an argillo-ferruginous crust (Fig. V.1). According to Maxwell (1972), this crust would probably be developed on sediments of Fonseca Formation, which are Eocenic in age (Lima & Salard-Cheboudaeff, 1981).

The deposit is rather uniform as concerning both the thickness (6 m) and the facies distribution. It presents, from the bottom to the top, the following facies: friable bauxite, alumino-ferruginous crust and nodular facies.

Friable bauxite. This facies is a reddish brown blocky bauxite with a thickness of 4 m. These blocks (> 10 mm) are constituted by nodules embedded friable matrix. The nodules (< 2 mm), having irregular shape, are formed by small rounded gibbsitic white volumes (0,3 to 0,5 mm), disseminated in a brown ferruginous matrix, mainly goethitic. The matrix enveloping the nodules is very porous and it is also formed by gibbsite and goethite. The pores are coated with ferruginous and gibbsitic cutans. The nodules and the matrix are relatively rich in quartz grains (1 to 5%), having diameters up to 0,5 mm and presenting dissolution features. This bauxite contains nearly 49% Al_2O_3, as gibbsite, and about 18% Fe_2O_3, mainly as goethite.

Alumino-ferruginous crust. This crust is formed, in the lower part, by a massive facies (1 m) and, in the upper part, by a lamellar facies (0,5 m). Both facies are heterogeneous and constituted by an association of brownish red volumes and white volumes. Its matrix is rather similar to the one of the bauxite, with more intense ferruginisation. This crust contains about 35% Fe_2O_3 and 32% Al_2O_3 mainly as gibbsite and goethite, in its lower part, and gibbsite, hematite and goethite, in its upper part.

Nodular facies. This facies is originated by the dismantling of the alumino-ferruginous crust forming a nodular horizon. The nodules are nearly rounded and with size varying from 1 to 3 cm.

As considering their morphological and chemical characteristics, the Macaquinho deposit type is totally different as compared to the other deposits of the "Quadrilátero Ferrífero". Despite the lack of reliable analytical data, the facies sequence, the high silica content associated to the presence of quartz, would allow to consider these bauxites as close to the Porto Trombetas deposit, developed on sediments. This fact reinforces the hypothesis of Maxwell (1972), who considered these bauxites as formed on the Tertiary sediments of Fonseca Formation.

IV. Discussion

The bauxite deposits of the "Quadrilátero Ferrífero" are grouped into 4 different types: the high plateau bauxites (Type I); the hill slope bauxites (Type II); the depression bauxites (Type III) and the low plateau bauxites (Type IV). The majority of the deposits were formed on metasedimentary rocks, except for the type IV, that were originated from sedimentary rocks.

The Figure V.8 shows a diagram with the distribution of the various deposits, according to their altitudes. It can be observed that the type I bauxites occurs always in altitudes higher than 1,500 m, while the type II deposits can be found in altitudes ranging from 1,400 to 800 m. The type III, despite having very few examples, can be associated with the depressions in different altitudes , but always related to hill slope bauxite of type II. The type IV deposits occurs only on a lower surface (900 m), at the external position of the eastern border of "Quadrilátero Ferrífero".

The bauxite of the higher plateaus shows, in general, no evidence of a relationship between the bauxite and the underlying rock and, as a consequence, an allochthonous origin cannot be completely discarded.

As a matter of fact, the deposit of Conta História presents also a clear discontinuity between the bauxite and the underlying hematitic itabirite. This discontinuity is underlined in the foot-wall of the bauxite, by a thin layer of goethite. This plateau is tilted towards the west and the iron and aluminum content show a variation, according to this inclination. Thus, the more aluminous facies are situated upwards, while the more ferruginous ones are downwards. The upper part of the plateau

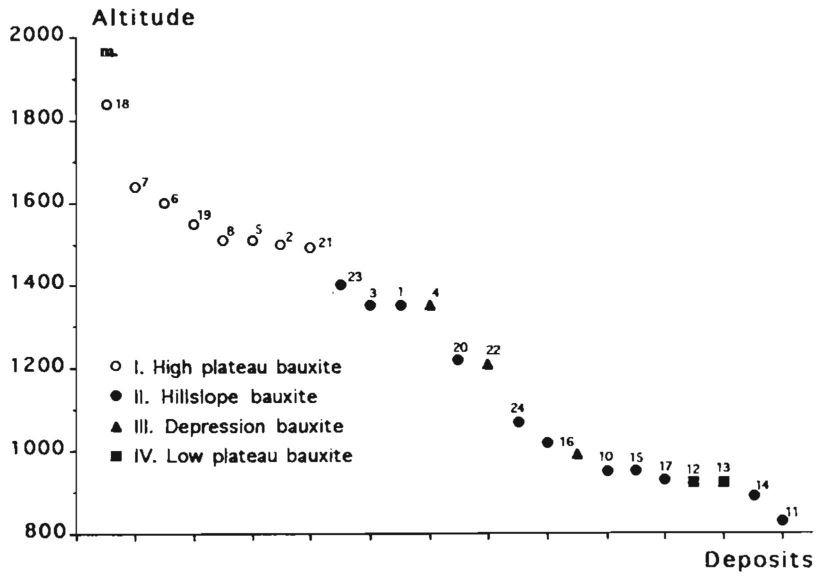


Figure V.8 - Heigh distribution of the Quadrilátero Ferrífero bauxite deposits.

constitutes a cliff, several tens of meter high, certainly related with a fault.

In this case, as well as in the Batatal plateau, it is quite possible that a tectonic event associated with an intense mechanical erosion, following the bauxitisation process, could be responsible for a topographic inversion that placed the recent plateaus in a relatively higher position. But, as considering the analysis carried out by Braun (1970), it seems to be quite difficult to accept these bauxites as correlated material developed on the Gondwana surface. Nevertheless, as for their different characteristics, these bauxites can be considered as the most ancient deposits of "Quadrilátero Ferrífero". They could be associated with a bauxitic alteration process occurring during the post-Gondwana cycle, described, by Braun (1970), as a period having a humid climate, a tectonic stillness and a paralic sedimentation with abundant fossils.

The beginning of the "Sul Americano cycle", in the upper Cretaceous, was marked, in other regions, as for example, the coastal basins, by an intense erosional activity, the formation of Barreirinhas and Paraíba do Sul grabens (see chapter Passa Quatro) and the uplifting of Serra do Mar and Mantiqueira ridges. In the "Quadrilátero Ferrífero", during this erosive period, new slopes were elaborated, cutting down the phyllites of Minas Supergroup, leaving in a high position the bauxite plateaus, as well as the itabiritic crest lines. At the same time, the sediments removed from the "Quadrilátero Ferrífero", specially by the penetration of Rio das Velhas or Rio Piracicaba, were deposited in the outermost zones to form the Fonseca Sediments, dated mid to upper Eocene by Lima & Salard-Cheboudaeff (1981).

Thus, it was after this erosive event that, between the end of the Eocene and the Pliocene, an intense bauxitisation period has occurred. Consequently, the phyllites were submitted to a bauxitisation process, forming a series of deposits, qualified as hill slope bauxite (type II), that are distributed within the altitudes of 1,640 m (Gandarela) and 830 m (Fazenda do Sapé). It was also during this period that certain sedimentary zones of Fonseca Formation have undergone a bauxitisation process (type IV deposits - Macaquinhos and Faria).

The profiles of the hill slope area, like Morro do Fraga, were normally formed by an "in situ" alteration of the inter stratified phyllites of Minas Group. These deposits are associated with itabiritic walls that forms the surrounding morphology. On the top of this itabiritic crest, a lateritisation process formed an iron crust, locally named "canga". The iron, liberated from the itabirite, occurring in the upper part of this slope, moves down as ferrihydrate and it is changed into hematite as soon as the profile is submitted to desiccation. Consequently, the hill slope bauxites are frequently very rich in iron.

On the other hand, the itabiritic crest lines, as well as the bauxitic hill slope, can dominate closed depressions, that are very common in the Moeda syncline. Some of them are completely closed, while others are totally opened by the regressive erosion due to the cutting down of Rio das Velhas. However, the depression of Vargem dos Óculos is only partially opened. In this case, the regressive erosion that cut down through the bottom deposits has preserved part of the hill slope.

In the depression of Vargem dos Óculos (Fig. V.9), it can be found iron crusts, forming the crest line and relicts products, and sometimes, even bauxites, scattered on the slope. Despite not have been studied, it seems that they were the result of a bauxitisation process. The bauxites would be of the same type of those of Morro do Fraga deposit

The study carried out on the bauxite and kaolinite deposits that occurs in Vargem dos Óculos has shown the presence of a discontinuity in the profile, between the lower kaolinite layer and the bauxitic layers, which is marked by deferruginisation and resilication of the bauxite. It was also noticed that this discontinuity was probably due to a process involving an alluvial/colluvial sedimentation.

Thus, at the same time of the bauxitisation or during the period of

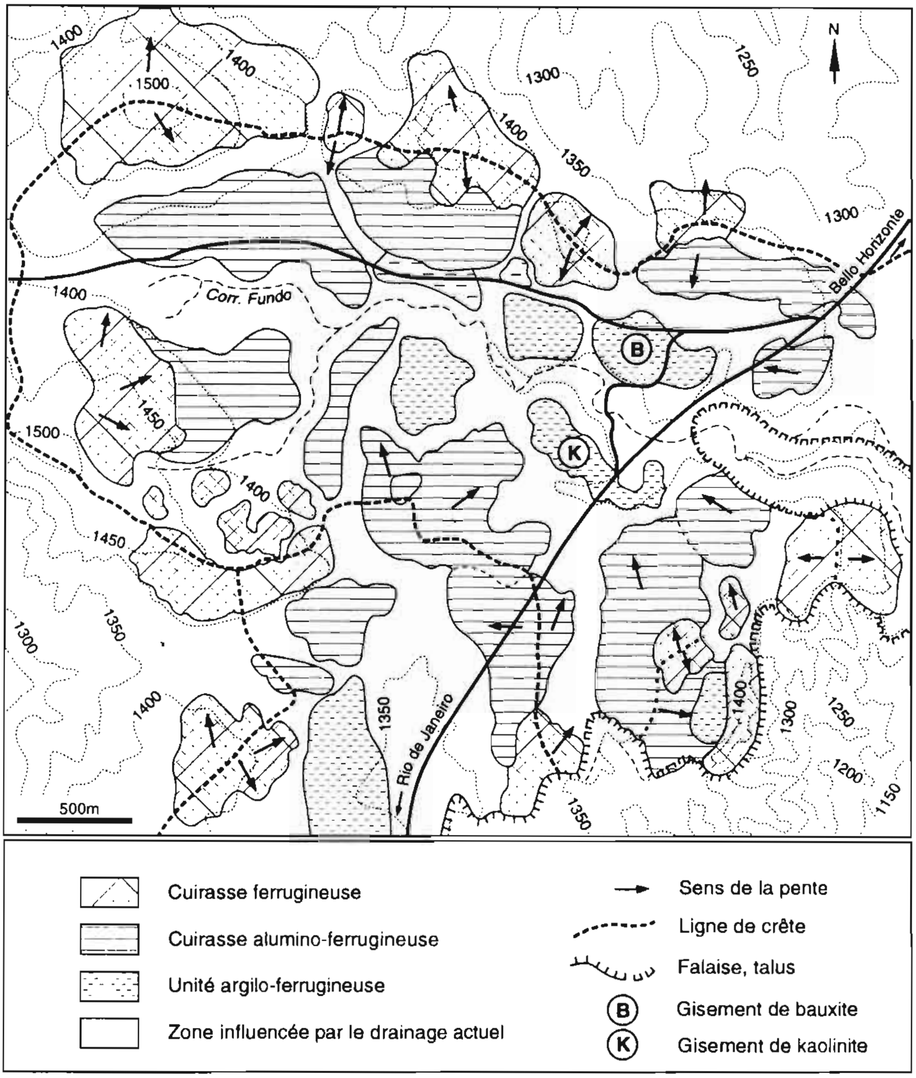


Figure V.9 - Schematic geomorphological map showing the distribution of the surficial formations in Vargem dos Óculos area.

a later mechanical erosion phase, the bauxite fragments removed from the slope were sedimented in the depression bottom, on the weathered kaolinite. The fact that very few bauxite was left on the slope would be an evidence that the mechanical erosion was quite strong. The bauxite deposit was later covered by the barren unit, constituted mainly by kaolinite and ferruginous nodules coming from the iron crust and presenting clear evidences of sedimentation.

Under this thick covering layer, the bauxites, previously deposited, were submitted to a degradation process. In the lower part, in the contact with the clay layer, the hydromorphic condition led to an important deferruginisation. Additionally, the silica supplied by the alteration of the itabirites, would favor the resilication process. The latest was much more accentuated in the kaolinite deposits, that occupy the lower part of the depression, and less developed in the bauxite deposits closer to the north slope.

In the upper part, an iron crust was developed and it still progress presently in the bauxite which is marked by clear signs of ferruginisation. The upper part of this crust, under the barren cover, is submitted to deferruginisation.

As concerning the parent material of the bauxite deposits of "Quadrilátero Ferrífero", its identification was rather difficult, particularly considering that the profiles were deeply modified by the successive aluminous and ferruginous accumulations, masking completely the evidences of the original rock. Nevertheless, the field observations and the laboratory data of the studies carried out recently (Varajão C., 1988) seem to indicate that, except for the type IV, the bauxite deposits were formed from metapelites, probably dolomitic phyllites.

However, in the case of Vargem dos Óculos deposit, the parent material seems not to be of the same kind. As a matter of fact, the origin of the deposits has been always a matter of controversy, nevertheless, a consensus about the allochtonous origin of the parent material was apparently achieved. Thus, for Pomerene (1964), these deposits were formed by an "in situ" evolution of alluvial sediments, that, according to Souza (1983), were derived from carbonated phyllites. Considering their topographic situation, the sediment was interpreted as deposited in paleo-playas (Barbosa & Rodrigues, 1965; 1967) or in karstic depressions (Barbosa, 1980; Dorr, 1969; Fleischer & Oliveira, 1969). Dorr (1969) interpreted the high Ti values as an evidence of a contribution of volcanic material in the sediments. On the other hand, Barbosa & Rodrigues (1965) suggested the climatic and hydric variations as the responsible for the formation of the different facies of the deposits. However, it has to be considered that these studies were mainly based on global analysis of the horizons observed in the deposits.

Recently, detailed studies carried out in the area (Varajão A., 1988; Varajão et al., 1989; Boulangé & Carvalho, 1991) allowed to have a better idea about the origin and the evolution of these deposits.

The complex evolution of the different products deposited in the depression bottom, finish by removing completely the limits of any sedimentation that could exist between the bauxite and the underlying clay layer. As a matter of fact, this discontinuity, shown by the petrographic and chemical analysis, is actually of sedimentary origin. Thus, it seems that the parent rock of the hill slope forming the bauxite and the one of the bottom depression originating the kaolinite are identical, and the RRE signature would be the proof of it. Additionally, this signature, close to the one for rhyodacite, would confirm the idea of Dorr (1969) that the parent rock would be of volcanic type.

There is no real evidences concerning the origin of these volcanic rocks. They could be contemporaneous to Cauê and Gandarela formations, or a result of a thrusting affecting the volcanites of Nova Lima group during the Transamazonic cycle, or even of a late paleo-Eocene eruption marking the beginning of Sul Americano cycle. The opening of the depressions and its mechanical erosion has either erased any trace of the alteration or preserved some relict islet of bauxite in the slope and/ or the bottom deposits. These events would correspond to the beginning of Velhas cycle (Pliocene).

Evaluating the period of the bauxitisation process in the "Quadrilátero Ferrífero" is not an easy task. However, taking into consideration that deposits of the same type are formed at the same age, it is reasonable to admit that the different altimetric levels were already present at the time of the bauxitisation.

Actually, the fact that the majority of the bauxite deposits of the "Quadrilátero Ferrífero" presents nearly the same sequence of facies and with the same characteristics, independently of their topographic situation, seems to indicate that they were originated under the same geological conditions. Thus, they would be formed by a bauxitisation process that occurred after the topography evolution, in different levels. Evidently, the process would happen later than the deposition of Fonseca Formation (Eocene) and, consequently, the bauxites of "Quadrilátero Ferrífero" would be formed in a post-Eocene period, probably associated with the Sul Americano cycle. The opening of the depressions and its mechanical erosion has either erased any trace of the alteration or preserved some relict islet of bauxite in the slope and/or the bottom deposits. These events would correspond to the beginning of Velhas cycle (Pliocene).

On the other hand, the association between the type I deposit and the post-Gondwana surface could be interpreted as an evidence of an older bauxitisation period, that would precede the topographic evolution that would be contemporaneous to the “Sul Americano” cycle.

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