SECRETARIA DE GEOLOGIA, MINERAÇÃO E TRANSFORMAÇÃO MINERAL
MINISTÉRIO DE MINAS E ENERGIA
PÁTRIA AMADA BRASIL GOVERNO FEDERAL

ALUMINUM IN IBEROAMERICA: MINERAL DEPOSITS AND MINING PRODUCTION

BRAZIL

GEOLOGICAL SURVEY OF BRAZIL
CPRM

ASGMI
Asociación de Servicios de Geología y Minería Iberoamericanos

Report prepared by Geological Survey of Brazil – CPRM for the Metallogenetic Expert Group of ASGMI (Asociación de Servicios de Geologia y Minería Iberoamericanos)

Brazil, 2020

SECRETARIA DE GEOLOGIA, MINERAÇÃO E TRANSFORMAÇÃO MINERAL MINISTÉRIO DE MINAS E ENERGIA PÁTRIA AMADA BRASIL GOVERNO FEDERAL

INSTITUTIONAL CREDITS

Bento Costa Lima Leite de Albuquerque Junior
Ministry of Mines and Energy
Ministro de Minas e Energia

Alexandre Vidigal de Oliveira
Secretary of Geology and Mineral Transformation
Secretário de Geologia e Transformação Mineral

Esteves Pedro Colnago
President-Director of the Geological Survey of Brazil – CPRM
Diretor Presidente do Serviço Geológico do Brasil – CPRM

Márcio José Remédio
Director of Geology and Mineral Resources
Diretor de Geologia e Recursos Minerais

Marcelo Esteves Almeida
Head of the Department of Mineral Resources
Chefe do Departamento de Recursos Minerais

Felipe Mattos Tavares
Head of the Division of Economic Geology
Chefe da Divisão de Geologia Econômica

COMPILED BY:

(First name alphabetical order)

Ana Cláudia A. Accioly, Geologist – D.Sc.	Superintendence of Strategic Planning (SUPLAN)
Francisco Valdir da Silveira, Geologist – D.Sc.	Department of Mineral Resources (DEREM)
Guilherme Ferreira da Silva, Geologist – M.Sc.	Division of Economic Geology (DIGECO)
Lila Costa Queiroz, Geologist – M.Sc.	Division of Economic Geology (DIGECO)

Summary

List of figures

1 Introduction

This report was compiled by researchers of the Geological Survey of Brazil to attend a demand of the Association of Iberoamerican Geological and Mining Surveys (ASGMI, which stands for Asociación de Servicios de Geología y Mineria Iberoamericanos), on the subject of Aluminum deposits and industry in Iberoamerican countries. Here, we summarize the history of Aluminum's exploration and mineral production in Brazil since the oldest available data refers to the early 20th Century. We also present statistical data about the raw annual ore production, discretization of share of production by the major companies, and the location of the primary resources and active mining sites across the country.

1.1 Data Sources

The main sources of this compilation are public documents produced by the National Mining Agency (ANM, for the Portuguese name "Agência Nacional de Mineração"), formerly Mineral Production National Department (DNPM, "Departamento Nacional de Produção Mineral"). For mineral occurrences location and the identification of anorthosite occurring sites, we consulted several works published by the Geological Survey of Brazil and kept them available on its online repository (RIGeo - http://rigeo.cprm.gov.br/?locale=en). For GIS data on map drawing, the sources are mainly available on the GeoSGB database (http://geosgb.cprm.gov.br/geosgb/index_en.html) compiled and curated by the Geological Survey of Brazil.

Several other documents have been published in the past few decades, many induced by actions to the Brazilian Government, represented by the Mines and Energy Ministery, and the Brazilian Aluminum Association (ABAL) efforts and other private associations.

All referred works and indicated bibliography are available in the References section at the end of this report.

1.2 Evolution of the Knowledge and Brazilian Scenario

The first formal study on bauxites in Brazil was published by Barbosa (1936), who described the deposits in Poços de Caldas (MG) based on field observations and chemical analyzes. Subsequently, Teixeira (1937); Souza-Santos (1937), Pinto (1938) studied the same deposits.

Following this scenario, a complete work was that of Harder (1949; 1952), who presented a detailed description of the ore, including studies of standard profiles and their physical characterization.

Another reference work was published years later by Weber (1959), where the detailed description of bauxites' types and addresses the main factors for formation processes.

Almeida (1977) published the work on the bauxites of Poços de Caldas classified the deposits according to their topographic position.

Other additional studies carried out on bauxite deposits are credited to Dennen and Norton (1977), Grubb (1979), Sigolo (1979); Aleva, (1981), Melfi and Carvalho (1982), among others, which allowed to identify the different types of lateritic bauxite deposits and to know their spatial distribution in the Brazilian territory. Studies have shown that basically, three major types of deposits occur in Brazil. The first of these refers to bauxites formed on clastic sedimentary rocks, which correspond to about 97% of known deposits. The remaining 3% are related to bauxites originating from other rocks, including Precambrian crystalline rocks and alkaline rocks.

The studies carried out by Melfi et al. (1988) postulate that the deposits of bauxite occur between the latitudes 3ºN to 27ºS, and in the Brazilian case-relevant occurrences of bauxite would be absent only in the northeast region and in the extreme south (RS) due to unfavorable climatic conditions. Therefore, the primary resources should be concentrated in three large regions; the North region, the central-east, and south-southeast regions.

In the northern region, bauxite deposits are directly associated with clastic sedimentary rocks in the Amazon Basin, whose geological history was relatively well-reported by Santos (1984), Bahia and Abreu (1985); Montalvão and Beserra (1985) and Caputo (1985). In this region, the deposits of Porto Trombetas, Paragominas, Almeirim, Marzagão, Nhamundá, and Juruti were studied (Boulangé and Carvalho, 1988).

In the central-eastern region, in the so-called Mantiqueira Province (Hassui and Almeida, 1984), composed of a considerable lithological variety of Precambrian rocks, it is possible to distinguish two distinct groups of rocks with which the bauxite deposits are associated. The first is formed by metasedimentary rocks that occur in the Quadrilátero Ferrífero region and are located in the central part, and another of the granulitic rocks occupy the south-southeast border of Minas Gerais.

Bauxite deposits are associated with intrusive alkaline rocks in the south and southeast regions, from Mesozoic to tertiary. Such magmatic manifestations are genetically related to the volcanic rocks of the Paraná Basin and the opening of the South Atlantic. According to Ulbrich and Gomes (1981), these rocks were classified into different associations that appear grouped in Alkaline Provinces. In the south of Brazil, three Provinces were formed, formed mainly by syenitic sequences subjected to bauxite ore genesis, the Anitápolis, Poços de Caldas, and Coastal Provinces.

It is essential to mention that before the discovery of deposits in the Amazon region, bauxite deposits in alkaline rocks formed the primary sources of Aluminum in Brazil. These deposits, associated with several alkaline Provinces, today have a total reserve of 100 million tons, and the most important deposit is that of Poços de Caldas (MG), with reserves of around 65 million tons. These are currently insignificant deposits concerning those in the Amazon. However, they were already the most important until the 1970s, which accounted for 65% of the national aluminum production. The bauxites in the Quadrilátero Ferrífero region (MG), with reserves of around 10 million tons, are made up of several small deposits, the most significant of which are Morro do Fraga, Vargem dos Glasses, Macaquinho, and Faria. The deposits that occur in the southeastern strip of MG and that form an extensive strip that goes from São João Nepomuceno to the NE of Cataguazes add up to estimated reserves that exceed 100 million tons.

2 Geological setting

The following paragraphs and figures were taken from Bizzi et al. (2003), who summarizes the geology diversity and tectonic evolution of the Brazilian territory, with some mentions to the South American Platform.

Brazil has rocs aging from all of the large chronostratigraphic units of the geological time scale, except for the Eoarquean. The geological history of Brazil is marked by several periods, followed by some rework of the crust, marked mainly in the Archean, Paleoproterozoic, and Neoproterozoic, where the last stage of the basement rock formation was developed, in the Brasiliano-Panafricano event.

The oldest rock cores, mainly Archean ones, are scattered in the basement units of the Sinbrasilian cratons (Cráton Amazonas and Cráton São Francisco superprovinces), the massifs and even the Neoproterozoic moving bands (Borborema, Tocantins and Mantiqueira provinces), in decreasing order of its importance and geographical expression. The most extensive, continuous, and notable exhibitions of Archaean units are those from the eastern part of the Amazonian block (Rio Maria and Carajás domains of the Carajás province), the central-eastern and southern part of the São Francisco Craton (Blocks Gavião, Jequié, Campo Belo– Cláudio) and the southern part of the Massif Central de Goiás (Bizzi et al., 2003).

The history of the Brazilian Neoproterozoic is, in essence, the history of a supercontinental cycle (destruction of one supercontinent and subsequent reconstruction of another), in all its fundamental features and related events that can be expected, and this is exceptionally consigned to the basis of the Southern Platform -American, as long as some complements are imported from the African Platform. This mentioned cycle deals with the diachronic fission (Tafrogenes from Tonian, Cryogenian, in its entirety, and partially from Neoproterozoic III) of a supercontinent - Rodínia; following the formation of a complex paleogeographic scenario, with continental, transitional, and marine crustal types, there was the posterior and diachronic agglutination of a group of fragments descending from this supercontinent (Rodinia) in the articulation/fusion of another supercontinent Gondwana or Gondwana Pannotia (in the most daring version), concluded only at the beginning of the Phanerozoic (Eo-Ordovician).

On the cratonic margins, the reworking of the pre-Brasiliano-Panafricano basement varies from little intense to completely restructured, notably, the installation of basins in the ante-country sediments from the pre-orogenic and post-orogenic (molassic) phases, associated with a massive Vulcan-Plutonism. Within the Brazilian mobile strips, the formation of intra-pits (molassic foredeep) and pull-apart basins (transtrational rifts) with post-orogenic deposits, thousands of meters thick, the latter following the line of shear belts or lineaments should be highlighted. This terminal stage of Brasiliano-Panafricano and at the same time the stage of formation and fixation of phanerozoic paraplatform coverings was with property designated as Transition Stage by Almeida (1969).

These polycyclic lineaments are present in all provinces and were primarily responsible for their last geological-geometric shape. Subsequently, they had significant influence as aligning zones of the syneclysis depocenters and boundaries of Paleo-Mesozoic and Cenozoic interior basins, geometrical places of different types of tectonic reactivation in the Phanerozoic.

The paraplatform initial stage was followed by a broad stage, with at least three sedimentary cycles from Ordovician to Triassic (or three chronic sedimentary sequences). In this second stage, of an orthoplatform nature, paleozoic syneclisis, characteristically entities of Gondwana substrate (there are equivalents in Africa, India, among others) par excellence, on areas affected or not by Brasiliano-Panafricano, with final elliptical and sub-circular forms with dimensions above 500,000 km2 and with depocenters reaching 7,000 m in depth (average of 4,000 to 5,000 m). This sedimentation was not limited to our synéclises - Acre, Solimões, Amazonas, Parnaíba, Paraná, Chaco – Paraná -, which are only where their main possessions and physiographic expressions are, but covered much of Gondwana, whose remains can be found from the Amazonia (Alto Tapajós and Parecis basins) to Patagonia (Claraomecó, Neuquén, Austral, Malvinas). Sometimes, these Gondwana sequences can be found in the ballast of the sequences of the interior basins and coastal basins of the continental margin, captured tectonically when the latter was formed, in the Meso-Cenozoic. In addition, an essential part of the records of this remarkable sedimentary cover, which did not achieve structural traps in synéclises and rifts, has been exhumed since the Paleozoic itself, along with tectonic, epirogenetic, and other events in the formation of Brazilian relief. This happened especially after the Triassic, but not exclusively.

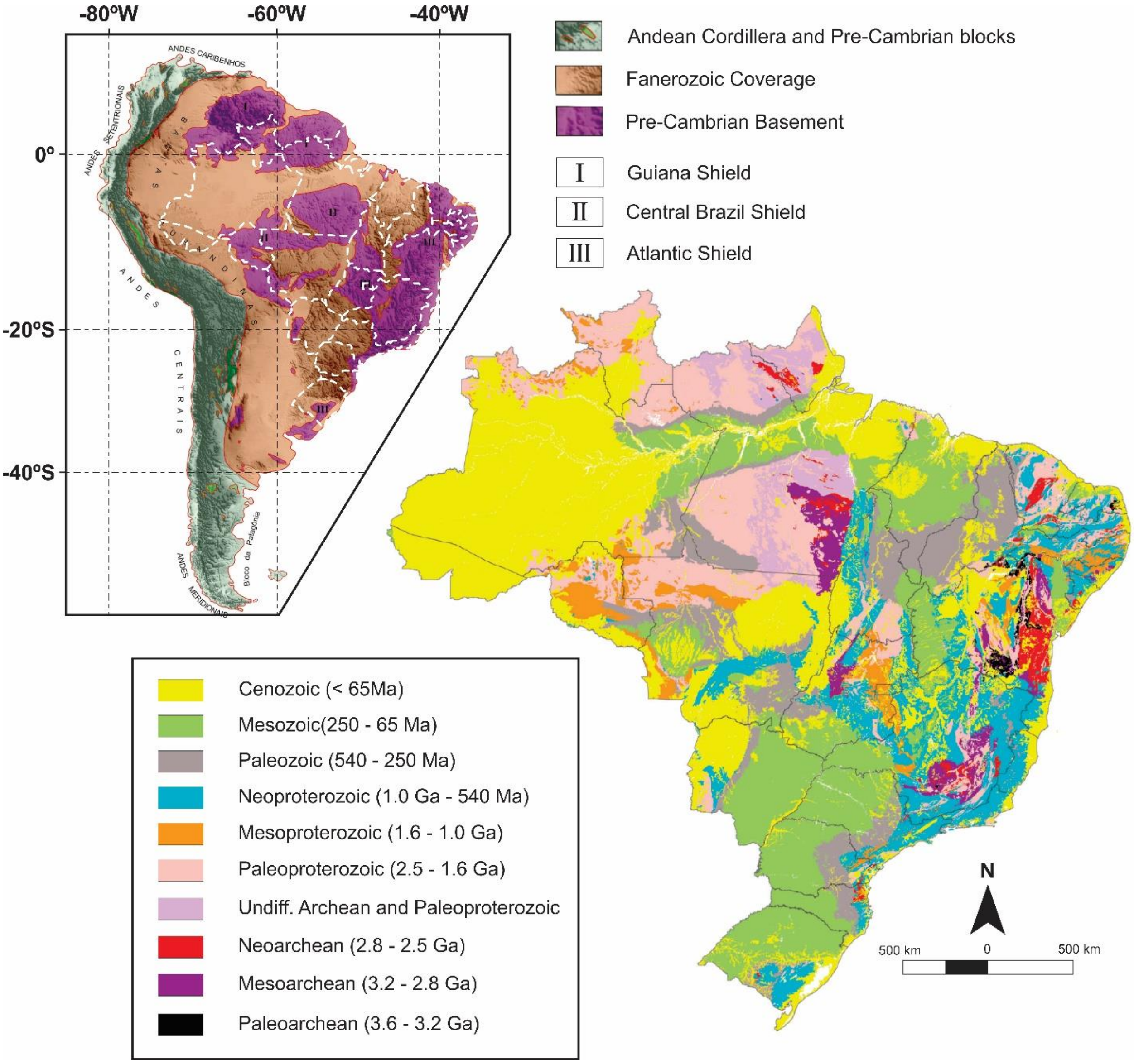

Figure 1 a) Brazilian border over the terrains of South American Platform and b) distribution of rock ages through Brazil (after Bizzi et al. 2003, Almeida et al. 1981)

Some of these large basins show rhythm precursors of the Transition Stage (initial, paraplatform), thus exhibiting a final geometry of koilogens. On the other hand, it is under the protection of syneclysis and paleozoic coverings that the different basins, rifts, and transtrational basins (e.g., pull apart) of the transition stage can preserve their most remarkable records. Outside these conditions, that is, protection by the Paleozoic sedimentary record, the covers of the transition stage were easily eroded and minimized in expression and dimensions, which is a characteristic of the Cambro-Ordoviciano of the South American platform.

3 Mineral deposits of Aluminum

The Brazilian territory is located mainly in the intertropical zone and has potential for aluminum mineralization. In Brazil, bauxite deposits were formed from different types of rocks, whose processes associated with their genesis were mainly controlled by geomorphology and climatic conditions that vary from humid equatorial to subtropical to temperate.

The first references of bauxite in Brazil date back to 1928, in the Annals of the Ouro Preto School of Mines, when there were already initiatives to implement aluminum production in the country's states Minas Gerais (Ouro Preto) and São Paulo (in the city of Mairinque). In 1983 the country went from being a major importer to one of the world's leading aluminum exporters. Since the 1990s, Brazil has surpassed the 1.0-million-ton barrier in the production of primary Aluminum. Currently, Brazil is the third-largest holder of metal reserves globally, with 3.4 billion tons (total reserves; Mártirez, 2010). Brazilian reserves are of the "gibbsite type" and have characteristics that meet world standards for either metallurgical (87%) or refractory (13%) use.

It was possible to distinguish four main types of bauxitic deposits;

1. Bauxites formed over clastic sedimentary rocks, which occur mainly in the Amazon region;
2. Bauxites formed over Precambrian metasedimentary rocks, which occur in the Quadrilátero Ferrífero Region, at the central portion of Minas Gerais;
3. Bauxites formed over granulitic and charnockitic rocks of the basement and which occur mainly in the southeastern portion of Minas Gerais;
4. Bauxites formed over alkaline rocks located in the south-southeast region of Brazil.

3.1 Conventional Resources and Reserves

Although Aluminum is the third most abundant element in the earth's crust, it does not occur naturally in its metallic form but as chemical compounds. Currently, the only economically relevant raw material to produce Aluminum is bauxite. Bauxite is composed of an impure mixture of aluminum minerals, the most important of which are gibbsite (formula $Al(OH)_3$), diaspore (formula AlO(OH)), and boehmite (formula AlO(OH)).

The principal Brazilian reserves are of the gibbsite type with aluminum oxyhydroxides in varying proportions of ore impurities, such as iron oxides, clay, silica, and titanium dioxide. For aluminum production to be economically viable, bauxite must contain at least 30% extractable aluminum oxide (Al2O3). Commercially, there are two types of aluminum ore mined in Brazil: refractory and metallurgical bauxites, the latter accounting for 95% of Brazilian production. The most relevant difference between these two types of bauxite is the Fe_2O_3 content. It is considered that refractory bauxite must have more alumina and fewer impurities.

Most occurrences in Brazil are hosted on Neogene/Quaternary rocks, although there are deposits on rocks of varying ages since the Paleozoic. The essential condition for bauxite formation is a tropical climate (an average annual temperature above 20ºC), alternating the dry and wet seasons, which favor the natural leaching process that generates the lateritic bauxites (predominant type in Brazil). Bauxite deposits are found in four different types of deposits: tabular surface layers, pockets, between different layers of soil, and debris deposits.

Table 1- Brazilian main deposits of Bauxite, after Melfi (1997), Mártires (2009) and Veiga (2008)

Province	**State**	**District**	**Rock-Source**	**Reserves (millions of tons)**
North (Amazonian)	Pará	Almerin		72.5
		Porto Trombetas (Oriximinár, Faro)	Arkose, Clay-rich sediments	1,226
		Juruti		
		Jari		639
	Pará/Maranhão	Paragominas	Clay-rich sediments	2,000
	Amapá	Morro do Felipe	Clay-rich sediments	4
Quadrilátero Ferrífero and Mantiqueira Province	Minas Gerais	Quadrilátero Ferrífero Fraga	Phyllite	> 25
		Nova Lima	Ryodacite	
		Macaquinho Cataguases	Sedimentary rocks Gneiss	
	São Paulo	Nazaré Paulista Curucutu Mogi das Cruzes	Amphibolite Dolerite Granite	12.5
	Rio de Janeiro	Resende	Alkaline rocks	
South-Eastern Brazil	Minas Gerais	Poços de Caldas	Alkaline rocks	47
	Santa Catarina	Lages	Dolerite, Phonolite	2.7
Center-Brazil	Goiás	Barro Alto	Anorthosite	100

The country's main reserves are in the states of Pará (90%), Minas Gerais (7%), São Paulo, Santa Catarina and Goiás (3%; Pinheiro et al. 2016). In Pará, three companies are responsible for the extraction and processing of aluminum: Mineração Rio do Norte, in Porto Trombetas, Mineração Paragominas, in Paragominas city and Alcoa in Juruti. In Minas Gerais, Companhia Brasileira de Alumínio (CBA) is responsible for production in the municipality of Miraí while Terra Goyana is responsible for the extraction and processing of ore in Barro Alto – Goiás (Figure 2).

The state of Pará has the ideal conditions for the formation of bauxite deposits and currently accounts for more than 90% of Brazilian ore production (Pinheiro et al., 2016). The occurrence of thick lateritic profiles on siliciclastic rocks of the Cretaceous shape the typical typology of bauxite deposits in the Amazon region. The evolution of Amazon's lateritic/bauxitic coverage was polyphasic and controlled by chemical processes and secondarily by physical rework in humid equatorial climate conditions. In addition to Pará, Maranhão and Amapá also have considerable reserves formed on sedimentary rocks, arkose-rich sediments, and minority rocks of basaltic composition.

In Minas Gerais state, under conditions of the humid tropical climate, the occurrences are developed over metasedimentary rocks in the Quadrilátero Ferrífero granulitic rocks. In Goiás state, the ore is originated from the alteration of Neoproterozoic anorthosites of the Superior Series of the Barro Alto Mafic-Ultramafic Layered Complex. In São Paulo, the primary deposits occur over amphibolites, dolerites, and granites. In the southern region and part of the country's southeast, bauxites come from alkaline rocks, basalts, diabase, and syenites in a subtropical climate regime.

3.2 Unconventional Resources: Anorthosites

Descriptions of anorthosites (or meta-anorthosites) are rare in Brazil and generally lack information (petrological, isotopic, or even geochemistry data). This may be due to Brazil's continental dimensions associated with logistic issues that difficult the advancement of the country's geological knowledge. On the other hand, even with the increase in systematic mapping, there are geotectonic peculiarities for the positioning of intrusions of anorthositic bodies and specific factors for their exposures. This topic summarizes some of the characteristics of anorthosite occurrences cataloged on the Geological Survey's database and reports available on the Institutional Repository (Figure 3).

Most anorthosites interpreted as being of the Massif type (forming or not a series with Anorthosite-Mangerite-Charnockite-Granite - AMCG) are described in Northern Brazil, in the Amazonian Craton region. Those include the Repartimento, Serra da Alegria, Serra da Providência and Siriquiqui Suites, aging from Paleo to Mesoproterozoic (Statherian to Callymian). Most ages generally are obtained by direct dating, and some of them are estimated through dating granitic rocks that are spatially associated with anorthositic bodies.

Figure 2: Infographic of a simplified map indicating the location of primary deposits of bauxite in Brazil

Some other Massif-type Anorthosites are identified in the northeast and south regions of Brazil. There are intrusive anorthositic bodies in Brazil's Northeast Region in cratonic and tectonostratigraphic terrains of the Borborema Province. Several anorthosites (Massif of the Piau River, Samaritana, Mirabela, Palestina, Fazenda Provisão, and Potiraguá) are intrusive in granulitic terrains in the Center-South portion of the São Francisco Craton. These bodies consist of alumina content in RT of around 25% with plagioclase ranging from Andesine, Labradorite to Bitownite (An50-80). Some of the massif-type anorthositic bodies outcropping in the Borborema Province (mapped on the 1: 100k scale) are Complexo Passira (Statherian age) and Boqueirão Anorthosite (inferred Paleoproterozoic age), located in the Rio Capibaribe and Alto Moxotó terrains, respectively. They are intrusive in Migmatitic Complexes and appear to be surrounded by Callymian meta granitic bodies.

In the North and Center-West regions, layered anorthositic bodies were identified in the Barro Alto Complexes, Serra dos Borges Sequence, Serra Azul, and Trincheira Complexes. Unlike the Massif type anorthosites, which predominantly point to Statherian-Callymian ages, Layered anorthosites Complexes present a wide range of ages from Archean to Neoproterozoic. Some Layered gabbro-anorthositic associations are referred to in systematic mappings. However, just a few occurrences of anorthositic bodies are detected, almost always subordinate to mafic and ultramafic intrusions. In Brazil's southern region, the Capivarita (Callymian age) is intrusive in a Gneissic terrain and is interpreted as paleo-continental fragments.

In the SGB repository, there are records of anorthosites in layered sequences with Fe-Ti-V(±Pt) mineralization and samples of anorthosites in cratonic nuclei or tectonically juxtaposed alloctonus terrains. In this context are the Rio Pardo Complex, Rio do Jacaré Suite, Canindé Complex, Malhada Vermelha Suite, and Sítio Piranhas Suite.

4 Mining Industry

The records show that the production of Aluminum in Brazil started between the 1930s and 1940s. It consisted of domestic utensils' manufacture, and the raw material was imported or came from the recycling of scrap recovered by small national processors. This activity was shown fundamental for the future of Aluminum in Brazil, as it kept the sector warm by opening up opportunities for industrial facilities, even in such an adverse environment. With the imminence of the Second World War, resulting in inevitable difficulties in the supply of strategic raw materials that followed, it motivated plans for the implantation of primary aluminum factories in the country, which at the same time met the internal needs, which grew in importance. Two initiatives, both supported by their bauxite reserves, ELQUISA in Minas Gerais, and CBA (Companhia Brasileira de Alumínio) são Paulo. CBA appeared in February 1941, and the plan was to explore bauxite in the fatty deposits of Poços de Caldas, MG. In turn, the ELQUISA Company, based in Ouro Preto-MG, could produce 10,000 tons of alumina per year and 1,500 tons of Aluminum per year. For economic reasons and the inability to compete with international competition, the factory stopped its activities in August 1946. In 1950 ALCAN, a Canadian company, bought ELQUISA's facilities, resuming regular production. In 1955, CBA- Companhia Brasileira de Alumínio, linked to the VOTORANTIM group, started operating until that time as the only producer of exclusively national capital. These two companies dominated the primary aluminum market until 1970. In the same year, the company ALCOA enters the market as a producer, which marks a significant expansion of the country's productive capacity.

Figure 3: Known occurrences of anorthosites of both types registered in the GeoSGB database. The name is indicating the geological unite name (Complex or Suite)

Subsequently, the verticalization process of companies producing primary Aluminum was accentuated. It is noteworthy that there was some specialization concerning the final products of the producing companies: CBA focused on the production of cables and Aluminum for use in the steel industry, while ALCAN turned to the production of powders, pastes, and manufactured products for domestic use.

Although the aluminum industry showed a significant growth rate during 1950-1974, production was insufficient to supply the domestic market demands. This fact led the Brazilian Government to approve the VALESUL project in December 1976, leading to a plant located in Santa Cruz, Rio de Janeiro. The project was carried out by CVRD (61%), in partnership with SHELL (35%) and REYNOLDS (4%), the latter supplying the technology and started operating in 1982.

The national industry's significant expansion took place in 1982 when the VALESUL plant comes into operation. In 1983, new plants started operating, and the companies were redirected to serve the foreign market as an alternative to the drop in domestic demand. In 1984 the ALUMAR plant (ALCOA. - Billiton), located in são Luiz (MA), started its production, manufacturing 100 thousand tons/year. ALBRAS (CVRD + Japanese consortium) started operating in 1985, producing 80 thousand tons/year. In 1989, Brazil produced 873 thousand tons, accounting for 6.5% of world production.

Vale S/A has implemented an audacious plan to produce bauxite, alumina, and primary Aluminum. In contrast, ALUNORTE, a major alumina producer, completed its expansion from 1.6 million tons to 2.4 million tons, where it invested around US$ 311 million until 2005, becoming the largest alumina plant in the world.

Currently, the total number of jobs generated directly or indirectly by all steps of the Aluminum industry in Brazil is above 400.000, for estimation made to the year of 2018, with the primary production of Aluminum been reported as 659 kt, equivalent to a positive balance of US$ 2 billion, discounted the imports (Table 2).

Table 2 – Aluminum industry profile in Brazil for the years of 2017 and 2018 according to ABAL

Break-down	2017	2018
Jobs (December 31st) ■ Directs ■ Indirects	412,915 114,972 297,943	419,247 113,807 305,440
Revenue (US$ billion) (1)	19.7	16.8
Investments (US$ billion) (1)	0.2	0.2
Paid taxes (US$ billion) (1) (2)	4.3	3.6
Primary Aluminum Production (1000 t)	802	659
Aluminum Domestic Consumption (1000 t)	1,258	1,373
Per Capita Consumption (kg/inhab/year)	6.1	6,6
Exports (1000 t – aluminum weight)	383	287
Imports (1000 t – aluminum weight)	526	690
Aluminum Industry Trade Balance (US$ million FOB) (*) (3) ■ Exports ■ Imports ■ Balance	 4,097 1,437 2,660	 4,001 1,984 2,017
Share of Aluminum Exports in the Total Brazilian Exports (%)	1.9	1.7

Note:
(1) Estimate based on data from ABAL and Ministry of Economy.
(2) Includes tax over production, consumption and property.
(3) Includes Bauxite and Alumina.

Source: ABAL (available at http://abal.org.br/en/statistical-information/industry-profile/; accessed in November 2020)

The states producing bauxite, alumina, and Aluminum with integrated plants are Minas Gerais and Pará. The São Paulo state's beneficiation plant receives ore (bauxite) from Minas Gerais and Maranhão's plant from Pará. Aluminum production in the State of Rio de Janeiro receives alumina from all provider states.

4.1 Mineral claims and exploration status

Since the early 1970 decade, two moments of demand rising were detected, followed by the increase in the number of mineral claims, with the first cycle been spotted between 1980 and 1986 and the second cycle developing between 2004 and 2015 (Figure 4).

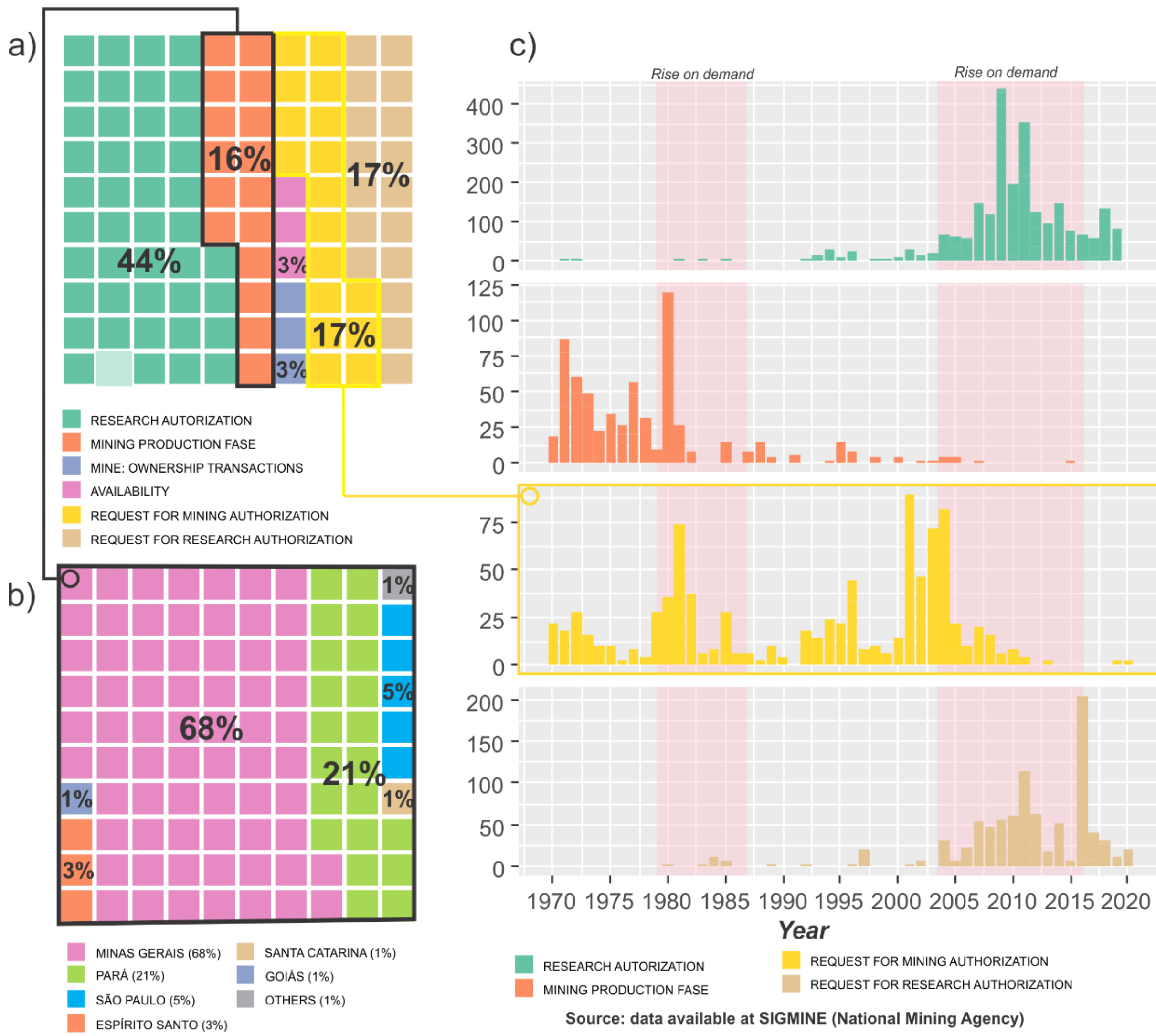

Figure 4:a) Proportion of active and inactive mineral claims registered on the National Mining Agency's database; b) distribution of the number of claims on Mining Production Phase by state; c) distribution of the number of claims according to each phase on time

There are 5,486 mineral claims registered on the database of the National Mining Agency (http://sigmine.dnpm.gov.br/webmap/) with declared substances "Aluminum," "Aluminum-rich clay," "Bauxite," "Aluminum ore," and "Phosphorous bauxite" distributed all over the country. The area covered by the claims sums up to around 17 million hectares, and the mineral processes are distributed in all legal stages, from "Request for Research Authorization" (initial phase) to Mining Production.

In the Pará state, the biggest producer, the number of Mineral claims is 1274, covering more than 8.5 million hectares. Minas Gerais, the following primary producer state, has about 2588 mineral claims, covering an area of more than 2.1 million hectares.

4.2 Production

In Brazil, primary aluminum production follows the following route: extraction of the ore, dissolved, sedimented, and filtered, obtaining alumina. Subsequently, through the Hall-Hérould process (reduction by electric current), alumina turns to primary Aluminum. Its high consumption of electrical energy characterizes the transformation of alumina into Aluminum.

In 2011, Brazilian production decreased 13%, compared to 2008, due to the closure of Valesul Alumínio S.A. (Santa Cruz, RJ) plants and Novelis do Brazil Ltda. (Aratú, BA), caused by competitiveness problems related to the cost of energy (Figure 5).

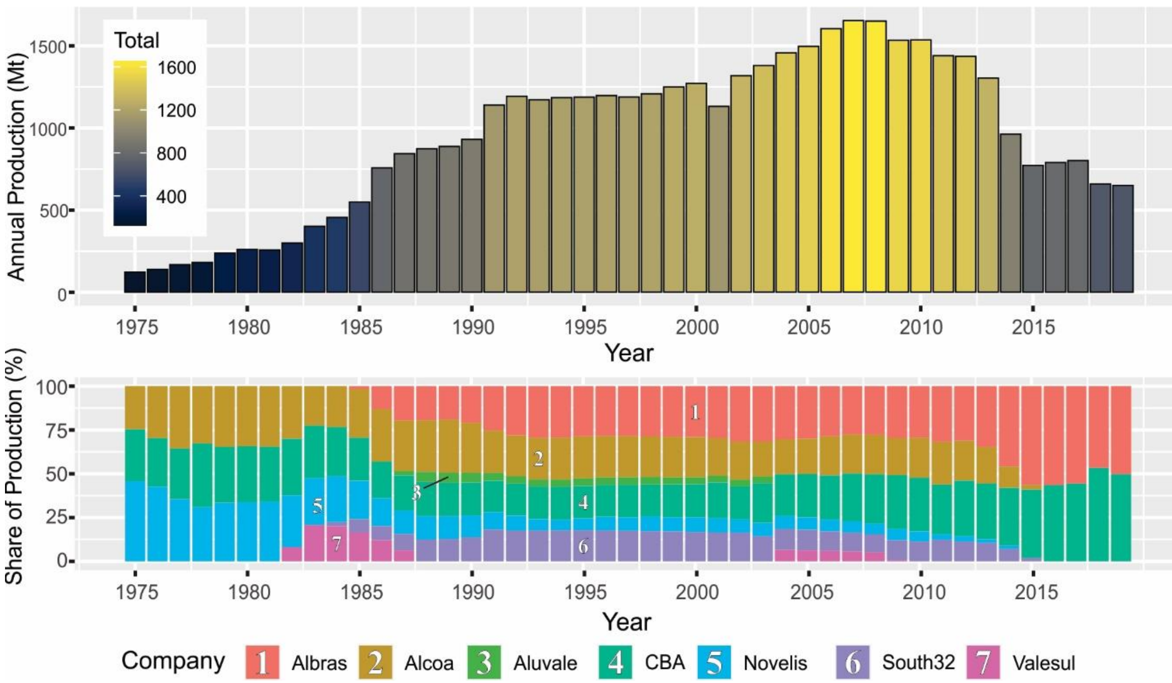

Figure 5: annual production and share of participation in bauxite production for the years from 1975 to 2019, according to ABAL (2019)

Data from 2019 (Table 3) points out that Brazil has the fourth-largest reserve of bauxite globally, produced 31.9 million tons, and consolidated itself as the fourth-largest producer of aluminum ore, accounting for 9% of world production and the third of alumina. The point of concern is in the production of primary Aluminum, which has been registering successive declines since 2011. In the last four years, Brazil dropped from 11th place in 2017 to 15th place in 2019.

Another critical point is that Brazil has become a reference in aluminum recycling. In the last ten years, reuse rates have always been over 96%. In 2018, the recycling rate for beverage cans and the proportion of recovered aluminum scrap was 96.9%, which is to say that almost all cans that came into consumption were collected and recycled. Likewise, the country is well above the world average in the relationship between consumption and recovered scrap. In 2018, this index closed at 56% - the world average was 25.9%. More than half of the Aluminum used in Brazil comes from recycling, which puts us ahead of powerful industries such as the leading countries in Europe, the United States, and Japan. The explanation for this reliable performance lies in the aluminum industry's investment in chain production efficiency (ABAL, 2019).

Table 3: Brazil's situation on the international scenario of reserves and production for the year 2019

O Brasil e o mundo em 2019 | *Brazil and the World in 2019*

Reservas de Bauxita | *Bauxite Reserves* (Em milhões de toneladas | *Million of tons*)		Produção | *Production* (Em mil toneladas | *Thousand tons*)						*Ranking*
Países | *Countries*	**Volume**	**Bauxita | *Bauxite***	**Volume**	**Alumina | *Alumina***	**Volume**	**Alumínio Primário *Primary aluminum***	**Volume**	
Guiné | *Guinea*	7 400	Austrália | *Australia*	105 172	China | *China*	72 531	China | *China*	35 044	1º
Austrália | *Australia*	6 000	Guiné | *Guinea*	70 173	Austrália | *Australia*	20 192	Rússia | *Russia*	3 896	2º
Vietnã | *Vietnam*	3 700	China | *China*	68 400	**Brasil | *Brazil***	**9 171**	Índia | *India*	3 184	3º
Brasil | *Brazil*	**2 600**	**Brasil | *Brazil***	**31 938**	Índia | *India*	6 561	Canadá | *Canada*	2 854	4º
Jamaica | *Jamaica*	2 000	Índia | *India*	26 055	Rússia | *Russia*	2 755	Emirados Árabes | *UAE*	2 579	5º
Indonésia | *Indonesia*	1 200	Indonésia | *Indonesia*	15 000	Jamaica | *Jamaica*	2 173	Austrália | *Australia*	1 570	6º
China | *China*	1 000	Jamaica | *Jamaica*	9 009	Irlanda | *Ireland*	1 893	Vietnã | *Vietnam*	1 374	7º
Índia | *India*	660	Rússia | *Russia*	5 572	Arábia Saudita *Saudi Arabia*	1 798	Bahrain | *Bahrain*	1 365	8º
Rússia | *Russia*	500	Arábia Saudita *Saudi Arabia*	4 781	Ucrânia | *Ukraine*	1 690	Noruega | *Norway*	1 279	9º
Arábia Saudita *Saudi Arabia*	200	Cazaquistão | *Kazakhstan*	3 812	Espanha | *Spain*	1 595	Estados Unidos | *USA*	1 226	10º
Malásia | *Malaysia*	110	Vietnã | *Vietnam*	3 600	Canadá | *Canada*	1 563	Arábia Saudita *Saudi Arabia*	967	11º
Estados Unidos | *USA*	20	Guiana | *Guyana*	1 992	Estados Unidos | *USA*	1 230	Malásia | *Malaysia*	760	12º
Outros | *Other*	4 610	Serra Leoa | *Sierra Leone*	1 927	Cazaquistão | *Kazakhstan*	1 144	África do Sul *South Africa*	717	13º
Total | *Total*	**30 000**	Grécia | *Greece*	1 607	Indonésia | *Indonesia*	1 110	Islândia | *Iceland*	703	14º
		Ilhas Salomão *Solomon Islands*	1 232	Vietnã | *Vietnam*	1 020	**Brasil | *Brazil***	**650**	15º
		Outros | *Other*	5 724	Outros | *Other*	3 008	Outros | *Other*	6 030	
		Total | *Total*	**355 994**	**Total | *Total***	**129 434**	**Total | *Total***	**64 198**	

Fontes | *Sources*: - Reservas de Bauxita | *Bauxite reserves*: U.S. Geological Survey, Mineral Commodity Summaries 2020
- Produção de Bauxita, Alumina e Alumínio Primário | *Production of Bauxite, Alumina and Primary Aluminum*: World Metal Statistics - May/2020

Nota | *Note*: Dados de 2019 para a produção de bauxita e alumínio primário. Demais dados referem-se a 2018.
The data for bauxite and primary aluminum production refer to 2019. Other data refer to 2018.

The convergence of these two factors - the high rate of recycling and production of primary metal from hydroelectricity - means that aluminum products manufactured in the country, with Brazilian metal, have a lower carbon footprint than imported ones. These two factors translate into a window of opportunity that Brazil has to explore, especially now that the country is experiencing a moment of intense pressure on the automotive industry to reduce fuel consumption and atmospheric emissions - and that it extends to other means of transport - and Aluminum has a great ally in reducing vehicle weight.

In Brazil, studies carried out by the Brazilian Aluminum Association predicted an increase in domestic consumption of Aluminum of around 9% per year, on average, for the next fifteen years, which may take Brazilian per capita consumption to the level of the most developed countries in Europe. However, this promising scenario for the Brazilian economy may not be accompanied by the industries installed here, since it has been undergoing an intense process of losing its competitiveness due to the production costs of the primary metal (especially electricity); costs that affect the entire chain (tax burden and Brazil cost); and the entry of imported semi-finished and finished products with higher added value, mainly from Asian countries. The risk of an imminent process of deindustrialization in the sector has already required attention from the Brazilian Government, which, on July 13, 2011, published Interministerial Ordinance No. 436, establishing the "Aluminum Working Group," with the objective of study alternatives to promote the competitiveness of the aluminum production chain in the country. With the coordination of the Ministry of Mines and Energy, the group also brought together appointed representatives of the Ministry of Finance; Ministry of Development, Industry and Foreign Trade; Energy research company; and National Bank for Economic and Social Development - BNDES.

ABAL estimates that 500 companies operate in the aluminum industry (producers, transformers, recyclers, and consumers) in Brazil. Of this total, five companies are the leading producers of primary Aluminum, and the others operate in the other stages of the production chain - mining, refining, transformation, and recycling/production of alloys.

5 Concluding Remarks

The studies carried out up to this date on several deposits have brought essential contributions about the genetic processes in the bauxite deposits, where it is possible to highlight the influence of the various factors of ore formation. The studies and field observations make it clear that bauxite formation occurs under conditions where there is a convergence of some factors, among which the climatic, lithological, and morphotectonic conditions stand out.

The demand for Aluminum, the history of consumption and prospects, the potential to generate value if the demand is met locally added to the challenges of competitiveness in some links and the risks to the chain, and the estimates of the impact on the aluminum industry and the Brazilian economy, are challenges that need to be understood to forecast future scenarios.

As Brazil has excellent potential for alumina, China, Japan, and the European Community are expected destinations of Aluminum national exports, sustaining an upcoming growth perspective for the following years. Also, the significant amount of available reserves and a competitive position on the world's production rank puts the country in an advantageous position in the international market. Yet, the unconventional and unexplored reserves offer some scope for the country to expand its production.

REFERENCES

ABAL, 2019 – STATISTICAL YEARBOOK, 2019, Associação Brasileira do Alumínio – ABAL.

ACCIOLY, A. C. A. 2001. Geología, Geoquímica e Significado Tectônico do Complexo Metanortosítico de Passira, província Borborema, Nordeste Brasileiro, Tese de Doutorado. Universidade de São Paulo – USP, São Paulo.

ALEVA, GJJ, 1981. The essential difference between the bauxite deposit along the southern and northern edges of the Guiana shields in South America. Econ. Geol., 76:1142-1152.

ALMEIDA, E. B. de, 1977. Geology of the bauxite Deposits of the Poços de Caldas Alkaline district, State of Minas Gerais, Brazil. Ph.D. Thesis, Stanford University, 265p.

BOULANGÉ, B. & CARVALHO, A., 1988. Guide Book. Excursion I and II. Int. Congr. ICSOBA, VI, Poços de Caldas, MG. 49 p.

BARBOSA, O., 1936. Notas preliminares sobre o planalto de Poços de Caldas e suas possibilidades economicas. DNPM-SFPM, av. N8, 33p.

BAHIA, R.R. & ABREU, F. A. M. de, 1985. O Rift do Amazonas – sistema aulacogenico na plataforma Amazônica. Simp.Geol. Amaz., II, Anais, Belém, P. 222-241.

BIZZI, L. A.; SCHOBBENHAUS, C., VIDOTTI, R. M., GONÇALVES, J. H., 2003. Geologia, tectônica e recursos minerais do Brasil: texto, mapas e SIG. Companhia de Pesquisa de Recursos Minerais – CPRM, Brasília – Distrito Federal, 692 p.

CAPUTO, M. V., 1985. Origem do alinhamento do Juruá. Bacia do solimões. Simp.Geol. Amaz. II, Anais, Belém, P. 242-258.

HASSUI, Y. & OLIVEIRA, M. A. F., 1984. Provincia Mantiqueira, Setro Central. In: O Pré-cambriano do Brasil. Edgar Blucher, Ed.São Paulo, 378 p.

HARDER, E. C., 1949. Stratigraphy and Origin of Bauxite deposit. Geol. Soc. Amer. Bull. 60: 887-908.

HARDER, E. C., 1952. Examples of Bauxite Deposits Illustrating variation in Origin. Symp. Probl. Of Clay and Laterite Genesis. Am. Inst. Min. Metall. Eng. N.Y.

GRUBB, P. L. C., 1979. The genesis of Bauxite Deposits in the Lower Amazon Basin and Guiana Coastal Plain. Econ. Geol., 74: 735-750.

DENNEN, W. H. & NORTON, H. A., 1977. Geology and Geochemistry of Bauxite Deposits in the Lower Amazon Basin. Econ. Geol., 72: 82-89.

MELFI, A. J., et al., 1988. The lateritic Ore deposits of Brazil. Sci. Géol. Bull., 41: 1-32.

MELFI, A. J. & CARVALHO, A., 1982. Bauxitization of Alkaline Rocks in Southern Brazil. Sci. Géol., Mém. 73: 161-172.

MONTALVÃO, R. M. G. de & BEZERRA, P. E. L., 1985. Evolução Geotectônica do Craton Amazônico (Amazônia Legal) Durante o Arqueano e Proterozóico. Simp. Geol. Amaz. II, Anais, Belém.

PINTO, M. da S. 1938. Bauxita em Poços de Caldas. DNPM., Min. Bol. 22, 71 p.

SANTOS, J. O. S., 1984. A Parte Setentrional do Craton Amazônico (Escudo das Guianas) e a Bacia Amazônica. In. geologia do Brasil, DNPM, Brasília, 501 p.

SIGOLO, J. B., 1979. Geologia dos Depositos Residuais Bauxíticos de Lavrinhas-SP e sua Viabilidade Econômica. Tese Mestrado, Inst. Geociências – USP, 190 p.

TEIXEIRA, E. A., 1937. Bauxita no Planlto de Poços de Caldas, estado de São Paulo e Minas Gerais. Min. Metal., I, 5: 205-214.

SOUZA SANTOS, P., 1937. Contribuição Para o Estudo da Bauxita de Poços de Caldas. Inst. Pesq. Tec., São Paulo, Bol. 17: 109-134.

WEBER, B. N., 1959. Bauxitização no Distrito de Poços de Caldas, Minas Gerais., Soc. Bras. Sci., vol. 8, 1, 30 p.

ULBRICH, H. H. G. J. & GOMES, C. B., 1981. Alkaline Rocks From Continental Brazil. Earth Sci. Review, 17: 135-154.