

THE CLASSIFICATION OF BAUXITES FROM THE BAYER PLANT STANDPOINT

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The mineralogy, chemical composition and physical characteristics of different bauxites, which are mined and processed today, reflect associated rock types, tectonics and other geological factors associated with the different deposits and provide a basis for their classification into distinct groups from the standpoint of the Bayer alumina plant. The aluminum ore minerals (gibbsite, boehmite and diaspore), and the amount and characteristics of the gangue minerals, of which the iron oxides and the clay minerals are the most important, are the main criteria used.

Most of these bauxite classes necessitated modification of the two basic Bayer technologies for optimum processing. The relative value of the classes of bauxite, having regard to their processing costs as affected by their mineralogy, chemical and physical characteristics, are discussed.

INTRODUCTION

From the inception of the modern aluminum industry in the early 1900s to the end of the Second World War, two distinct types of bauxites - a hard high iron boehmite rich ore and the somewhat softer gibbsite bauxite initially obtained from Arkansas, but subsequently from Guyana and Suriname, were the ores on which the aluminum industries of Europe and North America respectively were based. As a result, two distinct Bayer technologies were developed for the beneficiation of these bauxites. These are the European Bayer process involving digestion in a 225 gpl caustic soda solution as Na_2CO_3 (140 gpl Na_2O), 230-240°C, and 6 atmosphere pressure, producing the so-called flourey alumina; and the American Bayer with digestion at 140-150°C in a 150 to 175 gpl caustic soda solution as Na_2CO_3 (94-103 gpl Na_2O) and 3 atmospheres pressure, producing a sandy type alumina. After World War II, new bauxite deposits were identified and developed in the Caribbean, Guinea and Sierra Leone in West Africa, Australia and more recently in Brazil and Venezuela in South America. In addition, some diaspore rich bauxite deposits of Greece, Romania, Yugoslavia, USSR and China are now being utilized or are being considered for mining. These new ores differ from the traditional ones in grindability, mineralogy and content of gangue minerals. These differences necessitated significant modifications to existing Bayer technologies for their optimum processing. It is desirable to clearly identify the differences between these bauxites which are currently being exploited, and their Bayer process implications as the bases for any rational system for evaluating different bauxites.

APPROACH

The approach used is firstly to examine the geology, chemical and mineralogical composition, and physical characteristics of the different bauxites currently being exploited, and secondly to assess the effects of these differences on Bayer alumina technology including the capital and operating costs per unit of alumina produced as the basis for assessing the significance of the differences identified.

BAUXITE DEPOSITS

The major bauxite deposits occur in well defined provinces. Firstly, there are the Karstic bauxites which occur in the Solomon Islands, Caribbean, Mediterranean, Central Urals - Kazakhstan and China bauxite provinces. Secondly, there are the lateritic bauxites which occur in the Guinea Shield, Cameroons, South American (the Guiana and Brazilian Shields), India, Australia and Arkansas provinces.

There are significant differences in geology, particularly relating to associated rock types, tectonism and geochemical history within these provinces. These factors largely determine the chemical composition and mineralogy of the deposits. For example, the deposits fringing the Guiana Shield include the low iron gibbsite deposits in the sediments of the Coastal Series, e.g. Onverdacht and Moengo in Suriname, and the Linden and Kwakwani deposits in Guyana, and the high iron *in situ* deposits of Trombetas, Brazil. This region also includes the high iron deposits in the Bakhuis Mountain of Suriname, the Las Pijiguas deposits of Venezuela, and the Pakaraima Mountain deposits of Guyana. Similarly, differences in the mineralogy and chemical composition of bauxite deposits due to post-bauxitization processes have been noted by Hill and Davis (1) and Hill (2) for the Jamaican deposits, and by Bardossy and co-workers (3) for other bauxites.

The usual minerals occurring in bauxite deposits are:

Ore Minerals

- Gibbsite, $Al(OH)_3$ or $Al_2O_3 \cdot 3H_2O$
- Nordstrandite, $Al(OH)_3$ or $Al_2O_3 \cdot 3H_2O$
- Boehmite, $AlO.OH$, $Al_2O_3 \cdot H_2O$
- Diaspore, AlO_2H , $Al_2O_3 \cdot H_2O$

Gangue Minerals

- | | |
|--|----------------------|
| - Corundum, $\alpha - Al_2O_3$ | - Manganese minerals |
| - Aluminian goethite, $(Fe, Al)_2O_2H$ | Lithiophorite |
| - Kaolinite, $Al_2Si_2O_5(OH)_4$ | Rancate |
| - Quartz, SiO_2 | Todorokite |
| - Hematite, $\alpha - Fe_2O_3$ | Manganite |
| - Rutile, TiO_2 | Woodruffite |
| - Anatase, TiO_2 | Hausmannite |
| - Hydromicas | |
| - Smectites | |

The essential and varietal minerals in some deposits are given by Bardossy et al (3), and elsewhere in the literature.

The chemical composition of different bauxites shows distinct associations reflecting the composition of the parent rock and the geochemical behaviour of the residulates aluminum, iron and silica during bauxitization. Low and high iron varieties of laterite bauxite occur, reflecting the provenance of the ore and its subsequent geological history. For example, basic rocks usually weather to iron-rich laterites, while granitic rocks weather to iron-poor gibbsite on bauxitization. The composition of sedimentary and metamorphic rocks similarly affect their bauxitization products. On the other hand karstic bauxites almost invariably have iron content of 18 to 30 per cent, which is similar to that of the high iron lateritic bauxite. Low iron karstic bauxites are rare and usually result from the loss of iron from the high iron type in a reducing environment. (2, 4, 5, 6, 7 and 8). Figure 1 illustrates the chemical composition of some bauxites and their general relationship to different source rocks.

As already stated, two main classes of bauxites are recognized: lateritic and karstic. The geological distinction between these is that Karstic bauxites are associated with limestones while lateritic bauxites are associated with other rock types. Bardossy and co-workers (3) have shown that the grain size distribution and crystallinity of most karstic bauxites increases with increasing age while porosity decreases. The lateritic bauxites have larger crystal sizes than the karstic types. Usually the gibbsitic lateritic bauxites are the coarsest with crystal sizes up to 100 μm and large single crystals in the order of mm sizes occur in cavities. In the case of those lateritic deposits containing boehmite as the varietal mineral, the grain size ranges from 1 to 10 μm , but large crystals occur in cavities. Gibbsite and diaspore form the largest crystals.

CLASSIFICATION

The distinction between karstic and lateritic bauxites has been traditionally recognized as a first order difference, and is associated with differences in particle size distribution, porosity and structure of the ore. It is, therefore, used here as the first grouping criteria. Similarly the distribution in iron content with some lateritic bauxites having a relatively low iron content while the iron content of the remainder are grouped at higher values (Figure 1). On the other hand, almost all karstic bauxites

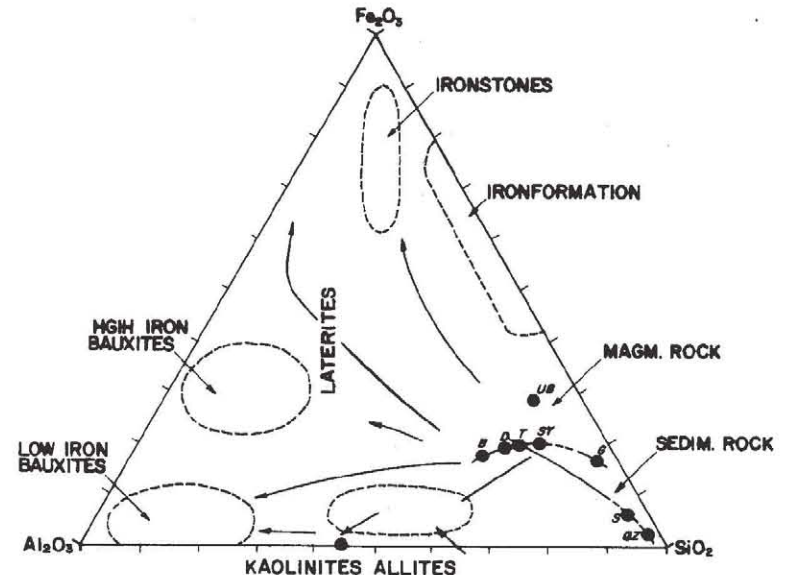


Figure 1: The differentiation by weathering: ironstones and Precambrian ironformation, laterites, bauxites, and kaolinitic sediments. (UB ultrabasites, B basites, D diorites, SY svenites, G granites, QZ Quartzites, S Sandstones, T clays). (Modified from 9, p. 37).

have iron content roughly equivalent to that of the high iron lateritic bauxites. This difference in iron content largely determines the requirements for the impurities separation circuits of Bayer plants (10). The species and concentrations of aluminum ore minerals gibbsite, boehmite and diaspore are the principal factors which determine the required digestion temperature, caustic concentration and alumina/caustic ratio, and so is used as the third factor in the classification. In addition, the presence of aluminian goethite in some bauxites is significant, because where this mineral is fine grained, it affects the mud separation characteristics of the bauxite. In addition, this mineral contains alumina values which are not extractable in most current Bayer technology. The clay mineral content is not considered because it can usually be blended and where this is not possible, the use of combinations of the Bayer and lime-sinter process are necessary. Table 1 outlines the classification scheme.

BAUXITE TYPE AND BAYER TECHNOLOGY

Bauxite type is a major determinant of Bayer processing costs in that it determines the most suitable technology and the equipment sizes for the optimization of the unit operations involved in the process. The three primary objectives in this are minimising capital and operating costs by the maximising of alumina production per unit volume of the liquor circulated and maximising the recovery of alumina from the bauxite (11). Most of these occur on the red side of the Bayer plant.

It is significant that the Suriname Coastal Type, to which Arkansas bauxite belongs, is the ore for which the American Bayer technology was developed

Table 1: Classification of Bauxite Types by Major Mines

Bauxite Type	Ore Minerals	Country	Mines
<u>Lateritic</u>			
(i) Iron Oxide (10%)			
(a) Suriname Coastal	Gibbsite + (<3% boehmite)	Guinea Brazil Guyana S. Leone Suriname	Sangaredi (upper) Pocos de Caldas Linden, Ituni, Kwakwani Makanji, Port Loko Moengo, Paramam, Onverdacht Arkansas
(b) Sangaredi (lower) type	Gibbsite + boehmite (5-20%)	Australia Guinea India	Weipa Sangaredi (lower) Gujarat States (Kutch Peninsular)
(ii) Iron Oxides (10%)			
(a) Darling Range type	Gibbsite + (<3% boehmite)	Australia Brazil Costa Rica Ghana Guinea Guyana India Indonesia Suriname Venezuela	Jarrahdale, Del Park, Mitchell Plateau, Worsley Saramenha, Paragominas, Trombetas, Pocos de Caldas El General Awaso, Kibi Fria-Kimbo, Debola Pakeraimo Mt. Orissa, Andhra Pradesh, Belgoum Bintan Island Bakhuis Mt. Los Piliquaes
(b) Gove type	Gibbsite + boehmite (5-20%)	Australia	Gove
<u>Karsitic</u>			
Iron Oxide (10%)			
(i) Jamaica-1	Gibbsite + (<3% boehmite)	Dom. Rep. Jamaica	Pedernales (LTD) Williamsfield Schwallenburgh Dry Harbour Mt. Lydford
(ii) Jamaica-2	Gibbsite + boehmite (5-20%)	Dom. Rep. Haiti Jamaica	Pedernales (HTD) Rochelois Plateau Essex Valley Mocho Mt. Lydford
(iii) Jamaica-3	Gibbsite+boehmite (5-20%)+aluminian goethite (10-100%)	Jamaica	Magotty
(iv) Mediterranean-1	Gibbsite+boehmite (~50%)	Yugos- lavia	Obrovac

Table 1 (continued)

Bauxite Type	Ore Minerals	Country	Mines
(v) Mediterranean-2	Boehmite (~50%) + gibbsite	France Hungary	Provence, Languedoc Halimba, Padragkut, Nyirad, Nagytarkany, Eszkaszentgyorgy Gant
		Yugoslavia	Vlasenica, Niksic, Jajce, Mostar, Obrovac
(vi) Mediterranean-3	Boehmite + diaspore	Greece Romania China USSR Yugoslavia	Parnassus Padurea Craulin Kwinin Arkaluk Kosovo

and the Mediterranean types 1 and 2 were the basis of the European Bayer technology. The other bauxite types necessitated modifications to these two initial technologies. For example, the processing of Jamaica-1 type necessitated the introduction of sedimentation and decantation followed by counter current decantation washing in the mud separation circuit. The processing of the Darling Ranges type of bauxite with higher levels of gangue minerals requires increased crushing and grinding facilities and control of particle size of the product from this operation so that much of the gangue minerals can be separated as a sand size fraction on leaving the digester. The Sangaredi and Jamaica-2 types of bauxite with 5-20 per cent boehmite required significant modification to the digester circuit so that the alumina values from both gibbsite and boehmite could be efficiently extracted. The results have been various systems which are grouped together as modified American Bayer technology.

Besides the relationship between bauxite type and Bayer processing costs, there are factors such as the location of the plant relative to the mine and the smelter, and hence transportation of bauxite, alumina or both. In addition local economic factors such as the source and cost of energy, and other inputs such as caustic soda, labour and investment. Finally, the age of the plant and maintenance requirements are all important. Table II gives a breakdown of the major inputs.

Table II: Major Inputs into Bayer Alumina Processing Costs

Inputs	Per tonne of alumina requirement
Bauxite dependent	
bauxite	1.8 - 4.7 t/t
caustic soda	25 - 170 Kg/t
capital charges	800 - 1200 \$/tonne yr.
Other charges	
energy - process	10 - 20 Gj/t
- calcination	3.5 - 5 Gj/t
labour	1 - 5 man-hrs/t
maintenance	1 - 4% of replacement cost/yr.
overhead and supplies	8 - 25 \$/t
transportation	0.40 - 30.00 \$/t

The above table shows that the major bauxite dependent inputs into Bayer alumina processing costs are capital charges, bauxite charges, and soda costs. In addition, from the bauxite standpoint, it is desirable that the costs for the separation and disposal of the red mud be treated as a separate input. The estimation of these for the different bauxite types is outlined below:

- (1) Capital charges: The estimation of differences in capital charges or various Bayer technologies is difficult because this input parameter reflects local conditions, the type of alumina produced, as well as differences in bauxite type. However, a preliminary estimate of the ratios of the capital costs of plants of similar sizes is given in Table III.

Table III: Preliminary Estimates of Ratios of Capital Costs Requirements of Bayer Plants for Processing Each Bauxite Type

Bauxite Type	Capital Costs Ratio
Suriname	1.00
Sangaredi	1.10
Darling Ranges	1.15
Gove	1.15
Jamaica-1	1.10
Jamaica-2	1.15
Mediterranean	1.40

The above excludes special environmental protection requirements and makes no allowances for the age of plants, modifications and separation and disposal requirements, etc.

- (ii) Bauxite/Alumina Ratio: This relates to the fact that bauxite is desired for its alumina content, but is purchased on a tonnage basis, which included the weight of the gangue minerals as well. The price paid for bauxite should be based on the alumina content rather than on the weight of bauxite. The bauxite/alumina ratio can be calculated from the equation

$$B/A \text{ ratio} = \frac{100}{0.95 \times TAA}$$

where the TAA is the "Total Available Alumina" and includes alumina from both gibbsite and boehmite in most bauxites (12). Where diasporite is present in significant amounts, it must also be reflected in the test. An efficiency factor of 0.95 is used.

- (iii) Mud Alumina Ratio: This relates to the penalty of processing and handling the essentially insoluble impurities. For example, a bauxite containing no impurities, but only gibbsite, would require 1.53 tonnes of bauxite per tonne of alumina and could be processed in a very simple plant of Bayer design. The presence of insoluble impurities requires redesign of the plant to incorporate a means of settling this insoluble material from the solution before it enters the precipitation section of the plant or else it would contaminate the product.

This mud separation section requires equipment to separate the insoluble red mud from the solution. The mud must be washed to recover soda and alumina and the returned wash water has to be removed from the closed Bayer solution in the evaporation section. The red mud must also be disposed of in a special disposal area where it will not inflict significant environmental damage.

Bayer capital and operating costs increase proportionately to the increased mud loading or insoluble impurities and include: increased costs for bauxite handling, crushing and grinding, digestion, mud separation, mud washing and mud disposal, along with increased costs in heat losses, solution losses and the costs to operate these facilities.

Using the assumption as presented in Table IV below, a cost per tonne of insoluble impurity can be worked out.

Table IV: Assumptions for Costing the Impact of Essentially Insoluble Impurities (10)

Operations	Dollars per tonne of mud	
	Range	Average
Incremental cost of bauxite handling, grinding and desilication	1 - 3	2
Red mud settling, washing, liquor filtration and mud disposal	7-9	8
Evaporation of the net wash input of 3 t/t mud, using an evaporator economy of 3.5, equivalent fuel heat per ton of steam of 3.2 GJ/ton, and \$4 per GJ of fuel. All other costs connected with evaporation are included.	9 - 13	11
Physical soda and alumina losses with the mud liquor	2 - 4	3
Heat loss with mud flow to disposal	1 - 3	2
TOTAL	20 - 32	26

The cost of removing these impurities per tonne of alumina then depends on the input per tonne or mud factor. The capital cost for all the mud separation, evaporation and steam supply facilities may take up over 25% of the entire Bayer plant for intermediate input levels of insolubles. The operating cost of insoluble impurities is given by the following equation:

$$\text{Cost, \$/tonne alumina} = 26 * \text{tonne mud per tonne alumina}$$

The mud factor can be calculated by the equation:

$$\text{M/A ratio} = \frac{(100 - 0.95 \times \%TAA - \%L01 + 0.67\%SiO_2)}{0.95 \times \%TAA}$$

Soda Loss

The soda loss can be calculated from the following equation:

$$\text{Kg soda/tonne alumina } K_1 = \% \text{ React. } SiO_2 \times \text{B/A ratio} + K_2$$

where:

$$K_1 = 0.50 \text{ for low temperature digestion (gibbsitic bauxites) and } 0.67 \text{ for high temperature digestion (boehmite and diasporic bauxites)}$$

$$K_2 = 15 \text{ Kg/tonne for lateritic bauxites, } 20 \text{ Kg/tonne for Mediterranean bauxites and } 75 \text{ Kg/tonne for Jamaican bauxites.}$$

The price of soda used in bauxite plants can be as low as the \$102 per tonne into one U.S. plant under contract to as high as \$220 per tonne for a European location with duty and inland transportation added. U.S. quoted producer prices were in the range of \$150-200 per short ton as of May 1980. Taking the mid-point and discounting 15% to allow for contract prices, the average price for caustic soda in 1980 is estimated to be approximately \$150 per tonne.

No attempt will be made at this stage to determine the relative costs, but instead the pertinent ratios are set out in Table V.

DISCUSSION

The different types of bauxites identified reflect differences due to host rocks, associated rocks, tectonism and leaching. Bauxitization processes play a significant role. In the Suriname Coastal type bauxite, for example, the mobilization and transport of most of the major elements except aluminum occurs. This may occur where there are severe fluctuations of the water table, as in the upper part of the Sangaredi deposit in Guinea, Pocos de Caldas in Brazil and Port Loco, Sierra Leone, or where the dominant factor is the organic matter content of the water. This is noticeably so in the Linden, Ituni and Kwakwani deposits of Guyana and the Moengo, Paranam and Onverdacht deposits of Suriname. In all cases, however, there is significant development of crystal sizes. Where there is significant crystal growth, there is also recrystallization to boehmite. In these cases different generations of gibbsite and boehmite crystals occur. Under these conditions transformation of hematite to goethite and aluminian goethite occurs.

The finer sizes of the crystals in the karstic bauxites to the lateritic bauxites are noticeable. The crystal sizes also increase with age. Scanning electron micrographs of these bauxites demonstrates that there is definite crystal maturation with gibbsite transforming to boehmite and diasporite possibly growing epitaxially on goethite formed from limetite.

Suriname Coastal type bauxite with its low iron content, large gibbsite crystal sizes and low boehmite content is the first type. This type is widely distributed and is the ore for which the American Bayer technology was developed. This type differs from the Darling Ranges type by its iron content. This latter type is simply diluted by the iron content and so more bauxite must be processed per tonne of alumina produced. However, because of the greater ease of solubility of gibbsite as compared to boehmite, it dissolves readily and there is no need for extremely fine grinding. Consequently, the Darling Ranges type of bauxite, which is usually digested at 140 to 150°C results in the formation of large sand fraction in the residue from the digesters. The Fria-Kimbo deposit in Guinea is the exception because its efficient extraction requires that it be digested at 105°C to minimize loss of alumina due to fine grained quartz reacting during digestion to form a desilication product. The consequence of this is that the mud separation is more difficult than if the ore were digested at 140 to 150°C.

The types of karstic bauxites are more complex than the lateritic bauxites even though they are all of the high iron variety. This is because they have been subjected to greater tectonism than the lateritic bauxites. Mediterranean-2 bauxite is the bauxite for which the European Bayer Technology was developed, Mediterranean-3 bauxite has only recently become a significant ore. The USSR, Romania, China and recently the Pechiney alumina plant in Greece, have been processing diasporic bauxites. The different types of Mediterranean bauxites reflect the intensity of diagenesis and so is associated with increased lithification of the ore. In this we recognize that diasporite may nucleate and grow epitaxially on goethite and aluminian goethite crystals as pointed out by Wefers and Bell (13), but these are usually at much lower concentration than we are considering here.

Table V: Bauxite/Alumina and Mud/Alumina Ratios of Selected Bauxites

	Bauxite Type	% Reactant		LOI	Sand		M/A Ratio
		Avail. Alumina	React. Silica		Fraction Correction	B/A Ratio	
AUSTRALIA							
-Weipa	Sangaredi	42.3	5.0	28.5	1.00	2.49	0.86
-Gove	Gove	44.4	3.6	27.4	1.00	2.37	0.78
-Darling Ranges	Darling Ranges	35.7	1.0	24.3	0.75	2.95	1.25
DOMINICAN REPUBLIC							
-Pedernales	Jamaica-2	41.9	4.5	23.6	0.90	2.51	1.00
GHANA							
-Awaso	Darling Ranges	49.3	1.3	27.7	0.75	2.14	0.56
GUINEA							
-Boké	Sangaredi	53.3	0.9	30.4	1.00	1.97	0.39
-Kindia	Darling Ranges	45.2	2.1	25.3	1.00	2.33	0.77
GUYANA							
-Linden/Ituni	Suriname	53.9	3.0	30.7	0.90	1.95	0.39
-Kwakwani	Suriname	52.2	4.5	29.7	0.90	2.02	0.48
HAITI							
-Rochelois Plateau	Jamaica-2	43.0	1.9	23.1	1.00	2.45	0.91
INDONESIA							
-Bintan Islands	Darling Ranges	47.3	4.4	28.8	1.00	2.23	0.64
JAMAICA							
-North Coast	Jamaica-1+2	41.7	0.9	26.8	0.90	2.52	0.86
SIERRA LEONE							
-Mokanji	Suriname	51.5	4.5	31.3	0.90	2.04	0.47
SURINAME							
-Moengo	Suriname	54.7	3.9	31.1	0.90	1.92	0.38
-Onverdacht	Suriname	48.2	4.0	28.5	0.90	2.18	0.62
-Paranam	Suriname	46.1	8.0	27.0	0.90	2.28	0.79
YUGOSLAVIA							
-Vlasenica	Mediterranean	45.5	6.5	12.0	1.00	2.31	1.14

Bauxite/Alumina (B/A) and Mud/Alumina (M/A) ratio calculated equations given in text from literature sources.

Similarly, the three types of Jamaican bauxites reflect progressive diagenesis as reported by Hill (2). The Jamaica-1 type corresponds to the plateau or *in situ* type of Hill and Davis (1) and occurs on the St. Ann and Manchester Plateau of Jamaica. It is the ore which is processed in Alcan's Kirkvine and Ewarton Works in Jamaica and currently exported by Kaiser from its mines in the Dry Harbour Mountains, and much of the ore which is exported by Reynolds Jamaica Mines. The Jamaica-2 type is the ore which is currently being mined by Alcoa from its mines in the Mocho Mountains and the Essex Valley ore for the Alpart Plant. The Jamaica-3 type is not presently being mined, but was the ore which Revere mined from 1971 to 1975 for its Maggoty Alumina Plant. The latter two types reflect different degrees of diagenesis associated with down faulting and the associated effects of the water table.

The classification is pragmatic and is designed to better relate bauxite to alumina plants. Consequently, possible types such as the lateritic equivalent of the Mediterranean bauxites as exemplified by the lateritic bauxites at Bielgorod, USSR (14), and the diasporic bauxites of Swaziland (15, p.305) of the Suriname Coastal and Sangaredi types are not considered as these have not been exploited for metallurgical purposes.

REFERENCES

1. V. G. Hill and C. E. Davis, "Progress Report on Compositional Correlation and Structural Relationships in Jamaica Bauxite Deposits", Jour. Geol. Soc. Ja. Proc. Bauxite/Alumina Symposium, Kingston, Jamaica (1971).
2. V. G. Hill, "Syngenetic and Diagenetic Changes in Jamaica Bauxite Deposits", Travaux ICSOBA 15, (1979), pp. 69-80.
3. Gyorgy Bardossy, A. Csanady and A. Csordas, "Scanning Electro Microscope Study of Bauxites of Different Ages and Origins", Clays and Clay Minerals, 26 (4) (1978) pp. 245-262.
4. S. Caillere, "Les Bauxites Blanches", Travaux ICSOBA, 2 (1966) pp.35-42
5. G. de Weisse, "La Bauxite blanche dans les Gisements français", Travaux ICSOBA 2 (1966) pp.43-39.
6. D. Dragovic, "Genetic Relation of the White and Relation of the White and Red Bauxite in the Region of 'Bijele Poljane' (Montenegro)", Travaux ICSOBA 1 (1966) pp.125-138.
7. S. M. Lukovic, "On the Mineralogy, Petrology and Genesis of Kaolin Bauxites with Special Reference to the White Bauxite of Montenegro (Crna Gora)", Travaux ICSOBA 2 (1966) pp.7-16
8. L. Maric, "Sur la Structure de la Bauxite Blanche de Trubjela", Travaux ICSOBA 2, (1966) pp.17-24.
9. E. Schroll, "Trace Elements in Kaolinities and Bauxites in Relation to their Genesis", Travaux ICSOBA 15, (1979) pp. 35-41
10. E. Bruce Teas and Jon J Koffe, "The Effect of Impurities on Processing Efficiencies and Methods for Impurity Control and Removal", Geol.Soc. Ja., Bauxite/Alumina Symposium, Kingston, Jamaica, June 1980.
11. W. H. Cundiff, "Influence of Bauxite Composition on Alumina Plant Technology", Travaux ICSOBA 12 (.974) pp.67-73.
12. Terry Overby and Charles E. Scott, "An Improved Method for Determining Boehmite and Gibbsite in Bauxites and Red Mud by X-Ray Analysis", Light Metals (1978) pp. 179-193.
13. Karl Wefers and Gordon M. Bell, "Oxides and Hydroxides of Aluminium", Tech. Paper No. 19, Alcoa Research Laboratories (1972) p.52
14. Gyorgy Bardossy, "Growing Significance of Bauxites", Episodes, 2 (1979) pp. 22-25
15. Nicolas De Kun, The Mineral Resources of Africa, p.740, Elsevier Pub. A. New York, N.Y. 1965.