CHAPTER 3
BAUXITE CHARACTERISTICS

3.1 <u>Mineralogical Characteristics</u> : Bauxite is a rock comprising chiefly of hydrated aluminium oxides like gibbsite, boehmite and diaspore, besides impurities in form of silica, clay, silt and iron hydroxide. Mineralogically, bauxite may be classified on basis of its predominant alumina minerals into five types e.g. (i) Pure gibbsitic bauxite (ii) Gibbsitic bauxite containing quartz (iii) Mixed gibbsitic-boehmitic bauxite (iv) Boehmitic bauxite and (v) Diasporic bauxite.

Silica in bauxite is mainly found in the form of kaolinite and quartz. The other mineral impurities present in bauxite are hematite, goethite, anatase, rutile etc. The gangue minerals present in some bauxites are chamosite, pyrite, siderite, ilmenite, sphene, calcite and dolomite.

Principal chemical, physical and optical characteristics of main minerals of bauxite are given in table 3.1 and discussed as below :-

(A) <u>Principal aluminous hydroxides</u>

(i) <u>Gibbsite (γ Al $(OH)_3$) or Al_2O_3, $3H_2O$)</u> :

This is by far the main alumina mineral of bauxites. The gibbsite content of bauxite horizon ranges from 10 to 90%, generally being in the range of 40-70%(1). It occurs as pseudomorphs of [illegible] in the bauxites of relict texture. In nodular and concretionary bauxite, the gibbsite is concentrated in the nodules and concretions, relative to matrix. In pisoids and ooids, the gibbsite concentration is more in matrix. The size of gibbsite crystals range from 10-100 microns. It occurs 1-2 mm in size in East Coast Bauxite (ECB) (India).

alumosilicate minerals

A rare alumina Mineral Bayerite (-Al (OH)$_3$) has been reported from Galikonda deposit of ECB, India.

(ii) Boehmite (γ- AlO (OH) or Al_2O_3, H_2O)

After Gibbsite, boehmite is the most abundant alumina mineral found in bauxites. Though boehmite content in bauxite increases 10-35% locally, its average is less than 1%(1). The size of the boehmite crystals is generally less than 10 microns. In most deposits, beohmite is enriched in pisoids relative to gibbsite.

(iii) Diaspore (αAlO(OH) or Al_2O_3, H_2O)

Almost in all surface deposits, diaspore is distributed from 0.1 - 0.5%(1). The highest average content (40-70%) have been reported from two burried bauxite deposits namely Taurus Mountains (Turkey) and Nowa Ruda (Poland). About 43% diaspore is recorded in a small deposit near village Saran in Kutch district (Gujarat). The diaspore crystals range from 10to50 microns in diameter. The matrix barring the pisoids, contain less diaspore and more kaolinite.

(iv) Besides above principle ore forming alumious hydroxide minerals, certain bauxites also contain minor constituent minerals such as corundum, cliachite (amorphous form of gibbsite having more hydroxyl molecules), sporogellite, gibbsitogellite, alumogel, allophance etc. (all amorphous hydrated aluminous substances)(12):

(B) Mineral Impurities :

(a) Iron Minerals:

(i) Goethite (α FeO (OH) or Fe_2O_3, H_2O) : This is the main iron mineral found in lateritic bauxites. Upto 05-15% goethite is recorded in Indian Bauxites but ranges upto 30-40% in Cape Bouganville, Western Australia . Goethite crystals are finely distributed in the matrix of bauxite having aphanitic texture. It has a typical yellow-brown colour. It occurs in the form of pisoids, nodules and concretions.

(ii) Hematite (αFe_2O_3) : Hematite is an iron mineral frequently found in lateritic bauxite. It has been detected in almost all deposits. Hematite is the major iron mineral in some burried Mesozoic and Paleozoic bauxite deposits e.g. the Taurus Mountains (Turkey) Decazville (France), and Belgorod (USSR). This imparts a typical red colour to bauxite.

(iii) Pyrite (FeS_2) : It is a sulphide mineral frequently found in Karst bauxites. The usual forms are hexahedral and octahedral. Occurrence of such grains is more common in oxide and pisoids than the matrix of bauxite.

(iv) Besides the above iron minerals, magnetite (Fe_3O_4), ilmenite ($FeO\ TiO_2$), maghemite ($4\ Fe_2O$), and Siderite ($FeCO_3$) are also found in bauxite deposits. Aluminogoethite is also reported from some deposits. These iron minerals commonly occur as nodules, concretions and fine disseminations intergrown with aluminous minerals[12].

(b) Titanium Minerals :

The common titanium minerals associated with bauxite are rutile (TiO_2), ilmenite ($FeO.TiO_2$) and titaniferous magnetite which occur as primary minerals. Secondary minerals anatase (TiO_2) and leucoxene (TiO_2) also occur as weathering products in some bauxites. Other titaniferous minerals found in bauxites are titaniferous haematite and sphene (CaO, TiO_2, SiO_2)[12].

(i) Anatase (TiO_2) : Anatase has been detected in almost all lateritic bauxite deposits in amounts ranging from 1 to 10%. Generally its percentage averages from 2-4%. An exceptionally high anatase content upto 15%, characterizes some of the basalt-derived bauxites of M.P. (India)[7].

(ii) Rutile (TiO_2) : Rutile is also a widespread mineral of bauxite, but its average quantity is generally less than 1%. Upto 6 % rutile has been found in some banded lateritic bauxite beds of the Overdacht deposits, Suriname. It is found disseminated throughout bauxite horizons. Rutile has been found in many karst bauxites also, viz. Devonian bauxites of the Northern Urals, (USSR) and the Austrian bauxites where it is found in acicular form.

(iii) Ilmenite ($FeOTiO_3$) : Ilmenite is less frequent in bauxite compared to anatase and rutile. It is found as a relict mineral in lateritic bauxites and as clastic grains in Karst bauxites. It's average distribution is less than 1 % in lateritic bauxites i.e., Hawaiian Islands, Oregon, Washington, Arkansas (USA), Bakhu-is Mountains (Suriname), Kindia (Guinea),etc. However max. 5% ilmenite has been reported from bauxite deposits of Taurus Mountains (Turkey) and Southern Vietnam. Eight to 33% ilmenite has been reported from Jamaican Karst bauxite where it is partly leucoxenised.

(C) Clay Minerals

The major clay minerals found in bauxite include kaolinite, halloysite $(OH)_8 Si_4 Al_4 O_{10}$) and endellite ($(OH)_8 Si_4 Al_4O_{10} 4 H_2O$). They occur as pockets, veins, concretions and are intergrown with Al & Fe minerals.

Kaolinite ($Al_2 Si_2 O_5 .(OH)_4$: It is by far the most frequent silicate mineral of lateritic bauxite. The high grade, low silica - bauxites contain less than 10 % kaolinite[7]. The kaolinite content is generally lowest in the middle parts of bauxite horizons but increases downward and becomes predominant in the saprolite horizon (lithomarge). The concentration of kaolinite is more in bauxite matrix.

3.1.1 Textural Characteristics :

(A) Textures of Authigenic Origin (Insitu Bauxite)[2] :

(i) Pelitomorphic or Aphanitic Texture : In this texture the grain size of the material constituting matrix is small and so is not visible to nacked eyes. The average particle size of the matrix is less than 1 micron (size of clay particle). No individual mineral particles can be distinguished on polished surface or even under electron microscope. Pelitomorophic matrix is typical of the post-triassic bauxite and is abundant in both, karst and lateritic bauxite, although much more so in Karst bauxites.

(ii) Microgranular Texture : In this texture the matrix has grains with average particle size of 1 to 5 microns. The individual mineral grains can be distinguished, although rather vaguely, under the microprobe and in thin sections.

(iii) Panidiomorphic-granular Texture : It consists predominantly of idiomorphic (perfectly shaped) mineral grains in the matrix. The average particle size ranges from 5 to 100 microns. This texture is usually found in strongly recrystallised old bauxites and in weakly metamorphosed bauxites. Individual mineral grains can be readily distinguished in thin sections. The grains show polygonal, mosaic or dovetail contacts.

(iv) Pseudoporphyritic Texture : It comprises microgranular texture embedding large authigenic (insitu) mineral grains in significant abundance.

(v) Ooidic (Oolitic) Texture : It is consisting predominently of ooids i.e. particles made up of darker and lighter concentric shells visible under the microscope or electron microprobe. The shells surround a central nucleus. The diameter of the ooids vary from 100 to 1000 microns (0.1 to 1 mm). Shells are sharp and distinct and the nuclei often comprise large authigenic (insitu) mineral grains (eg. of hematite). The shells show increasing sphericity outwards. Ooidic texture is most common in concentric-textured bauxites. The ooides/oolites develop due to diagenesis taking place under an overburden cover permanently saturated with ground water. The ooidic texture is more common in karst bauxites than in lateritic bauxites.

(vi) Pisoidic (Pisolitic) Texture : It consists of pisoids/pisolites 1 to 5 mm (pea sized) in diameter, texturally similar to ooids. As a rule, either the nuclei of the pisoid are larger or the shells are thicker. Pisoids tend to be dark coloured due to higher iron content compared to embedding matrix. They are often harder, in which case they do not break on hammering but are scattered as balls on weathering. Flattened lens or ellipsoid shapes are more common among pisoids rather than among ooids. Pisoidic bauxite are more abundant in karst bauxite than in lateritic bauxites. Pisoids from Dudh ipahar,India show nuclei made of gibbsite and shells consisting of boehmitic bauxite(3).

(vii) Macropisoidic texture : This texture consists predominantly of large bean sized pisoids with diameter greater than 5 mm. They are rare in karst bauxites, but rather frequent in lateritic bauxites. Their usual size ranges from 5 to 15 mm, larger ones being very rare. The thickness of the shells and size of nucleus increases here. The outermost shells tends to be thicker and richer in iron. They are darker-coloured than the embedding matrix and are often criss-crossed by hair cracks. They are seen in few bauxite deposits of Katni area (MP - India).

(viii) Pseudobrecciated texture : The texture is common in karst bauxite. Here the matrix is traversed by a dense network of veins due to gel ageing. The lumpy matrix separated by the veins, give it deceptive brecciated appearence.

(ix) Nodular texture : It is made up predominantly of larger (2 cm) nodules of circular outline or of concretions of irregular form. Most of the nodules are rich in iron (goethite). Their outer mass is harder and inner mass is porous or spongy. They often contain gibbsite crystals or kaolinite lining forming geodes(7).

(B) Textures of Allothigenic - Clastic Origin (Reworked or Transported Bauxite)

(i) Microclastic texture : It is made up predominantly of microfragments of clastic (sedimentary) origin having less than 60 microns size. Good examples are furnished from karst bauxites of Southern Urals (USSR) and Hungary.

(ii) Orbicular (Roundgrain) texture : This texture comprise predominently of round grains and is prevalent in karstic bauxites of Hungary and USSR.

(iii) Conglomeratic Texture : This texture comprises predominently of bauxite pebbles larger than 2 mm size. It is seen in bauxite deposits of Nezsa open pit (Hungary) and Samgaredi (Guinea). It is commonly seen in deposits of Jamnagar (Gujarat, India).

(iv) Brecciated Texture : It predominantly comprises angular bauxite fragments ranging in size from 2 to 100mm. The fragments are embedded in an aphanitic cement, e.g. Halimba and Malomvolgy X lens, (Hungary).

(v) Agglomeratic Texture : It is made up predominantly of bauxite boulders larger than 10 cm size e.g. Mas de Flechons deposit, Alpilles, (France) and Jamnagar (Gujarat-India).

(C) Textures of Metamorphic Bauxites (Emeries) :

(i) Granoblastic Texture : It is made up of macrocrystalline grains of roughly equal size. The average grain size is greater than 1 mm e.g. Turkistan Range (USSR).

(ii) Porphyroblastic Texture : It consist of fine grained matrix embedding porphyroblast (fully developed crystals) of larger size.

(iii) Lepidoblastic Texture : It comprises predominantly of flacky or platy macrocrystals.

3.1.2 Structural Characteristics

(i) Homogeneous Massive Structure : Unstratified bauxites are homogeneous in composition and textures. In thin section, individual mineral grains are seen with no preferred orientation at all. Such a structure may be formed during slow crystallisation of a gel like pulp, under very quiet conditions. This type include huge karst-bauxite deposits of Central America, deposits of Pacific and parts of the deposits of Yugoslavia and Greece.

(ii) Heterogeneous Structure : In this the blocks of bauxite of given texture and constitution are embedded in an altogether different type of bauxite mass. The blocks as a rule are composed of hard and high-grade bauxite while the embedding bauxite is soft and more clayey. One of the most remarkable examples of this structure of karst bauxite is cited from Bedarieux (Southern France).

(iii) Stratified Bauxite : The stratification in bauxite develops due to major textural elements that are arranged parallel to the plane of deposition. This type is common in the karst bauxite of China and Vietnam.

In a bauxite zone , often graded arrangement of clastic particles with a gradual upward decrease of particle size may produce graded bedding.

3.1.3 Role of Mineralogy in Alumina Production

In extractive metallurgy of aluminium, the mineralogy of bauxite plays a very significant role eventhough the specifications for different industries are mainly based on chemical characteristics of bauxite. In alumina industry the dominance or otherwise of the aluminous oxide minerals, gibbsite, boehmite and diaspore present in the bauxite ore, would determine the modifications, if any, required in the leaching process. For example, a high boehmite content in bauxite would render the digestion process more difficult as compared to one with high content of trihydrate or gibbsite form. Thus the mineralogy of bauxite plays an important part in the recovery of alumina. Other minerals of iron, titanium and silica only increase the handling of the waste , which in turn reduces the productivity of the plant and increases the production cost. Similarly reactive silica in form of clay minerals also plays a significant part in alumina processing because each percent of reactive silica present increase the loss of both alumina & soda. In non-metallurgical uses of bauxite, however the mineralogy plays a subordinate role.

3.2 PHYSICAL CHARACTERISTICS [9]

Bauxite occurs in a variety of shapes, types and physical forms. The physical characteristics of bauxite which are useful in their identification, nomenclature and classification, are briefly described below :-

(A) The Fracture of Bauxite

G. Bardossy (1990) has classified the fractures normally found in bauxite into following six types :-

1. Uneven Fracture : The fracture surface is irregular.
2. Smooth Fracture : The fracture surface is entirely smooth or exhibits minor irregularities only.
3. Rhombohedral Fracture : The bauxite on being struck, falls apart into rhombohedral pipes of larger or smaller size with plane and smooth fracture surface.
4. Conchoidal Fracture : The fractured surface is grooved with concentric depressed outline similar to inner surface of bivalve shell.
5. Foliated Fracture : The bauxite, on being struck falls apart into thin sheets (foils).
6. Earthy Fracture : The fracture surface is granulate or earthy, resembling the fracture of soil.

The fractures most commonly found in bauxites include uneven followed by earthy type.

(B) The Touch of Bauxite

Bauxite may be (1) Very rough on touch (2) rough (3) slightly rough (4) smooth (5) greasy slick (6) earthy.

Touch is a function of bauxite texture in which the mineral composition of the rock plays important role.

(C) The Hardness and Compactness of Bauxite

(i) Hardness

The time honoured Mohs' Scale is applied to assess the hardness of bauxite. The various types of karst bauxites have been assigned the following hardnesses :-

Sl. No:	Hardness	Bauxite hardness
1	8	high hardness
2	4-8	very hard
3	3-4	hard
4	2-3	medium hard
5	1-2	low hardness
6	0.5-1	friable soft
	0.1-0.5	unconsolidated

All rocks of bauxitic composition having hardness greater than 8 are emeries. Their extreme hardness is the result of metamorphism. In general, the hardness of bauxite increases with age. Bauxites rich in diaspore are invariably harder than the boehmitic ones, as the mineral diaspore (H 6.5 to 7) imparts it greater hardness. Lateritic bauxites are soft as a rule when in ground and harden considerably after winning.

(ii) Compactness : The compactness of bauxite is determined by its porosity. The compactness of karst bauxite is a function of its age, as determined by Bardossy and Komorb which is given below :-

Sl. No:	Age of bauxite	Compactness
1.	Oligocene	10-34 %
2.	Paleocene	8-12 %
3.	Turonian	8-10 %
4.	Malm	2-5 %
5.	Middle Triassic	1.5-3 %

The nature and type of space - fillings is even more important than the percentage of porosity. Bardossy has distinguished the following types of bauxite based on their pore spaces.

1. Microporous Bauxite : Pore size is less than 0.05 mm.
2. Porous Bauxite : Pore size ranges from 0.05 - 0.5 mm. The pores can be identified under hand lens.
3. Vacuolar Bauxite : The vacuoles are 0.5 - 5 mm in diameter with roughly round or oval cross sections.
4. Tabulo-Vacuolar Bauxite : The bauxite containing straight or curved tubular cavities of 1 to 2 mm diameter and 1-2 cm length.
5. Vescicular Bauxite : The cavities are larger than 5 mm and are more or less equidimentional in outline.
6. Tubulo-Vescicular Bauxite : It contains tabular cavities of more than 5 mm diameter and several centimetres length which may be straight or curved in outline.
7. Spongy (Alveolar) Bauxite : In this type the vacuoles and pores are very closely spaced, giving the bauxite a spongy appearance. These are smallest interstices distinguished (16 mm).

(D) The colour of Bauxite : Bauxite may vary in colour from pale yellow, ochre, yellowish brown, brown-pink, brick-red, chocolate-brown, violet, green, pale grey and even black. The aluminium and titanium bearing mineral constituents of bauxite are grey white or colourless and so are kaolinite and halloysite. The colour of the bauxite is therefore determined by its iron, manganese oxides and hydroxides, its clay minerals and organic matter. Hemacite imparts a red, pink or violet colour to bauxite while goethite gives it a yellow or yellowish brown colour. Meghemite imparts bauxite a yellow brown colour while ferrichamosite gives a dark brown colour. Finely dispersed pyrite and marcasite give it a grey colour. Siderite gives a light grey tinge. Green colour is due to chlorites, grey and black due to organic matter and manganese oxides and hydroxides. Greater the content of darker minerals in the bauxite darker is the resulting shade.

The most common colour of laterites is brownish red. The lateritic bauxites range in colour from yellow to brown, reddish brown and less frequently red. The upper parts of bauxite horizons is often mottled in the deposits of Maharashtra and M.P. and consists of patches of white, pink, violet and brown colour.

3.3 CHEMICAL CHARACTERISTICS

The five major chemical constituents i.e. Al_2O_3, Fe_2O_3 SiO_2, TiO_2 and loss-on-ignition (LOI) on dry basis, including CO_2 and SO_2 in some bauxites, constitute more than 99 % of bauxite composition. The rest is contributed by FeO, CaO, MnO, MgO, K_2O, Na_2O and P_2O_5, which in total rarely exceed 1%. The silica (SiO_2) is found mainly in form of kaolinite and quartz, respectively known as 'reactive' and 'free' silica. A comparative account of the chemical composition of few selected bauxite deposits of the world is given under table 3.3.

TABLE 3.3 : Comparative Chemical Characteristics of Few Bauxite Deposits of the World[7]

Sl. No:	Deposit	Country	Chemical Constituents (Average Percentage)				
			Total Al_2O_3	Reactive SiO_2	Fe_2O_3	TiO_2	LOI
1.	East Coast belt	India	47	3	21	2	28
2.	Weipa-Aurukan	Australia	49	5	12	2	25
3.	Darling-Range (Alcoa)	Australia	37	2	17	15	22
4.	Gore	Australia	51	3	16	3	26
5.	Sangaredi	Guinea	60	1	5	4	29
6.	Kindia	Guinea	48-50	2	22	2	25
7.	Fria	Guinea	42-44	1	23	2	28
8.	Trombetas	Brazil	50	5	10	1.5	28
9.	Paragominas	Brazil	52	5	12	1.5	29

(i) Alumina :

The alumina content in the bauxite deposits in the world vary from 20 to 70 %[7]. The highest Al_2O_3 (67-73%) has been encountered in gibbsite-rich concretions, containing boehmite or diaspore whereas lowest alumina values are found in concretions and intercalations of ferritic or kaolinitic bauxites. Based on this consideration the bauxite of the world can be generally divided in following two groups :-

Sl.No	Groups	World Bauxite abundance	Range of Al_2O_3
1.	High Alumina bauxite	80%	40-52 %
2.	Low Alumina bauxite	16%	< 40%

The variability in Al_2O_3 content in the bauxite may be related to its texture and structure. In bauxite with aphanitic & relict textures the chemical variations occur gradually while it changes in pisoidal, concretionary, blocky and bouldary bauxites. In Kutch deposits (Gujarat), large sized, massive bauxite blocks containing upto 58.62% Al_2O_3 are surrounded by an earthy, friable, kaolinite-rich matrix with only 40-46 % alumina. A similar chemical hetrogeneity has been observed in several basalt-derived deposits of M.P. (India) and in southern Vietnam.

In a bauxite profile, the alumina generally increases gradually downwards from the top of the bauxite horizon, reaches its maximum in the middle part and decreases again towards the base. In some areas, the vertical distribution of alumina is remarkably constant e.g. Aurukun-Merapah areas in the Weipa district (Australia). Irregularities in the vertical distribution of alumina are either due to difference in composition and permeability of the parent rock (e.g. Eastern Ghats (India) or to local redeposition of bauxite (e.g. Sangaredi and Mitchell Plateaux). In some areas, a complicated polyphase development of bauxite with mobilization of Al within the profile is the reason for the unusual variable vertical chemical profile.

(ii) **Silica** : As described earlier, the silica (SiO_2) in bauxite is mainly found as kaolinite and quartz which are respectively termed 'reactive' and 'free' silica together called 'total silica'.

Bauxitic material containing reactive silica upto 10% are generally referred to as bauxite. Those having more than 10% are called siliceous bauxite and those containing more than 23% SiO_2 are called bauxitic kaoline (bauxitic clay). Bauxites with free-silica (quartz) upto 5% are known as 'quartz bearing' bauxite.

Bauxites containing on an average 1-3% total silica are most common. In strongly desilicated deposits like those of Guinea, Cameroon, Eastern Ghats (India), Mt.Saddleback, Cape Bogainville, Los Guaicas etc., the strong desilication of the bauxite can be inversely correlated to its alumina, iron and titanium contents. A large number of lateritic bauxites contain 4-8% total SiO_2. Both quartz-free and quartz containing bauxites belong to this group. This less perfect desilication can be explained by a higher silica content of the parent rock and less perfect drainage. There are relatively few bauxite deposits where the average SiO_2 content (non reactive) is more than 8%. These are mainly Paleozoic bauxite deposits. The texture and structure-dependent variability of the silica content is highest in nodular, concretionary and blocky bauxites. The vertical and lateral distribution of the non-reactive silica being a component of residual origin, depends mostly on mineralogical differences of the parent rock composition.

There is generally a pronounced increase of the reactive silica at the bottom of the bauxite horizon. Infiltrating the bauxite horizon, it reacts with the alumina minerals to produce secondary kaolinite.

(iii) Iron

The iron content in bauxite samples ranges from 0.5 to 65 %, the common range being 1 to 40%. The lowest average iron content is reported from the deposits of white bauxite in the Guyana coastal belt (1-4%). The low iron content in the parent rocks is reflected in low iron content in bauxite deposits. A particularly low iron content has been found in the white bauxite of the Escape River district, Australia (1%) and in the granite-derived bauxite east of Dalat, in Southern Vietnam (2%) (7).

The majority of the laterite bauxite deposits contain 10- 5% Fe_2O_3, such as most Guinean, Indian and Australian bauxites. A smaller number of deposits derived from basic rocks, contain 25 - 35% iron.

The variability of iron vis-a-vis other major chemical components is highest in bauxite. This is best illustrated by highly ferruginous duricrusts with 50-65% Fe_2O_3 occuring over white bauxite containing less than 3% iron e.g. Guiana coastal belt, and granite-drived bauxite in southern Vietnam.

In the bauxite zone ,the iron decreases downwards from top, in several deposits and tends to increase again at the bottom of the bauxite horizon; e.g. Weipa deposits and Andhra Pradesh (India). In other deposits, the decrease of iron contiues through the transition zone and into the saprolite zone (lithomarge). In the Eastern Ghats, the iron tends to be concentrated on the highest altitude of the uneven plateau surfaces.

(iv) Titanium

In bauxite, the titania (TiO_2) ranges from 0.1 to 25%, the most common range being 1-4%. The highest TiO_2 content have been reported from the basalt-derived bauxite deposits of M.P., India (8-10%). The lowest averages are characteristic of the granite-derived bauxites of Southern Vietnam (0.5%) and Los Pijiguaos (1-2%). In most deposits, the average TiO_2 content is 2-3%. The average increases to 4-5% in basalt and dolerite-derived deposits. Both low and high TiO_2 averages are directly related to the TiO_2 content of the parent rock[7].

(v) Loss on Ignition/Combined water

Lateritic bauxites are characterised by high value of combined water mainly because of high trihydrate (gibbsite) content of most surface deposits. The loss on ignition in bauxites can be close to that of gibbsite, that is, it can frequently reach 31-34%. The average loss on ignition of the bauxite horizon is highest (28-31%) in the high alumina, tri-hydrate type, low iron deposits. The lowest average loss-on-ignition (15-19%) is found in the monohydrate type-boehmitic and diasporic deposits[7].

3.4 Technological characteristics

(i) Al_2O_3/SiO_2 Ratio[11]

The ratio of Al_2O_3/SiO_2 can be used as a parameter for aluminium production. However, this can be used for individual bauxite deposit with defined mineralogy, texture and other technological characteristics. For example, the economically acceptable alumina/silica ratio for Korba plant of BALCO is more than 14 for Amarkantak and Phutkapahar type ores. However this ratio may be different for different bauxite deposits.

(ii) Mineralogical Forms of Al_2O_3

Pure gibbsitic ore is considered best for alumina production as it contains easily digestable tri-hydrate minerals with mono-hydrate minerals constituting less than 5 %. Major bauxite deposits of the world such as East Coast Deposits (India), Darling Range (Australia), Sangaredi, Fria and Kindia deposits (Guinea) fall under this category. Indian deposits other than East Coast, Australian and Jamaican deposits mainly belong to boehmite type (monohydrate) ore. Boehmitic bauxite doesn't have minor quantity of gibbsite. The bauxite deposits of Jammu & Kashmir(India) falls under the diasporic type (monohydrate) with more than 70% alumina locked-up in diaspore. This is not considered suitable for Bayers process as per the present techno-economics of alumina production.

(iii) SiO_2 content

The silica in bauxite plays a very significant role in alumina production and is responsible for the loss of caustic soda and alumina in Bayer's process. It is found mainly in the form of kaolinite(reactive silica) and quartz, (free silica), the later one is technologically less deliterious than the reactive silica locked-up in kaolinite. In the Bayer's process reactive silica dissolves and reacts with alumina and caustic soda to form sodium aluminium silicate (desilication product) thus resulting in loss of both alumina and caustic soda. At high pressure digestion, even part of free quartz also becomes reactive and causes similar losses. It is thus observed that for one percent increase in SiO_2 in bauxite, about 19 Kg. NaOH per tonne of Al_2O_3 is consumed along with the loss of about 1.1 units of alumina in the form of desilication product[11].

(iv) Presence of other mineral impurities :

Haematite (Fe_2O_3), geothite, rutile, anatase, organic matter, carbonate, sulphur compounds, phosphorus, zinc and vanadium minerals are deliterious constitutents of bauxite for the Bayer's process. It not only promotes formation of phases which increase the NaOH and Al_2O_3 losses and decrease the separat ability of red mud but also tends to dissolve and accumulate in the digestion liquor.

The technological characteristics of bauxite in some of important alumina plants in India and the world are furnished in table 3.4.

3.5 Characteristics of Indian and World bauxite

3.5.1 Indian Bauxites[10]

(i) Eastern Ghats (A.P. & Orissa) : The bauxite of this belt is low in silica (1.5 - 3.5%), low titania (1-3%) high iron (8-28 % Fe_2O_3) and contains less than 1 % P_2O_5, V_2O_5, MnO, MgO, CaO, Na_2O_3 and K_2O put together. The main aluminous mineral in this deposit is gibbsite (more than 95%) while the boehmite is insignificant (<2%).

The silica occurs mainly in form of kaolinite with only 20–30 % SiO_2 occurring as free quartz. Anatase is the major titanium mineral followed by rutile and ilmenite. Geothite and hematite occur in variable proportions[10].

(ii) Western Ghats

The Dhangarwadi and Udgiri deposits of Maharashtra mainly represent this group. The average Al_2O_3 content is 51%, whereas SiO_2, Fe_2O_3, TiO_2 and LOI constitute 3.5 %, 13%, 4.8% and 27% respectively. The major aluminous mineral is gibbsite followed by boehmite and traces of diapore. About 20–25% alumina occurs in form of boehmite. More than 90% silica is locked up in kaolinite.

(iii) Inland High Level Plateaux :

A large number of scattered bauxite deposits of Central India are classified under this group. In physico-chemical characters and minerology, the bauxite is similar to Western Ghat deposits. The only exception is higher content of titanium and noticeable quantity of diaspore in some deposits falling under this group.

(iv) Inland Low Level Hillocks :

Few of the bauxite deposits falling under this group viz. Katni deposits are characterised by fairly low and silica content and thus can be used for refractory purpose.

(v) Coastal Plains :

The bauxite deposits of Kutch and Saurashtra in Gujarat uniquely occur nearer to MSL. These are known for their superior quality, and are most suitable for refractory and chemical industries. Two types of bauxite formations, for example hard massive bouldery type and transported type are noticed in this group which are characterised by very high alumina ($>$55% Al_2O_3), low to medium silica (1.5 – 5%) and low iron ($<$10% Fe_2O_3). The dominant aluminous mineral is gibbsite followed by boehmite and traces of diaspore. The silica is mostly found in kaolinite and quartz is present only in small quantity.

The main characteristics of Indian bauxites are furnished in Table 3.5.1 and 3.5.2.

3.5.2 World Bauxite

(i) Australia : Except for Darling Range deposit, mineralogically, other bauxite deposits of Australia, either boehmitic or mixed gibbsite-boehmitic types, are characterised by high reactive silica.

(ii) Jamaica : Bauxite occurs here in the form of pockets or blankets on karst surface of the underlying limestone. The profile of the bauxite is so uneven that pipes of bauxites extend in limestone or pinnacles of the later intrude the bauxite zone.

(iii) Guinea : The Kindia deposit is the third largest deposit of the country. The ore contains approximately 48 % Al_2O_3 although there are high grade ores where the alumina content reaches 60%. The bauxite is largely gibbsitic with subordinate amounts of boehmite, which occasionally goes upto 20%. Iron is high (18-20% as Fe_2O_3) and occurs as hematite and hydrated oxides.

The main characteristics of some of bauxites deposits of world are given in Table 3.5.3.

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TABLE NO.3.1 MAIN MINERALS OF BAUXITE DEPOSITS

Bauxite Minerals	CHEMICAL CHARACTERISTICS: Composition Formula	Al_2O_3%	Fe_2O_3%	SiO_2%	TiO_2%	Water of Crystallisation %	PHYSICAL CHARACTERISTICS: Density	Mohs Hardness	Crystal form	Colour	Lusture	OPTICAL CHARACTERISTICS: Crystal System	Crystallographic angles	Birefringence	Interference Colours	Optic Sign	Extinction	Anisotropism
Gibbsite (Hydraargillite)	Y-$Al(OH)_3$ ($Al_2O_3.3H_2O$)	65.4	-	-	-	34.6	2.42	3-3.5	Plates, Scales, Twins	White, greyish-ite, greenwhite.	Vitreous, Pearly	Monoclinic	$\angle\beta$=85°29'	0.022	Bright Upper 1st Order	(+)	Oblique 25°	-
Boehmite	Y-AlOOH ($Al_2O_3.H_2O$)	85.0	-	-	-	15.0	3.4	6.5-7	Plates	White, light-yellow, yellowish, green.	Vitreous Pearly	Orthorhombic	-	0.015	Lower First Order	(+)	Parallel	-
Diaspore	α-AlOOH ($Al_2O_3.H_2O$)	85.0	-	-	-	15.0	3.4	6.5-7	Striated Plates, Twins	Colourless, White, Yellow, Pink, reddish Violet, grey	Vitreous, Pearly	Orthorhombic	-	0.048	Upper Third Order	(+)	Parallel	-
Kaolinite	$Al_2Si_2O_5(OH)_4$	39.5	-	46.5	-	14.0	2.58	2-2.5	Thin Plates	Snow white, Yellowish, grey green	Dull, Pearly	Triclinic	α 91°48' β 104°30' Y 90°	0.005	Gray & White	(-)	Oblique 1-3°30'	-
Goethite	α-FeOOH ($Fe_2O_3.H_2O$)	-	89.86	-	-	10-14	4.28	5-5.5	Prisms, fibrous,	Brown, Black	Adamantine, Submetallic	Orthorhombic	-	0.138	Higher Order Colours.	(-)	Parallel	-
Hematite	α-Fe_2O_3	-	Fe: 69.94 O: 30.06	-	-	-	5.26	5-6	Plates, Scales, rhombohedra, twins.	Reddish brown, grey-black or black	Metallic, dull	Trigonal, rhombohedral	O P A	Q U	E	(-)	O P A Q U E	distinct in greenish grey to light brownish tints
Pyrite	FeS_2	-	Fe: 46.60 S: 53.40	-	-	-	5.00	6-6.5	Cubes, Octahedra, twins	Yellow, brass yellow, variegated tarnish colours	Metallic	Cubic	O P	A	Q	U E	———	Yellowish to greenish tints.
Anatase	TiO_2	-	Ti: 59.95 O: 40.05	-	-	-	3.90	5.5-6	Sharp dipyramics	yellow, blue darkblue, red, brown to black	Adamantine, greasy, submetallic	Trigonal	-	0.097	-	-	Parallel	light brown to yellowish or colourless
Rutile	TiO_2	-	Ti: 59.95 O: 40.05	-	-	-	4.2	6-6.5	Twinned Crystals	brown to black	Sub-metallic, greasy	Tetragonal	-	0.286	-	(+)	Parallel	Strong without colour
Ilmenite	Fe TiO_2 (FeO. TiO_2)	-	FeO: 47.34 TiO_2: 52.66	-	-	-	4.5	5.6	Plates	Black	Metallic, Greasy	Trigonal	-	0.286	-	(+)	Parallel	Strong with greenish gray colour

SOURCE :
1) Anon (1982), The world Aluminium Industry, Vol.I, Australian Mineral Economics Pvt.Ltd, Sydney, Feb, 1982 p.6
2) Valeton Ida(1972), Bauxites, Elsvier Publishing Company in Main Minerals of Bauxite Deposits, Table XI pp.29-36
3) Dada Rudolf and Rejr Lubos (1989), Minerals of the world, Arch Cape Bress, New York.
4) Kerr P.F.(1959), Optical Mineralogy Mc Graw-Hill Book company, Inc., Newyork & London.
5) Winchel A.N and Wichel H (1956), Elements of Optical Mineralogy, Part II, Description of Minerals, John Wiley & Sons Inc., Newyork, Chapman & Hall Ltd, London.
6) Picot P. and Johan Z.(1982), Atlas of Ore Minerals, BRGM Elsevier.

TABLE – 3.4 : TECHNOLOGICAL CHARACTERISTICS OF BAUXITE USED IN ALUMINA PLANTS OF INDIA AND FEW OTHER WORLD DEPOSITS—A COMPARISION

THE TECHNOLOGICAL CHARACTERISTICS	COMPANY'S, LOCATION OF PLANT, MAJOR BAUXITE SOURCE							
	BALCO	NALCO	HINDALCO	INDALCO		MALCO	QAL	HUNGALU
	Korba (M.P.) Amarkantak, Phutkapahar Kakni, Manikpur, etc.	Dhamanjodi (Orissa) Panchpatmali	Renukoot (U.P) Shrengdag Maidenpat, Pakhar,	Belgaum (Karnataka) Nagartaswadi Kasarde	Muri (Bihar) Bagru Hill	Mettur (T.N.) Shevaroy Hill	Queensland Alumina Ltd. Australia Gladstone (Queensland) Weipa.	Hungary Ajka Plant
(1) Average plant feed grade of ore								
Al_2O_3 %	47-49	42-46	47-52	48-52	49-50	46-49	53-56	58.7
SiO_2 %	3-4	1.5-2.5	2-3.5	2-4	3-4	2-4.5	4.5-9	7.3
Fe_2O_3 %	16-20	20-30	10-18	15-18	12-15	20-23	13	24
TiO_2 %	7.5-8.5	2-3	7-10	5-7	8-10	1.5	3	2.5
LOI %	20-24	20-30	20-25	25-27	23-25	22-23	13	13.8
CaO/MgO	-	-	-	-	-	-	-	1.5
(2) Mineralogy :								
Alumina from Gibbsite %	70-60	90-97	70-75	70-80	70-75	dominates	65-75	15-45
Alumina from Boehmite %	10-25	0-2	15-25	10-20	15-25	-	30-40	15-70
Alumina from Other minerals %	2-7	2-5	3-8	2-6	2-7	-	2-10	10-15
Silica from Kaolinite (Reactive SiO_2) %	60-85	70-80	-	75-80	80-85	-	30-60	90-95
Silica from Quartz (free silica) %	15-20	20-30	-	20-25	15-20	-	40-70	5-10
(3) Bauxite consumption per tonne of alumina (tonnes)	2.5-2.7	2.8-2.9	2.7-2.8	3.0	3.0	3.0	2.2-2.4	[illegible]-3.2
(4) Caustic soda Consumption per tonne of alumina (Kgs)	110-130	70-80	100-110	80-100	80-90	100-110	110-130	-
(5) Capacity of the plant (t/y)	200,000	800,000	300,000	180,000	75,000	60,000	3000,000	400,000
(6) Starting year	1973	1987	1960	1970	1959	1965	1967	1973

SOURCE : Nandi A.K., Indian Bauxite – Present Status and Future Prospects for Metal Production.

TABLE – 3.5.1 : ANALYSIS OF IMPORTANT INDIAN BAUXITES AND THEIR APPROXIMATE MINERALOGICAL COMPOSITION BY NORMATIVE CALCULATION.

STATE	DISTRICT	LOCALITY	CHEMICAL CONSTITUENT (PERCENT) Al_2O_3	SiO_2	TiO_2	Fe_2O_3	CaO	LOI	APPROX. MINERALOGICAL COMPOSITION (PERCENT BY NORMATIVE CALCULATION) GIBBSITE	BOEHMITE DIASPORE	KAOLINITE	GOETHITE	HEMATITE	LIMONITE	RUTILE AND OTHER TiO_2 MINERALS	QUARTZ	CALCITE	DISTRIBUTION OF ALUMINA % GIBBSITE	BOEHMITE DIASPORE	KAOLINITE	REMARKS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19	19	20	21	22
A.P*	Visakhapatnam	Anakuvalley, Raktakonda, Galikonda, Katuki	46.04 to 49.00	2.60 to 3.40	1.90 to 2.40	18.20 to 22.50	-	-	73.36	-	3.31	8.31	9.29	0.86	1.36	32 to 40%	-	-	1.33	-	-
ORISSA*	Koraput	Pottangi	38.79	1.99	2.00	21.13	-	-	64.92	0.19	2.76	11.00	14.12	0.81	1.30	30 to 35	-	-	2.55	-	
	-do-	Panchpatmali																			
		i) South block	46.69	2.42	-	-	-	-	67.68	0.60	-	3to9	13to17	-	-	-	-	-	-	-	
		ii) North block	48.63	2.29	-	-	-	-	68.22	0.65	-	3to9	13to17	-	-	-	-	-	-	-	-
		iii) Central block	46.03	2.08	2.10	24.40	-	25.05	67.84	-	4.09	9.10	13.63	-	1.12	0.15	-	-	-	-	
BIHAR	Ranchi and Palamau	Bagru Hill	53.20	3.30	9.60	7.80	-	25.90	66.5	8.4	6.4	7.5	0.8	-	9.6	0.3	-	43.2	7.1	2.6	
		Pakharpat	48.70	3.90	8.80	15.10	-	23.50	55.7	10.9	7.5	15.1	1.4	-	8.8	0.4	-	36.2	9.3	3.0	
		Serangdag	49.90	6.00	8.60	11.90	-	23.40	54.6	11.3	11.6	11.9	1.1	-	8.8	0.6	-	35.5	9.6	4.6	
		Jamirpat	50.00	10.00	7.80	10.14	-	20.25	39.3	19.6	19.4	10.1	1.0	-	7.8	1.0	-	25.5	16.6	7.8	
		Laimatia, Rannepat, Gudhapat, Hisri	53.70	2.90	9.16	9.50	-	25.80	64.9	10.6	5.6	9.5	1.0	-	8.2	0.3	-	42.2	9.0	2.2	-
		Bhaglatoli	60.56	1.40	7.84	6.84	-	20.04	38.2	40.6	2.7	6.9	0.6	-	7.8	0.1	-	24.8	34.5	1.1	
		Chandipat	58.27	0.36	11.27	3.12	-	26.34	64.7	18.4	0.7	3.2	0.3	-	11.3	0.04	-	42.0	15.6	0.3	
		Lachutpat	55.26	2.01	9.20	6.44	-	27.18	71.6	8.2	3.9	6.4	0.6	-	1.2	0.2	-	46.5	7.0	1.6	
		Serangdagtoli	54.52	2.05	6.45	12.11	-	23.63	54.3	20.5	3.9	12.1	1.3	-	6.4	0.2	-	35.3	17.4	1.6	
		Netherpat	53.44	2.10	8.10	12.11	-	24.17	57.4	16.8	4.1	12.1	1.3	-	8.1	0.2	-	37.3	14.3	1.6	
		Jalim-Sanai	50.00	3.00	8.00	13.00	-	20.00	41.0	24.6	5.8	12.8	1.4	-	8.0	0.3	-	26.6	20.9	2.3	
GOA		Betul	53.02	2.75	2.66	7.42	0.17	28.64	74.4	8.6	5.2	7.3	0.8	-	2.7	0.3	0.3	48.4	7.3	2.1	
		Sakti	57.88	3.64	2.56	6.72	0.19	28.74	74.6	7.3	7.1	6.8	0.6	-	2.6	0.4	0.3	48.5	8.2	2.8	
		Aradi	52.85	5.08	2.68	11.46	0.17	27.42	69.9	3.8	9.8	11.4	1.3	-	2.7	0.5	0.3	45.4	3.2	3.9	
		Etc.																			

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
			47.45	8.23	0.10	19.71	0.92	21.07	38.5	18.7	15.9	19.7	1.9	-	0.2	0.8	1.6	25.0	15.6	6.4	
			46.52	7.96	2.48	20.32	0.20	21.40	42.9	14.5	15.5	20.3	2.0	-	2.5	0.8	0.4	27.9	12.3	6.2	—
			50.02	5.97	TR	13.43	0.88	26.92	66.0	2.6	11.5	13.5	1.3	-	-	0.6	1.6	42.9	2.2	4.6	
MAHARASHTRA	Kolhapur	Dhangarwadi	51.26	3.58	4.85	13.04	-	26.89	69.6	3.6	7.[illegible]	12.8	1.4	-	1.8	0.4	-	45.2	3.1	2.8	
		Bogiri	51.77	2.19	4.81	11.47	-	29.76	76.7	-	4.2	-	-	13.5	4.8	0.2	-	49.8	-	1.7	
		Ringewadi	49.37	3.14	4.01	13.27	-	27.88	71.5	0.4	6.0	[illegible]	-	15.8	4.8	0.3	-	46.5	0.3	2.4	
		Radhanagari	52.00	3.30	5.10	1.90	-	26.70	68.3	5.8	8.3	12.8	1.4	-	5.1	0.3	-	44.4	4.9	2.5	—
		Idarganj	52.80	3.30	4.90	11.50	-	27.50	71.8	4.1	6.3	11.6	1.1	-	4.9	0.3	-	46.7	3.5	2.5	
		Nagartaswadi	52.10	2.70	6.10	12.20	-	26.90	69.6	5.4	5.2	12.1	1.3	-	6.1	0.2	-	45.2	4.6	2.1	
	Kolaba	Nandgaon	57.96	1.53	2.29	5.75	-	32.20	86.7	-	3.0	-	-	6.7	2.3	0.1	-	56.3	-	1.2	
		Karvine	55.55	2.12	3.66	8.79	-	29.99	82.4	0.1	4.1	8.7	1.0	-	3.7	0.2	-	53.6	-	1.6	—
	Ratnagiri	Kosdoli	56.19	2.06	3.20	5.11	-	31.30	86.3	0.2	4.2	-	-	6.0	3.2	0.2	-	56.1	-	1.7	—
KARNATAKA	Belgaum	Kirwale	51.30	2.30	4.30	14.20	-	27.10	70.2	3.8	5.4	12.8	1.4	-	4.3	0.3	-	45.6	3.2	2.2	
			48.50	4.30	3.60	16.10	-	25.60	63.3	4.6	8.3	18.8	1.8	-	3.6	0.4	-	41.1	3.9	3.3	
		Jamboti	52.50	2.80	4.60	13.60	-	27.60	71.9	4.0	5.4	13.5	1.4	-	4.6	0.3	-	46.7	3.4	2.2	—
			48.50	5.50	4.40	11.60	-	25.20	61.6	5.0	10.1	16.7	1.5	-	4.4	0.5	-	40.0	4.2	4.0	
	North and South Kanara	Pauware	52.13	6.40	1.50	13.37	-	27.45	69.4	2.2	12.4	13.5	1.3	-	1.5	0.6	-	45.1	1.9	5.0	
		Nagan-Kalbare	45.15	0.90	1.65	25.50	-	25.50	64.3	2.9	1.7	25.6	2.6	-	1.9	0.1	-	41.8	2.5	0.7	—
		Bhatkal Plateau	48.05	4.54	1.80	18.75	-	26.60	67.7	0.4	8.8	18.7	1.9	-	1.8	0.5	-	44.0	0.3	3.5	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
MADHYA PRA-DESH	Shahdol Mandla	Mazerioa-dar	50.32	2.86	7.59	12.36	-	25.18	63.6	7.6	5.6	12.3	1.3	-	7.9	0.3	-	41.3	6.5	2.2	
			46.33	4.50	7.57	18.06	-	23.72	56.9	6.6	8.7	18.1	1.8	-	7.6	0.4	-	37.0	5.6	3.5	
	Bilaspur	Kabiroadar	50.65	3.22	7.10	13.02	-	26.05	66.6	5.5	6.2	13.0	1.3	-	7.0	0.3	-	43.3	4.7	2.5	
			45.65	4.39	6.83	18.65	-	24.29	59.6	4.0	8.5	18.5	1.9	-	6.8	0.4	-	38.7	3.4	3.4	
		Daikisonda	52.76	4.29	6.91	13.00	-	23.05	51.3	18.7	8.3	13.0	1.3	-	6.9	0.4	-	33.3	15.9	3.3	
		Pamar	46.57	6.42	6.35	18.62	-	21.68	46.5	13.2	12.4	18.5	1.9	-	6.3	0.4	-	30.2	11.2	5.0	
		Siriaponoi	52.60	1.80	9.14	12.13	-	23.90	56.8	16.4	3.5	12.1	1.3	-	9.1	0.2	-	36.9	13.9	1.4	
		Pahar	46.84	3.55	8.42	18.86	-	22.08	49.4	13.9	6.8	16.7	1.9	-	8.4	0.3	-	32.1	11.8	2.7	
		Bangladadar	50.89	2.20	6.59	13.69	-	26.57	68.9	4.8	4.3	13.7	1.3	-	6.6	0.2	-	44.8	4.1	1.7	
			46.00	3.70	6.44	19.40	-	24.46	60.2	4.4	7.1	19.4	1.9	-	6.4	0.4	-	39.1	3.7	2.8	
		Bangladadar (Main)	50.74	2.39	7.87	13.16	-	25.99	66.8	6.2	4.6	13.2	1.3	-	7.9	0.2	-	43.4	5.3	1.8	
			45.55	3.94	7.40	18.66	-	24.18	59.6	4.2	7.7	18.5	1.9	-	7.4	0.4	-	38.7	3.5	3.1	
MADHYA PRA-DESH	Shahdol Mandla Bilaspur	Chakmi-Dadar	50.77	2.52	7.68	13.52	-	25.27	63.3	8.6	4.9	13.5	1.3	-	7.7	0.2	-	41.1	7.3	2.0	
			45.76	4.13	7.33	19.25	-	23.81	57.7	5.8	8.0	19.2	1.9	-	7.3	0.4	-	37.5	4.9	3.2	
		Pondibahra	52.04	3.69	6.56	14.47	-	23.37	53.0	17.0	7.1	14.4	1.4	-	6.6	0.4	-	34.4	14.4	2.6	
		Pahar	45.53	6.06	5.99	16.84	-	21.46	46.3	12.5	11.7	18.9	1.9	-	6.0	0.6	-	30.1	10.6	[illegible]	
		Jamunadadar	45.59	4.67	6.55	21.67	-	21.31	45.4	14.5	9.0	21.5	2.2	-	6.5	0.5	-	29.5	12.3	3.6	
		Raktidadar	45.62	5.77	6.51	20.86	-	20.96	43.5	15.0	11.1	20.8	2.1	-	6.5	0.4	-	28.3	12.7	4.4	
		Nanhudadar	45.36	4.93	6.42	20.77	-	21.85	48.0	12.0	9.5	20.6	2.1	-	6.4	0.5	-	31.2	10.2	3.8	
		Umargohan	45.39	5.06	7.14	19.33	-	22.69	52.1	8.8	9.8	19.4	1.9	-	7.1	0.5	-	33.9	7.5	3.9	
	Bilaspur	Phutkapahar	51.80	3.50	7.60	11.40	-	23.90	56.9	14.0	6.8	11.4	1.1	-	7.6	0.4	-	37.0	11.9	2.7	
			47.00	4.50	7.20	16.60	-	23.10	54.1	9.6	8.1	16.7	1.6	-	7.2	0.4	-	35.2	8.2	3.2	
	Shahdol	Amarkantak Mine of M/s. HINDALCO	61.25	1.80	6.09	2.86	-	24.71	58.0	25.8	3.5	2.8	0.3	-	6.1	0.2	-	37.7	21.9	1.4	Mine face Sample Results
			48.39	3.70	5.70	13.02	-	22.82	54.1	12.0	7.0	12.0	1.4	-	5.7	0.4	-	35.2	10.2	2.3	
			53.12	2.65	7.44	13.51	-	23.28	52.7	19.6	5.2	13.5	1.3	-	7.4	0.3	-	34.3	16.7	2.1	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
			53.68	4.36	4.66	8.25	-	29.04	76.3	0.6	8.3	-	-	9.5	4.7	0.4	-	49.6	0.5	3.3	Mine Face Sample Result.
			45.05	8.89	3.00	21.19	-	21.87	45.9	9.7	17.2	21.2	2.1	-	3.0	0.9	-	29.8	8.2	6.9	
			52.87	2.51	4.24	14.41	-	25.97	64.4	10.3	4.9	14.4	1.4	-	4.2	0.2	-	41.9	8.7	2.0	Stack Sample Results
			53.21	2.10	5.83	13.28	-	25.58	63.2	12.2	3.9	13.2	1.4	-	5.8	0.2	-	41.1	10.4	1.6	
			53.58	2.00	4.45	13.41	-	25.56	62.7	13.0	3.9	13.7	1.1	-	4.4	0.2	-	40.7	11.0	1.6	
	Jabalpur	Katni	52.51	1.97	4.62	12.97	-	27.06	70.4	5.9	3.8	12.8	1.4	-	4.6	0.2	-	45.8	5.0	1.5	
			55.72	4.85	7.65	4.00	-	26.70	68.5	8.5	9.4	3.9	0.5	-	7.6	0.5	-	44.5	7.2	3.8	
			52.62	11.69	6.01	3.67	-	24.52	57.7	7.0	22.6	3.6	0.5	-	6.0	1.2	-	37.5	5.9	9.0	
	Surguja	Rainpat (Parpatia)	54.19	0.86	11.89	7.77	-	24.70	62.1	15.4	1.3	7.3	1.3	-	11.9	0.1	-	40.4	13.1	0.5	
GUJARAT	Jamnagar	Bhatia Kennedy Lamba Virpur etc.	53.43	4.70	3.07	6.75	-	28.30	76.0	0.2	9.0	6.8	0.6	-	3.1	0.5	-	49.4	0.[illegible]	[illegible].6	
		Bhopamadhi	58.50	3.41	2.43	2.94	0.62	31.10	84.5	0.7	6.6	3.2	-	-	2.4	0.3	1.1	54.9	0.6	2.6	
			57.69	1.72	3.00	2.57	2.61	32.36	84.9	1.1	3.4	2.9	-	-	3.0	0.2	4.7	55.2	0.9	1.3	
			52.42	2.70	3.06	3.14	5.97	32.72	77.1	-	5.2	-	-	3.7	3.0	0.3	10.7	50.0	[illegible]	2.1	
			59.08	2.18	1.49	4.26	1.49	31.43	82.5	4.3	8.5	2.6	-	-	4.3	0.2	2.7	53.6	3.7	1.4	
		Karamkund	62.67	1.55	2.66	1.14	0.56	31.5	84.6	7.4	2.9	1.3	-	-	2.7	0.2	1.0	54.9	6.8	1.2	
			69.08	3.15	2.65	0.57	3.17	31.30	77.2	1.3	6.0	0.5	-	-	2.7	0.3	5.7	50.2	6.2	2.4	
			68.30	1.70	3.02	2.86	-	32.06	90.5	-	3.2	2.8	0.3	-	3.0	0.2	-	38.8	-	1.3	
			56.00	2.77	2.50	8.58	0.78	29.15	75.4	4.6	5.5	6.8	0.6	-	2.8	0.3	1.3	49.7	3.9	2.2	
		Rewasa	56.44	3.38	4.48	4.08	3.20	27.69	62.9	16.7	6.3	4.1	0.3	-	4.5	0.5	5.7	40.9	14.9	2.6	
			55.90	4.10	4.19	4.69	2.89	28.66	60.2	14.5	7.9	5.2	-	-	4.2	0.4	5.2	39.[illegible]	12.3	3.2	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
		Kundadhar	51.83	7.41	3.61	4.31	2.61	30.82	70.5	-	14.4	-	-	5.2	3.6	0.7	4.7	45.8	-	8.8	-
	Kutch	Ganggpur Hamla Punadi etc.	53.31	3.06	4.32	10.25	-	37.59	72.5	4.2	5.9	10.3	1.0	-	4.3	0.3	-	7.1	3.6	2.4	
			44.65	9.73	4.26	15.04	-	23.86	56.9	-	18.8	15.1	1.4	-	4.3	1.0	-	37.0	-	7.5	
		Nakhthrana	56.88	3.17	4.98	6.41	-	27.06	69.1	10.9	6.1	6.4	0.6	-	5.0	0.3	-	44.9	9.3	2.4	
			56.38	1.74	6.42	8.23	-	26.36	66.5	13.7	3.3	8.2	0.8	-	6.4	0.2	-	43.2	11.6	1.3	
		Punadi	53.18	3.92	3.10	5.05	2.58	31.05	76.6	-	7.7	-	-	5.5	3.1	0.4	4.6	45.8	-	3.1	
		Ghangra	53.90	3.74	2.34	4.37	5.05	30.61	69.9	6.2	7.2	3.3	-	-	2.3	0.4	8.0	45.8	5.3	2.9	
		Tundi Wangh Ratadia etc.	48.52	6.57	4.52	11.61	1.56	26.35	61.9	4.1	12.6	12.8	-	-	4.5	0.7	2.8	40.2	3.5	5.0	

* Source : Based on technical resume of mineral map of bauxite prepared by Mineral Map Cell of IBM.

Rest of the analytical data are adopted from Bauxite monograph No.5 (1977).

TABLE 3.5.2 : CHARACTERISTICS OF MAJOR INDIAN BAUXITES

BAUXITE CHARACTERISTICS		EASTERN GHATS VIZ.PANCHPATMALI	WESTERN GHATS VIZ.DHANGARWADI	INLAND HIGH LEVEL PLATEAUX VIZ.AMARKANTAK	INLAND HILLOCKS VIZ.KATRI	COASTAL PLAINS VIZ GUJARAT
Chemical Constituents :						
	Al_2O_3	42-50%	48-54%	46-52%	48-54%	52-60%
	SiO_2	15-4%	2.5-4.5%	3.4-4.5%	2-4%	1.5-3%
	Fe_2O_3	1.5-25%	9-16%	9-18%	4-16%	2-12%
	TiO_2	2-3%	3-6%	7-9%	6-7%	3-6%
Contaminants :	P_2O_5					-
	V_2O_5					-
	MnO	< 1%	low level	low level	low level	-
	MgO					0.05-1% (MgO)
	CaO					0.5-2% (CaO)
	Ga_2O_3					-
	Na_2O					-
	K_2O					-
Mineralogical : Composition		Gibbsite bauxite (Gibbsite 90-95% Boehmite 2-3%)	Boehmitic Bauxite	Boehmitic Bauxite with Significant diaspore in some.	Boehmitic Bauxite	Mixed gibbsitic boehmitic ore

SOURCE: Nandi A.K., Indian Bauxite – Present Status and Future Prospects for Metal Production.

TABLE 3.5.3. : CHARACTERISTICS OF WORLD BAUXITE DEPOSITS

S.No.	Major Bauxite Deposits	Country	Bauxite Resource (Million Tonnes)	Thickness (Metres)	Overburden (Metres)	SiO_2%	Al_2O_3%	MINERALOGY Alumina	Silica	Remark
1.	Weipa & Andoon	Australia	3073	1-10	< 1	4.5-9	48-56	Gibbsite 65-75% Boehmite 30-40%	Kaolinite 30-60% Quartz 40-70%	-
2.	Darling Range	Australia	750	2.5-5	0.5-1.5	15-22	30-38	Mostly Gibbsite Negligible boehmite (< 3%)	Kaolinite 0.02-12% Quartz dominates	High content of quartz & low alumina
3.	Gove deposit	Australia	250	3.4-5	< 1	3.4-4.2	48-50	Gibbsite 50-70% Boehmite 5-20%	Kaolinite upto 85%, rest quartz	-
4.	Jamaica	Caribbean Island	2032	9-12	0.5-2	1-3	42-50	Gibbsite with Significant Boehmite (5-20%)	Kaolinite and Quartz almost 50-50%	High Organic content
5.	Sangaredi, Boke CBG area	Guinea	2000 (Boke)	25	None	1.5-3	58-62	Mostly gibbsitic upper layer - 3% boehmite, bottom layer - 25% boehmite	Kaolinite 75% Quartz 25%	High quality with low impurities.
6.	Fria-Kimbo (Friguia)	Guinea	500	8-12	0.1-0.2	2-3	45-48	Mostly gibbsitic	Kaolinite 70% Quartz 30%	-
7.	Debele de Kindia	Guinea	200	6-8	0.3-0.5	2-3	48-52	Mostly gibbsitic boehmite (< 10%)	Kaolinite 80% Quartz 20%	-
8.	Trombetas	Brazil	910	5-6	6	4-7	47-50	Mostly Gibbsitic (boehmite < 10%)	Kaolinite 90-95% Quartz 5-10%	
9.	Paragominas	Brazil	750	-	-	3-7	53-58	-	-	-
10.	Parnassos	Greece	580	1.3	-	2.5-7	52-58	Boehmite & Diaspore	-	Diaspore

SOURCE : Nene S.G., Nandi A.K. and Aga I.M., Position of Indian Bauxite in the world and Prospects of the Exports.

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