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# Mode of Occurrence and Distribution of Bauxite Deposits in Andhra Pradesh and Feasibility of Aluminum Industry

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## Abstract

Bauxite forms four groups of capping in high hills of the Eastern Ghats which are form SW to NE the Gurtedu group, Chintapalli group, Paderu group and Araku (or Anantagiri) group in a belt 130 km long and 20 km wide. It occurs both on Khondalite and charnockite. The capping on the khondalite are more in number than on the latter. The in situ formation of bauxite by alteration on khondalite is indicated by the relict foliation of khondalite in bauxite, parallel to the foliation of the underlying khondalite, the pseudomorophs of the bauxite mineral gibbsite after garnet, silliminate and feldspar and the boulders with core of fresh rock and cover of bauxite. Boehmite differs from diaspore in that it has a lower specific gravity and occurs in the form of minute crystals (rhombic or bladed) which can only be seen with a microscope. Both minerals, if separated from impurities are usually colourless. Gibbsite (or hydragillite) is the only alumuna mineral found in trihydrated bauxites both in the crystalline and non-crystalline forms. It is colourless like the monohydrated minerals but has a lower specific gravity (2.35). Aluminium manufacture consists of two phases, i.e., manufacture of alumina from bauxite ($Al_2O_3$) and the alumina is to be refined and fabricated. The location of the smelters is being controlled by the location of the ore deposits and the power sites. The ore moves to power if they are wide apart as this industry is very power intensive and the cost of transportation determine the exact site. From the alumina by electrolysis process aluminium is manufactured by the application of cryolite, India is being used to import entirely from S.W.Greenland. At present synthetic Cryolite is being used as a substitute which is prepared from fluorspar. Alumina is a light metal and can stand long haulage. Hence the source of power has become the most dominant factor for the location of aluminium plants which subsequently fabricate the aluminium.

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*Keywords:*Bauxite Deposites,Formation of Bauxite,Anshra Pradesh minerals

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## 1. Bauxite deposits of Andhra Pradesh

Bauxite forms four groups of capping in high hills of the Eastern Ghats, which are form SW to NE the Gurtedu group, Chintapalli group, Paderu group and Araku (or Anantagiri) group in a belt 130 km long and 20 km wide. It occurs both on Khondalite and charnockite. The capping on the khondalite are more in number than on the latter. The in situ formation of bauxite by alteration on khondalite is

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indicated by the relict foliation of khondalite in bauxite, parallel to the foliation of the underlying khondalite, the pseudomorphs of the bauxite mineral gibbsite after garnet, silliminate and feldspar and the boulders with core of fresh rock and cover of bauxite (Ramam, 1976). Scraps of unaltered khondalite and charnockite are also present. Ramam (1978A) compares the bauxite derived formkhondalite with that derived formcharnockite and shows how the mineralogical and structural character of the rock plays a decisive role in chemical weathering and the insitu formation of bauxite. Thirteen plateaus in sapparla -region are estimated to contain over 350 million tonnes of potential reserves of bauxite of grade2 (48-51%$Al_2O_3$). A total resource of 780 million tonnes of potential reserves of bauxite have been estimated from all the deposits including the Chintapalli (Sapparla-Gudem-Jerrale, 480 million tonnes) deposits of Visakhapatnam and Gurtedu (Katamrajukonda-Dumkonda, 42 million tonnes) deposits of East Godavari district (Ramam, 1978B).

Table 1. Study of bauxite derived from Khondalite and Charnockite

| Characteristics | Bauxite derived from Khondalite | Bauxite derived from Charnockite |
|---|---|---|
| Disposition of plateau | Moderate to steep slopes in one or more directions. | Relatively flat or gently undulating. |
| Area of capping | Up to 505sq.km | Up to 1.5sq.km |
| Vegetation | Scarce | Relatively more |
| Scarps | Up to maximum height of 22 meters | Maximum height of 10 meters |
| Thickness in plateaus overlying both charckonite | Up to 32 m(up to 55m in Galikonda of Khondalite only) | Up to 16m khondalite |
| Hard cap | Iron crust is too thin or absent | Iron crust is invariably present |
| Structure | Relict foliation and joints pronounced, fracture cleavages of minerals | Relict foliation and joints are feeble and occasional. |
| Color | Pink, cream, yellow brown and reddish brown | Relatively dull looking and dark red |
| Hardness | Medium hard and soft, owing to numerous planes of weakness; porous and spongy top sections vermicular and vesicular in places. | Very hard and hard owing to massive character of rock and meager planes of weakness; vermicular and vesicular massive. |

## 2. Classification of bauxite deposits

Bauxite is the rocks consisting of hydrates of aluminium oxide (27-80%) and various iron oxides. The most undesirable impurity is silica ($SiO_2$), the amount of which in ores should not exceed 3-6% if the Bayer technique is used to extract alumina and not more than 8-12% if the calcining technique is used.

(i) Under the Bayer technique, ground bauxite ores are treated with solutions of caustic soda, which extract the alumina and thus separate it from the other constituents.

(ii) Under the calcining technique, ground bauxite ore and limestone are mixed with calcinated soda and the whole is calcined in a rotary kiln at 1,200-1,300ºC, the resultant product being solid sodium aluminate. In the next stage, the sinter is leached with water or a weak solution of soda at 60-90ºC.

Bauxite generally contain small admixtures of oxides of calcium, magnesium, phosphorous, manganese etc. alumina minerals (aluminium oxide) present in the bauxite may have trihydrated or mono hydrated molecules. Consequently, the water content of bauxite varies from 10-28%.

(a) In monohydrated bauxites the alumina minerals are diaspore and boehmite.

(b) Diaspore is very dense (specific gravity 3.0-3.5) and hard (it will scratch glass). In rocks crystals (rhombic) usually represent it which are so small that are invisible to the naked eye.

Boehmite differs from diaspore in that it has a lower specific gravity and occurs in the form of minute crystals (rhombic or bladed) which can only be seen with a microscope. Both minerals, if separated from impurities are usually colourless.

Leptochlorites – complex silicates of iron (present mostly in the form of ferrous oxide), aluminium and magnesium are a characteristic component of some monohydrated bauxites. Leptochlorites have a high specific gravity (more than 3) and green colour which they sometimes impart to the bauxites.

Gibbsite (or hydragillite) is the only alumuna mineral found in trihydrated bauxites both in the crystalline and non-crystalline forms. It is colourless like the monohydrated minerals but has a lower specific gravity (2.35).

In trihydrated bauxites, gibbsite is usually accompanied by kaolin, the mineral of porcelain clays.

One should say, however that practically always the bright or mottled colour of bauxites is due to the presence of some impurities and not to the alumina minerals which enter into their composition.

The most distinguishing feature of bauxites is their pisolitic or oolitic structure. However, not all bauxite ores shows such a structure which evens an inexperienced prospector will not fail to recognize.

Bauxite pisolites are spherical and elliptical formations generally of uranium composition and colour varying in size from a fraction of a millimetre to 10-12 millimetres. Pisolotes do not have a concentric structure and are only sometimes enclosed in a shell. On the other hand, the structure of oolites which are also spherical formations is concoidal or concentric.

Pisolites or oolotes are scattered more or less densely through the homogeneous non- crystalline matrix which may differ from the pisolotes in color, fracture and even chemical composition. The boundary between the pisolites and the ground mass is always well defined.

Monohydrate bauxites occur either in red-brown or grey-green varieties in a wide range of tints. Usually the pisolites and the groundmass are of the same color.

From the viewpoint of structure and outward characteristics, the following varieties may be identified among monohydrate bauxites:

a. Brown-red or cherry red, occasionally brick red bauxites which strongly soil the fingers have a fine pisolitic structure and high specific gravity. With regard to mineral composition, they are diaspora bauxites.
b. Brown-red to dark red bauxites without a pisolitic structure, a sub-concoidal fracture and a smooth surface, which do not soil the fingers. In view of their resemblance to ural jaspers, these bauxites came to be known as jasper-like. Alumina is present in the form of Boehmite.
c. Dark red fine-pisolitic ores which do not soil the fingers and the outward appearance of which is intermediate between the first two. Alumina or to be more specific, its hydrate is present in the form of both diaspora and Boehmite.
d. The following two types are recognized among bauxites grey and green-grey:
    - Dark grey (occasionally almost black) bauxites with an indistinct fine-pisolitic structure containing alumina in the form of diaspora and Leptochlorites.
    - Green-grey to pale pink clayey schistose bauxites of a pisolitic structure. In addition to diaspora and leptochlorite, they contain an admixture of kaolinite.
e. Mottled bauxites among which in addition to blue and green-grey tints, brown and cream colored varieties occur occasionally. The pisolitoc or oolitic structure is not always well pronounced. The minerals are diaspora, boehmite and leptochlorites.

The following three principal varieties are recognized among trihydrated bauxites which strikingly differ in outward appearance from monohydrates:

a. Stony bauxites, a hard strong rock with a coarse-pisolitic structure, high specific gravity and a great variety of colors. The matrix is generally of a lighter color than the pisolites. The color of the pisolites varies from brick or brown-red to nearly white. The ore may simultaneously contain black, brick red and light yellow or varicoloured pisolites.
b. Loose bauxites (products of destruction of stony bauxites). They occur as acemented or completely loose mass, sometimes containing scattered pisolites. In addition to gibbsite they may contain considerable quantities of kaolinite.
c. Clayey bauxites (greatly resembling loose bauxites). They are usually brick or pink red. Pisolites occur in them rather infrequently. They are distinguished from loose bauxites by their plasticity when they are wet they can be needed into a dough like mass, suitable for modelling.

The high silica content of clayey bauxites makes them economically unimportant but they should be closely examined because they are often associated with stony and clayey bauxites whose economic importance is exceedingly great.

Along with monohydrate and trihydrate bauxites, there are varities in which alumina is present in both monohydrate (Diaspora and Boehmite) and trihydrated (gibbsite) forms. Besides rocks of a pisolitic structure, they sometimes contain jasper-like and earthy rocks with few pisolites or none at all. The pisolites that are found are generally pink or dirty grey or yellowish.

The earthy varieties of bauxites of this mixed type are non-plastic and soil the fingers.

It has already been pointed out that most typical feature of bauxite ore is their pisolitic structure. However, this structure is also found in some rocks other than bauxites (hydrous and silicate iron ores and kaolin rocks).

## 3. Formation of bauxite deposits

Hydroxides of aluminium and iron, the materials which give rise to bauxite ores accumulated as a result of the deposition of the mineral particles in seas, lakes and bogs. During periods marked by relative regressions of the sea, great masses of rocks including some width a high alumina content were exposed. The climate was warm, even hot and humid; the shores were deeply indented width bays and lagoons and the surface of the earth was dotted with countless lakes, drained with numerous rivers and covered with luxurious vegetation. The abundance of water saturating the rocks in the winter and evaporating in the dry summer, the large quantity of carbon dioxide in the atmosphere and the water, the organic acids produced by the decay of plants in bogs and lastly, the vigorous bacterial processes in the hot humid climate combined to cause chemical weathering, i.e., the destruction of rocks and the dissolution of their constituent minerals. Alumina silicates are the source of alumina in magmatic rocks, which succumb to weathering. In the great majority cases as weathering they are stripped of sodium, calcium, potassium, magnesium and iron dissolves aluminosilicates, a strong bond is established between aluminium and silica to form kaolinite. This process is called kaolinisation, gives rise to kaolin clays. It has been demonstrated experimentally that minerals contain free alumina which is not associated with silica. The separation of alumina from silica which is a necessary step in the formation of bauxite ores could only occur in nature if the solutions which attacked the rock contained a strong acid that caused the silica to coagulate and precipitate rapidly and at the same time dissolved the alumina. Sulphuric acid the usual product of the oxidation of sulphur pyrite and other sulphides naturally played the decisive role in the liberation of alumina. It seems that nascent sulphuric acid destroyed the strong bond between the aluminium and the silicon of the alumina silicates and stripped them of alumina in the form of soluble salts. Dilution by atmospheric water sharply diminished the acidity of sulphuric acid solutions, thus making possible the precipitation and deposition of alumina form solution. Then the organic acids present in the water of most rivers and lakes came into play: humic substances quickly combine with aluminium to form soluble compounds which are transported by rivers over large distances without being precipitated. When alumina bearing solutions reached the saline or brackish waters of a marine basin, the chemical and physical equilibrium of these solutions were upset, and this started the precipitation of aluminium and iron hydroxides. These rise to bauxite beds. In fresh water basins the coagulation of solutions might have been brought about by the mixing of acidic waters of the solution with the weakly alkaline waters of lakes. In marine conditions bauxite deposits usually overlie light color limestone with an irregular surface. The lower part of a bauxite bed constitutes therefore a haphazard accumulation of angular limestone fragments embedded in a bauxite matrix called bauxite breccia. The upper boundary of the bed is generally smooth. The thickness of the bed depends on the contours of the base. Bauxite beds are usually covered with a mass of dark coloredlime stones or clayey sandy formations saturated with organic matter. Thus, bauxite deposits of a marine origin are usually sandwiched between two series of lime-stones. Bauxite deposits of a continental origin formed in lakes and bogs are associated with mottled clayey rocks which often overlie the rocks of the crust of weathering, i.e., rocks altered on the surface of the earth by the action of the atmosphere circulating vadose water and by the vital activity of plants and animals. These weathering products are usually varicoloured (various shades of red, yellow, violet and other tints) which makes them conspicuous. Such bauxite beds are usually confined to depressions in the more ancient rocks, corresponding to lakes which seems to have excited there in the past. They are frequently associated with coal series. In some cases, bauxites underlie coal series while in other the position is reversed.

## 4. Bauxite deposits in igneous and metamorphic rocks

Bauxite deposits are known to have formed throughout the earth's history on plateaus during long terrestrial periods. In most cases they eroded but bauxite sediments which surround the fossil plateaus prove their original existence. Some intercalated bauxite in Cambrian lime-stones is derived from the oldest known lateritic bauxites on igneous or metamorphic rocks. Laterite bauxite of Late Devonian to Early Carboniferous age occurs on basalts and also Jurassic to Cretaceous. Frequently links of weathered plateau and foreland covered with redeposit weathering products are disrupts through deep erosion. Therefore, complete reconstruction of areas of denudation and distribution is not always possible. A belt of bauxite deposits formed mainly during Late Cretaceous and Early Tertiary times spread over continent wide pen plains on Precambrian rocks. The youngest lavas capped by bauxites which can be dated precisely about 10,000 years old. Valleys already cut into the bauxites and recent flows are not lateritized. The scope of the present day transformation may be studied best in areas with recent volcanic tuff. Extensive research is undertaken on the so called “andsols”. However our knowledge concerning the extent and speed of transformation is still incomplete. Inspite of the continuous movement of Fe, Al and Si to date all observations from Tertiary Laterite bauxite indicate not further development but destruction of Laterite profiles. Movements of the earth’s crust resulted in different morphology, ground water movements and vegetation and old laterites represent polygenetically altered soils.

Two types of bauxite deposits are distinguished on the basis of facies

a. The slope type (gibbsite) which forms lens shaped bodies on the slope does not develop a typical vertical profile. Gibbsite is the main Al mineral.
b. The plateau type (gibbsite Boehmite) is a lateral facies of the plateau laterites along valley slopes with good drainage and marked profile differentiation.

### *4.1. Alumina industry*

Among all the non-ferrous metals aluminium is the metal of the modern age which is an essential pre requisite for a country’s progress and industrial growth. While it requisite for a country’s progress and industrial growth. While it ranks only next to steel in production in the world it exceeds the combined output of the three nonferrous metals – copper, lead and zinc. Aluminium was first discovered only in 1886AD and hence is one of the youngest metals of the world. During 1885-1888 the use of aluminium was only confined to fancy and luxury articles. The first commercial exploitation and technical application took place during 1890-1910. A technical revolution was achieved in 1909 when strength duralumin alloys could be produced by a German metallurgist as a result of discovery of “age harding” techniques. Along with the technical development the prices have come down considerably but yet aluminium is about 5-7 times more boost because of the First World War started in1914. Aircraft’s needed light metal and aluminium was suitable for aircraft industry. At present more than ¾ of aircraft are being built of aluminium and its alloys. Later it was used in transmission lines. The latest phase started after 1930 when this metal was extensively used in transport, building, architectural and structural engineering fields. In India this industry is hardly two decades old as in 1944 the aluminium plant was started at Asansol by the A.C.I. This versatile metal is being used from spoons to satellites because of its lightness, cheapness, good alloy properties, high thermal conductivity, resistance to corrosion, excellent reflectivity and good workability. Because of the lightness it has a special value for the transport industry like aircraft, railways and automobiles. For its resistance to corrosion and strength when alloyed with other metals it is being increasingly used in construction industries like building bridges, roofs and more so in prefabricated structures. Aluminium foils for wrapping and packing material for the cigarette, chocolate etc., are winning more and more popularity every day. Aluminium powder is being used as paste in the paint industry because of its resistance to some chemical reactions. It is also used in oil refineries, chemical works and breweries. After the Second World War the use of aluminium has been diversified considerably as prior to that it was only confined to utensil and household wares in the kitchen.

Thus apart from building construction, canning and packing, food and farming industries, manufacturing of engineering equipment, textile machinery plant and equipment for the food and chemical industries are also being manufactured out of aluminium. Even though aluminium comprises about 80% of the earth’s crust it is seldom found in its natural state. Production of aluminium’s going up to 24.18 m. tonnes. World production has increased by about six times since 1948. India has also taken long strikes since 1944 and 1951. The total production was only 3.9 thousand tones. India could produce 120.0 thousand tonnes of aluminium by 1968-1969 and it anticipated being increased to 220.0 thousand tonnes by 1973-1979 and thus production will record about 30.9fold increase within a span of 22 years. This industry has a bright future in India as there are extensive occurrences of bauxite deposits and relative absence of other nonferrous metals like copper, lead and zinc. Aluminium’s potentialities for substituting copper in electrical grade industries, stabilization in prices over a relatively long period increasing tempo of industrialization as a result of the implementation of the Five-Years Plan are also important factors in favor of aluminium industry. Requirements for distributing electric power large tracts in rural India will also entail build use of aluminium in future for transmission lines. The present low per capita consumption and raising standard of two contributing factors for a bright future of aluminium industry in India Where it is destined to play a greater role than in other industrially advanced countries like U.S.A., U.K., and USSR because of the shortage of non-ferrous metals.

## 5. Locational factor

The locational factors are primarily determined as per the degree of importance of three principal items like requirement of raw material, availability of power and lastly the location of the markets. Mostly the industries are located at the point of minimum transfer costs in relation to the assembly of the raw materials, power and disposal of the finished products to the consuming points.

The following are the requirements for the production of 1.02 tonnes of aluminium:

| | | |
|---|---|---|
| a. | Raw material (Bauxite) | …..4.1 to 5.1 tones. |
| b. | Calcined petroleum coke for electrode paste | …..0.51 tones. |
| c. | Cryolite | …..0.10 tones. |
| d. | Aluminium | …..0.036tones. |
| e. | Caustic soda | …..0.10 tones. |
| f. | Electric energy | …20,000/24,000 kWh. |

For production of 1.02 tonnes of aluminium,

(i) Aluminium 2.03 tones (which equivalent to 4.06 tonnes of bauxite).
(ii) Cryolite 0.10 tones(Imported from abroad), and
(iii) Power 22,000 to 25,000 kWh are required.

Thus both the estimates as regards the requirements for the production of 1.02 tonnes of aluminium are almost identical. They pointed at one common factor the importance of power. Vast majorities of the aluminium plants are power oriented in India which is in no way exception to the conditions prevalent in the world as a whole. The sources of power must necessarily be cheap and adequate through the factor which is only combined with hydel plants rather than the thermal power stations. Hence aluminium production units are preferably located within the easy reach of the hydel power station with interrupted power having favourable transport facilities to bauxite deposits or vice versa. Plants are also located at a point of minimum transfer costs with regard to ore and power.

Availability of power at economic rates is one of the primary pre requisites as 20-25% of the cost of production is accounted by power. At an estimated rate of 20,000/25,000 kWh per 1.02 tonnes of aluminium production to achieve target of 0.23 m.tons of aluminium by 1973-1974 about 0.6 m kW of power would be required. Power generation units located in proximity to bauxite occurrence, may be regarded as the optimum site for aluminium plants. Aluminium manufacture consists of two phases, i.e., manufacture of alumina from bauxite ($Al_2O_3$) and the alumina is to be refined and fabricated. The location of the smelters is being controlled by the location of the ore deposits and the power sites. The ore moves to power if they are wide apart as this industry is very power intensive and the cost of transportation determine the exact site. From the alumina by electrolysis process aluminium is manufactured by the application of Cryolite, India is being used to import entirely from S.W.Greenland. At present synthetic Cryolite is being used as a substitute which is prepared from fluorspar. Alumina is a light metal and can stand long haulage. Hence the source of power has become the most dominant factor for the location of aluminium plants which subsequently fabricate the aluminium. In India because of the short supply of hydel power many of the Indian aluminium plants had to be coal-based. When the cost of production per unit of aluminium is primarily determined by power it should be allocated to the aluminium manufacturing units at cheaper rates.

## 6. Conclusions

Thirteen plateaus in sapparla -region are estimated to contain over 350 million tonnes of potential reserves of bauxite of grade2 (48-51%$Al_2O_3$). A total resource of 780 million tonnes of potential reserves of bauxite have been estimated from all the deposits including the Chintapalli (Sapparla-Gudem-Jerrale, 480 million tonnes) deposits of Visakhapatnam and Gurtedu (Katamrajukonda-Dumkonda, 42 million tonnes) deposits of East Godavari district.

The high silica content of clayey bauxites makes them economically unimportant but they should be closely examined because they are often associated with stony and clayey bauxites whose economic importance is exceedingly great.

Power generation units located in proximity to bauxite occurrence may be regarded as the optimum site for aluminium plants. Aluminium manufacture consists of two phases, i.e., manufacture of alumina from bauxite ($Al_2O_3$) and the alumina to be refined and fabricated.

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