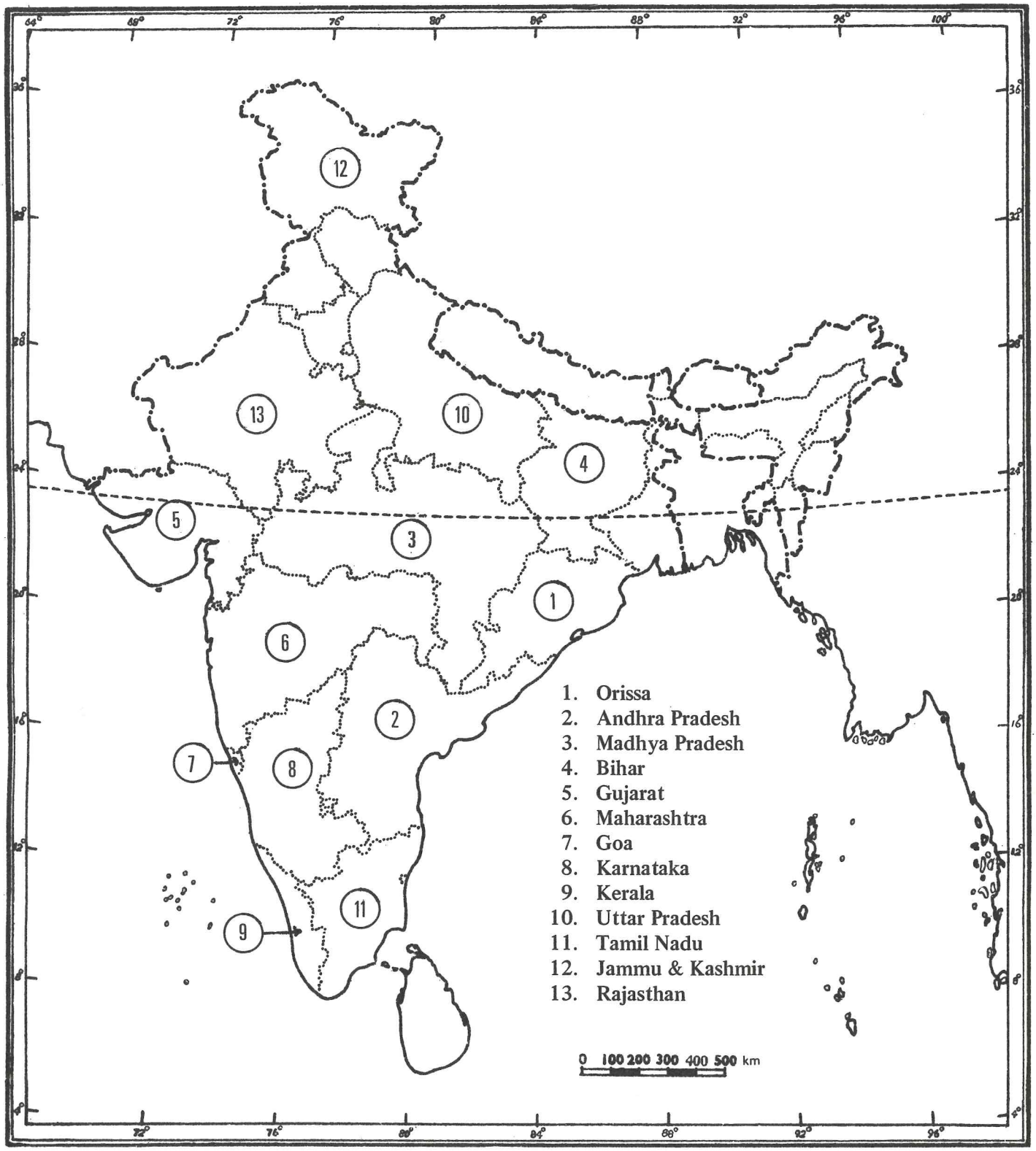
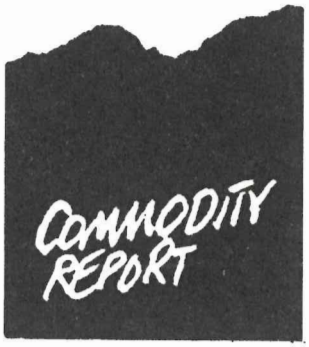
India: States and union territories where bauxite deposits occur





The bauxite wealth of India – a panoramic view

By P R Bose
and V B Lal

India is emerging as a major producer of a number of minerals, but aluminium is still the only non-ferrous metal for the production of which the country has adequate ore resources. However, in the view of P R Bose and V B Lal, it is not in the interest of India, which has an extensive national market, to become a major bauxite exporter. In this article they examine Indian bauxite resources and production in detail.

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Introduction

Today, after steel, aluminium is the second most widely used metal in the world and bauxite is the principal ore used for its production. Aluminium comprises approximately 7.45 per cent of the earth's crust, making it second only to silicon 27.7 per cent. Iron is third at about 5 per cent.[1] More importantly, it has the lowest enrichment factor, of about 5, i e the factor by which the metal concentration in the poorest ore, fit for economic extraction, exceeds the average concentration of the metal in the earth's crust. However, despite this abundance, over three fourths of all bauxite reserves of the world are found in developing countries. India happens to be among the seven countries of the world, each of which has bauxite reserves of over 1 Gt. These countries are Australia, Brazil, Guinea, Guyana, India, Jamaica and Cameroon. By contrast, the largest aluminium producers of the world have limited or no reserves: USA (40 Mt), USSR (150 Mt), and Canada, Japan, Norway, West Germany all negligible or nil reserves.

Various estimates of the world bauxite reserves place them in the vicinity of 30 Gt. The Indian reserves are estimated to be of the order of 2.4 Gt.

Bauxite – origin and constituents

Bauxite is not the name of a mineral. P Berthier seems to have given this name to a clayey rock, coming from a place called Les Baux in southern France, which, on his analysis in 1821, was found to have the following chemical composition: Al_2O_3–52%; Fe_2O_3–27%; combined water 20.4%. Since then rocks with comparable composition have been called as bauxite.Though there is now a tendency to apply this term loosely to any aluminium bearing substance, 'bauxite is best defined as an aluminium ore of varying degrees of purity in which aluminium in the form of hydrated oxide is the largest single constituent'.[2]

The largest bauxite deposits occur above kaolinitic clays and shales. They are of two main types – lateritic and terra rosa, and were formed in tropical or subtropical environments by the chemical weathering process, known as laterization and vary in age from precambrian to Quaternary.[3]

Bauxite is at present the most economic ore for the production of aluminium. Commercial bauxite should contain at least 50 per cent alumina (Al_2O_3) and less than 7 per cent silica. The less silica in a bauxite the higher its quality as an aluminium ore. In a good ore, the aluminium content is 25–27 per cent roughly half as high as the metal content in high grade iron ores.[4]

The quality of bauxite is determined by its chemical and mineralogical composition. The principal ore forming minerals of bauxite are:

- Aluminium oxide *trihydrate* (gibbsite) – $Al_2O_3 \cdot 3H_2O$
- Aluminium oxide *monohydrate* (boehmite and diaspore)

Besides the principal hydrated aluminium oxide minerals, bauxite may contain minor constituent minerals (corundum, cliachite, sporogellite, alumogen etc), and mineral impurities which include:

(a) Iron minerals – hematite, Fe_2O_3; goethite, $Fe_2O_3 \cdot nH_2O$; magnetite, Fe_3O_4; ilmenite, $FeTiO_3$; pyrite, FeS_2; etc.

(b) Titanium minerals – rutile, TiO_2; ilmenite and titaniferrous magnetite; anatase TiO_2; and leucoxene TiO_2, etc.

(c) Clay minerals – kaolinite and halloysite, both with a composition, $(OH)_8Si_4Al_4O_{10}$, and endellite $(OH)_8Si_4Al_4O_{10} \cdot 4H_2O$; etc.

(d) Silica minerals – 'reactive' silica in the form of clay or other silicates; 'non-reactive' silica – free quartz, sand, chalcedony.

Bauxite quality – implications for use, quality of Indian bauxite

Alumina present in bauxite in the form of trihydrate (gibbsite) is most easily and

Indian bauxite is used by INDALCO, which supplies aluminium plate, sheet and extrusions to the motor and transport industry such as this bus in Bombay.

economically recoverable in Bayer's process. Thus the presence of gibbsite mineral determines the value of bauxite ore in metal production being easily digestible in caustic soda at lower temperature and pressure (100–150g of Na_2O per litre at 120°C to 140°C).

Boehmite and diaspore have almost the same chemical composition but diaspore has a more dense atomic structure compared to boehmite, and is valued for its refractoriness. Bauxite with boehmite for digestion needs a higher concentration of caustic soda (200–300g of Na_2O per litre) at high temperature (200°C–250°C) corresponding to a pressure of 35 kg/cm^2. Diaspore is more difficult to dissolve in caustic soda. The Bayer process can handle it now with temperatures of 250°C and above, and higher caustic concentrations in the range of 200–300g/litre of Na_2O.

Implications for use

In making alumina, while the principal minerals play a very significant role during the leaching process, other minerals increase the volume of the waste burden. The more the waste burden in the feed, the lesser will be the productivity of the alumina plant, entailing a higher production cost. Reactive silica (alumino-silicates) reacts, in the Bayer's process, with caustic soda, to form insoluble hydrous sodium aluminous silicates. This results in a loss of alumina and caustic soda in the red mud of the following order: Alumina loss = 1.0 x reactive silica; caustic soda loss as NaOH = 0.9 x reactive silica; caustic soda loss as Na_2CO_3 = 1.2 x reactive silica. When monohydrate bauxite is digested at high temperature and pressure, all silica becomes 'reactive'.[5]

Thus the lesser the silica in a bauxite the higher is its quality as an aluminium ore. Iron and titanium oxides are primarily dilutants, there is no generally accepted maximum limit for their contents. Table 1 shows the composition and properties of major minerals of bauxite.

Quality of Indian bauxite

The mineralogical composition of alumina, silica, and iron oxides in bauxite varies from ore to ore. The mineralogy of Indian deposits has not been studied exhaustively, and many gaps remain. However, gibbsite, followed by boehmite, would appear to be the major mineral content[6]. The same publication gives the approximate mineralogical composition of Indian bauxite deposits, estimated from normative calculations. The range of chemical constituents of Indian bauxite is Al_2O_3 45–60%, SiO_2 1–5%, Fe_2O_3 3–20%, TiO_2 5–10%, and Loss on Ignition (LoI) 22–27%.[7]

In industries, other than alumina making, specifications are based essentially on chemical composition, and the mineralogy plays a subordinate role. Bauxite used for refractories, abrasives, chemicals and cement must meet more restricted specifications than bauxite used for metal. Refractory grade bauxite is high in alumina and low in iron oxides and silica. Chemical grade bauxite is low in iron content and should be readily soluble in sulphuric acid. The silica content of cement grade bauxite is usually lower than 6 per cent since higher contents decrease the rapid hardening quality of high-alumina; cement, on the other hand, a relatively high iron content is desirable due to the hardening properties of iron. Table 2 shows the range of grades for use in non-metallic bauxites.

Table 1

Composition and properties of major minerals in bauxite

Mineral	Chemical name	Chemical composition	Al_2O_3 content (%)	Water of crystallization content (%)	Crystal system	Hardness (Mohs scale)	Specific gravity
Gibbsite	aluminium oxide trihydrate	$Al_2O_3 \cdot 3H_2O$	65.4	34.6	monoclinic	2.5–3.5	2.30–2.40
Boehmite	aluminium oxide alpha monohydrate	$Al_2O_3 \cdot H_2O$	85.0	15.0	orthorombic	4.0–5.0	3.01–3.06
Diaspore	aluminium oxide beta monohydrate	$Al_2O_3 \cdot H_2O$	85.0	15.0	orthorombic	6.5–7.0	3.35–3.45

Source:
The World Aluminium Industry, Vol I. Australian Mineral Economics Pvt Ltd, Sydney, February 1982, p 6.

Table 2

Specification of non-metallic bauxite
(percentage by weight)

Constituents	Limits	Chemical and petroleum	Abrasive	Cement	Refractory	Fused refractories	Fire bricks Calcined basis	Fire bricks Dry basis
Alumina (Al_2O_3)	Min	58.0	80.0	30–70	85.00	80.0	87.00	59.4–61.0
Silica (SiO_2)	Max	3.0	7.0	6	7.00	5–8	6.00	1.5– 5.5
Iron Oxide (Fe_2O_3)	Max	2.0	8.0	5–20	3.75	2.0	2.75	0.5– 2.0
Titanium (TiO_2)	Max	4.0	3.5 (Min)	2	3.75	5.0	3.75	1.7– 2.6
LoI	Max	32.0	–	–	0.50	1.0	0.75	31.0–32.0
Phosphorous pentoxide (P_2O_5)	Max	0.3	0.5	–	–	–	–	–
Manganese oxide	Max	0.1	–	–	–	–	–	–
Calcium & magnesium as oxide	Max	2.0	–	–	–	–	–	–
Bulk density		–	–	–	–	–	3.10	–
Lime (CaO)	Max	–	0.4	25–45	–	–	–	–
MgO		–	0.4	–	–	–	–	–
Total alkalies (as oxide)	Max	–	0.7	–	–	–	–	–
$MnO_2Cr_2O_3 + V_2O_5$	Max	–	1.0	–	–	–	–	–

Source:
From data in: *Mineral Facts & Problems.* No 5, Monograph on Bauxite; Indian Bureau of Mines, Nagpur, 1977, p 19–23.

Bauxite deposits in India

India has a huge deposit of bauxite estimated to be about 2.4 Gt with about 77 per cent being located along the east coast of Orissa and Andhra Pradesh.[8] It is greater than that in the rest of Asia and next only to the iron ore deposits in India. India ranks fifth in the world in bauxite reserves. According to USBM estimates, India has 5.7 per cent *reserves* and 4.9 per cent *resources* of the total world bauxite.[9] The SiO_2 – content is only rarely higher than 5 per cent. These reserves occur in thirteen states of the country. Table 3 shows the state-wise reserves of bauxite. It may seen that only two states, Orissa (57 per cent) and Andhra Pradesh (20 per cent), account for over 77 per cent of the country's reserves.

Orissa

The reserves in Orissa are estimated at 1.3 Gt. They form the larger segment of the east coast belt of bauxite deposits which covers 50,000 km^2 and contains estimated stock of 1.9 Gt of bauxites, which are among the largest of their kind in the world.[10]

Bauxite deposits occur as lenses and pockets in the khondalite suite of rocks on some of the plateaux in Koraput, Kalahandi and Sambalpur districts. The ores at Panchpatmali are the most promising with reserves estimated around 377 Mt. This deposit is expected to last for more than 100 years mined at the rate of nearly 2.5 Mt a year which is proposed for NALCO. The Gandhamardan and Pottang deposits contain about 231 Mt and 92 Mt respectively. In the Koraput district there are over 100 Mt of reserves which are of a better grade.

Andhra Pradesh

Bauxite occurs as blanket type cappings with areal spreads up to 5 km^2 and thickness attaining a maximum of 53 m. The resources are localised in the districts of Visakhapatanam and East Godavari of north coastal Andhra Pradesh. A total resource of 780 Mt has been identified so far and can be categorised into five groups, three of which are in Visakhapatanam district and two in East Godavari district. The possibility of this figure swelling to about 1 Gt is not very remote if the relatively smaller cappings of low grade ore are also included after some preliminary studies. The resources estimated, group wise, are as follows:[11]

	Mt
Visakhapatnam district	
Anantigiri group	58
Paderoo group	100
Chintapalli group	480
East Godavari District	
Gurtedu group	42
Maredmalli group	100
Total	**780**

Madhya Pradesh

Katni area of Jabalpur district was the first to report production of bauxite in India in 1908 and was responsible for the major indigenous production up to 1950.

In Madhya Pradesh bauxite is found in the Maikala range of hills in the district of Shahdol, Bilaspur, Mandla, Raigarh, Jabalpur, Rewa and Sarguja. There are over 350 known occurrences and deposits of bauxite of varying dimensions and shapes in the state. Out of the total estimated reserves of 187.46 Mt for the state, the Maikala range alone accounts for over 33 Mt.[12]

In 1982 the production of bauxite in Madhya Pradesh was 381.865 kt which is 19.54 per cent of the total production in the country.

Table 3

State-wise reserves of bauxite in India (Mt)

State	Measured	Indicated	Inferred	Total	% of total
Andhra Pradesh	54.63	76.43	376.60	507.66	20.40
Bihar	18.63	17.70	62.75	99.08	3.98
Goa	10.25	8.39	9.69	28.33	1.14
Gujarat	40.50	8.08	41.95	90.53	3.64
Jammu & Kashmir	–	3.04	4.18	7.22	0.29
Karnataka	2.13	9.22	15.32	26.67	1.07
Kerala	0.79	7.47	6.14	14.38	0.58
Madhya Pradesh	61.20	65.12	61.14	187.46	7.53
Maharashtra	51.48	13.53	23.38	88.39	3.55
Orissa	209.03	360.25	847.03	1 416.31	56.90
Rajasthan	–	–	1.07	1.07	0.04
Tamilnadu	4.42	3.76	2.81	10.99	0.44
Uttar Pradesh	10.38	0.64	–	11.02	0.44
All India	**463.42**	**573.63**	**1 452.06**	**2 489.11**	**100**

Note:
More recent data has been incorporated in the discussion.

Source:
Indian Minerals Year Book 1980, Indian Bureau of Mines, Nagpur, 1983, p 2.6.1.

Maharashtra

A production of about 28 t of bauxite was reported from Thana district in 1950, continous production commenced in Maharashtra only in 1960 with the exploitation of bauxite deposits in Kolaba district. The estimated resources of all grades of bauxite is 88.39 Mt in the state. It is found in Kolhapur and Satara districts and along the low lying plateaux of the Konkan terrain in Kolaba and Ratnagari districts. At present Maharashtra ranks second in the bauxite production. In 1982 its production was 415.154 kt, which is 21.24 per cent of the total production in the country.

Gujarat

Bauxite production in the state first began in 1920 in Kaira district at Kapadvanj for supplying bauxite to petroleum companies for purifying kerosene. During the period of 1960–62, Gujarat was the leading producer of bauxite. It was the second leading producer during the period of 1963–1966 and 1969–1970. Today the reserves are estimated at 91 Mt. Gujarat Mineral Development Corporation is mining bauxite both in Kutch and Jamnagar. Several private parties are also mining bauxite in Jamnagar district. Jamnagar district supplies bauxite to the chemical, refractory and abrasive industries. Bauxite from Kaira district is used in cement manufacture. Gujarat ranks third in bauxite production in the country. In 1982 its production was 413.732 kt, which is 21.1 per cent of the total production in the country.

Bihar

Bauxite mining in Ranchi district dates back to 1933. The continuous mining of bauxite began only in the 1940s after the commissioning of bauxite processing facilities of the Aluminium Corporation of India and Indian Aluminium Co Ltd, at Jaykaynagar and Muri respectively. The bauxite was mainly supplied to the aluminium industry although small quantities were supplied to the refractory, steel and chemical industries. Today total bauxite reserves in the state are estimated at about 99 Mt, of which 12.83 Mt have been proved in unleased areas in Ranchi and Palamau districts at a number of places like Bagru hills, Jarda Pahar, Chiro Kukud and Orsa. In Monghyr district at Khapra Maruk, Maira and Jhadi 2.61 Mt of bauxite are estimated. At present Bihar tops in bauxite production in the country. In 1982 its production was 575.904 kt of bauxite, which is 29.47 per cent of the total production in the country.

Goa

The known reserves are 9.42 Mt. The Geological Survey of India has reported the following eleven occurrences of bauxite all along the sea coast from the northern to the southern tip of Goa over a distance of 130 km:

1. Polen-Loliem-Galgibaga area
2. Dabolim-Consua area
3. Quelossem-Verna-Rain area
4. Betim-Porvorim area
5. Provorim area
6. Mopa area
7. Calangute area
8. Taleigo-Bambolim area
9. Pernem area
10. Morgim area
11. Camorlim area.

In addition to the above, laterite cappings are noticeable practically in the whole of Goa, and they offer a promising exploration target for locating bauxite deposits. It has so far not been possible to understand the genetic features of the Goan bauxites. In 1982 Goa produced 8.651 kt of bauxite, which is 0.44 per cent of the total production in the country.

Karnataka

In Karnataka, the principal deposits of bauxite occur in the Belgaum district. The reserve potential of seven deposits has been recorded by Indian Bureau of Mines, situated on Karle hills, Boknur-Navige ridge, Kiniya, Kirvale, Jamboti, Betne and Mendil. About 0.6 Mt of possible metal grade ore, with 44–54% Al_2O_3 are estimated to be available. Kalhatgiri, Kemmangundi and other localities in the Bababudan hill range of Chickmagalur district, contain about 100 kt of bauxite with 48% Al_2O_3. In North and South Kanara castal areas, bauxite deposits are located at Kumta plateau, Haldipur, Honavar, Bhatkal, Baindur and Coondapur. In 1982, Karnataka produced 46.655 kt of bauxite, which is 2.39 per cent of the total production in the country.

Kerala

The important bauxite occurrences are located in the following regions:

Quilong district
Cherukad-Vadakkamuri
Chittavattam
Pallikal

Allepey district
Chirayinka taluk

Cannanore district
Anantupur gudda
Perla
Narala
Talakanam

Trivandrum district
Mangalapuram-Chilampil-Mudaparum
Adicchanallur
Adikkattukulangara
Kudiravattamkunnu

Geological Survey of India (GSI) carried out studies on the Nileshwar deposits of Cannanore district, in which six blocks with probable reserves of 6.10Mt, with 40–50% Al_2O_3 and less than 8 per cent silica have been delineated.[13]

Tamilnadu

Bauxite occurrences are known in the Salem, Madurai, and Nilgiri districts. In the Palni hills of Madurai district, bauxite was first discovered as early as 1902 by Dr Warth and Dr Hayden, both of the G S I. Much of the Palni bauxite is suitable for aluminium manufacture. The bauxite deposits in the Shevaroy hills of Salem district were accidently found by a coffee planter, E C Dickins in 1938. Here bauxite occurs in laterite capping leptynites exposed in five hills. The white bauxite of the Shervaroy hills have been utilised for the manufacture of aluminous abrasives known by the trade name of "Alirox".[14] In the Nilgiri hills, the important deposits occur near Idyada and Belthal. In 1982 the bauxite production from this state was of the order of 111.570 kt, which is 5.71 per cent of the total production in the country.

Uttar Pradesh

Bauxite deposits have been reported to occur as isolated pockets in the Vindhyan plateau extending into Banda district and in parts of Varanasi, Allahabad and Mirzapur districts. Most of them are believed to be of medium grade but rather high in titanium (about 12 per cent).[15] The total bauxite reserves of all grades are estimated at about 11 million tonnes. In 1982, this state produced 675 t of bauxite which is 0.03 per cent of the total production in the country.

Jammu and Kashmir

Bauxite occurs near Chakkar, Sangar Marg, Panhasa, Salal, Sukhawalgali and Jangalgali areas. Here bauxite, developed from the limestone is a blanket type of deposit varying in thickness from 3–7 m. The bauxite of this region is generally hard and dense and contains the highest percentage of alumina (70–80 per cent) with the minimum amount of impurities.

Rajasthan

In Rajasthan the investigation carried out by G S I have revealed the presence of bauxite near Baselio, Majola, Mamoni and Sherol-Khera in Kota district. It is found in the form of blanket cappings. The average thickness of the bauxite zones is 3 m but the maximum thickness is more than 15 m at places. Exploratory work undertaken has indicated a probable reserve of over one million tonnes containing on an average 49.54% Al_2O_3[16]. In 1982 this state produced 55 t of bauxite which is 0.002 per cent of the total production in the country.

Bauxite production in India

In 1980 there were 78 mines in operation; 6 in the public sector and 72 in the private sector. About 75 per cent of the total production was accounted by only 10 mines producing over 50 kt each. The share of public sector accounted for 25 per cent, while captive mines accounted for 75 per cent of the total production of bauxite in the year 1980.[17] In 1982 the bauxite production was about 2 Mt, which came from 9 states: Bihar, Maharasthra, Gujarat, Madhya Pradesh, Tamilnadu, Karnataka, Goa, Uttar Pradesh, and Rajasthan. Bihar alone produces a little less than one third of the total production in the country. Bihar, Maharasthra, Gujarat and Madhya Pradesh together account for around 90 per cent of the total volume of production. Table 4 shows the state-wise production of bauxite in India in 1982.

Production of bauxite started in India in 1908 in Katni district of Madhya Pradesh followed by Kaira district of Gujarat in 1920. Bauxite mining in the country came to a halt in 1931. The state of the Indian bauxite industry in the 1930s has been described by Dr C S Fox as follows:

> "The Indian bauxite industry has never been actively developed in spite of several efforts justified by the large occurrences of this material in various parts of the peninsula. The trade so far has depended on small orders from oil companies for the purification of kerosene and similar demands by chemical companies for preparation of aluminium sulphate, etc."[18]

The Second World War gave a boost to this industry, when Aluminium Corporation of India commissioned its aluminium plant at Jaykay Nagar near Asansol. On March 6, 1943, the first virgin metal was produced in India at the reduction works of the present Indian Aluminium company at Alwaye in Kerala. This metal was made from imported alumina as owing to war conditions the company was not permitted to build an alumina plant. In July 1944, the Aluminium Corporation was successful in producing metal from Indian bauxite. The aluminium industry which accounted for only 30 per cent of the bauxite consumed within the country during the period 1949 to 1953 has become a major consumer of the commodity from 1960 when the aluminium industry was expanded. The impetus given to bauxite mining by the demand created by the aluminium industry between 1958

Table 4

Bauxite production in India 1982

States/Union territories	Production (t)	Percentage
Bihar	575 904	29.47
Maharasthra	415 154	21.24
Gujarat	413 732	21.17
Madhya Pradesh	381 865	19.54
Tamilnadu	111 570	5.71
Karnataka	46 655	2.39
Goa	8 651	0.44
Uttar Pradesh	675	0.03
Rajasthan	55	0.002
All India	**1 954 261**	**100.0**

Source:
Mineral Statistics of India, Indian Bureau of Mines, Nagpur, 1983, 15(1), p 105.

and 1972 was further augmented by an increase in the bauxite requirement of other bauxite consuming industries and by sizeable exports of bauxite to Italy, UK, Canada, Japan, West Germany, etc. Table 5 shows the year-wise trend of bauxite production in the country from 1920–1982.

Export of bauxite

Bauxite export from India has not been significant. The cumulative export from India during the seventies i e 1971–1979 was of the order of 0.3 Mt, against the total production of about 19 Mt in 1979. The bauxite exports reached the maximum level of about 135 kt in 1970 after which they gradually dropped to a mere 18 kt in 1978–79 and afterwards it has an increasing trend again. Table 6 shows the quantity of bauxite exported from India from 1960 to 1980–81.

Most of the quantity exported from India has come from the coastal deposits of Gujarat and Goa. The export was confined to the high grade ore only. The limited export of bauxite so far follows from the well considered policy of the government of India not to encourage the export of the raw ore. As it happens the bauxite – aluminium industry of the world is in the grip of a few, highly vertically integrated multinational corporations with extensive control on world's raw resources and the aluminium metal markets. The developing countries have traditionally been obliged, by and large, to play the role of suppliers of raw ore at low prices. The value – accretion in the bauxite – aluminium industries is very large at each stage of processing. If aluminium metal prices are taken as base (100), the following indicative price structure emerges for products at each stage:[19]

Bauxite		2–3
Alumina		13–16
Aluminium metal		100
Aluminium series	Coils	145–155
	Plates	195–205

Thus it is evident that normally a country should endeavour to add as much value to its raw material as feasible, before exports. India happens to be among the few developing countries which have not only the capacity, and other favourable conditions for developing a full, vertically integrated industry right upto the stage of semi products, but an extensive national market also. Export of bauxite is therefore not a compulsion for India, and it is hardly in her interest to take resource to it.

In 1972, the Government of India has formulated a policy that no intending bauxite exporter was to enter into contracts for more than 5 years from the date of the announcement of the policy. There was no restriction on the quantity of the bauxite to be exported if the alumina content was less than 40 per cent. Similarly, any quantity of bauxite could be shipped for exports if the silica content of the ore was more than 5 per cent with alumina content up to 50 per cent.

Table 5

Bauxite production in India 1920–1982

(kt)

Year	Production	Year	Production
1982	1954	1966	750
1981	1923	1965	707
1980	1740	1964	593
1979	1952	1963	567
1978	1663	1962	587
1977	1519	1961	476
1976	1449	1960	387
1975	1274	1955	92
1974	1114	1950	65
1973	1297	1945	14
1972	1684	1940	8
1971	1517	1935	7
1970	1370	1930	2
1969	1085	1925	10
1968	958	1920	6
1967	804		

Table 6

Indian bauxite export

Years	Quantity (t)	Years	Quantity (t)
1980–81	84 241	1970	135 035
1979–80	45 526	1969	126 020
1978–79	18 536	1968	98 916
1977–78	42 624	1967	60 873
1976–77	34 531	1966	77 936
1976	21 190	1965	62 832
1975	14 320	1964	94 423
1974	18 264	1963	135 170
1973	28 498	1962	249 121
1972	27 575	1961	99 293
1971	53 782	1960	75 641

Note:
The price of bauxite varies according to the grade (and destination), and for alumina, aluminium and series, according to material specifications (and destination).

Sources:

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World Mineral Statistics Production: Exports; Imports. London Institute of Geological Sciences. Her Majesty's Stationary Office, 1981–1982.

Obviously, not many customers were interested in importing such a grade of bauxite.

It may also be stated here that for various reasons, particularly the formation of the International Bauxite Association (IBA) in 1974, for securing better price of bauxite for member countries, on the on hand, and a natural readjustment of strategy for securing ore-supply by the leading MNCs, on the other, plus the rising cost and difficulty of transporting ever increasing volumes of raw ore, the preference of importers has also tended to shift to alumina from bauxite.

Bauxite consumption in India – industry wise

Around 90 Mt of bauxite is produced every year all over the world and is consumed by a number of countries in a number of industries. The metallurgical industry consumes around 95 per cent of the total production of bauxite. But it has a significant application in the industries other than the metal industry such as abrasive, cement, ceramics, chemicals, foundry, oil, paints, refractory and even as building stones. Its use in different industries depends on its "silica module" (Al_2O_3 weight %). The best bauxite has a silica module greater than 10, whereas second and third class bauxite have modules of 7–10 and 4–7, respectively[20] (See Table 2 for bauxite specifications). India produces over 19 Mt of bauxite per year. Table 7 shows the consumption trend of bauxite by a dozen of industries from 1976–1980.

Metallurgical industry

Bauxite is used as the main raw material for alumina making, which in turn is mostly utilized for aluminium manufacturing purposes. 2 to 2.5 t of bauxite are used for the production of 1 t of alumina, and about 2 t of alumina are used for the production of one tonne of aluminium metal. Some Indian plants requires larger quantities of bauxite – 2.6 to 2.8 t – per tonne of alumina, and 1.92–1.98 t of alumina per tonne of the metal.

In the country aluminium is produced by four companies, one wholly in the public sector *Bharat Aluminium Company (BALCO)*, one with 73 per cent ownership of the government of India *Madras Aluminium Company (MALCO)*, and two in the private sector *Hindustan Aluminium Company (HINDALCO),* and *Indian Aluminium Company (INDALCO).*

BALCO was built with the assistance of USSR. HINDALCO, owned by Birlas (73 %), was built in collaboration with the American multinational Kaiser Aluminum (27 %). INDALCO was established in collaboration with the Canadian multinational Alcan (55 %) and MALCO, in collaboration with Montecatini-Edison Co of Italy (27 %). NALCO in the public sector is under construction in collaboration with the French multinational Pechiney Ugine Kuhlmann and is likely to start production by the year 1985–86.

Table 8 shows installed capacity and production by the 4 companies in the period 1979–1982.

Bauxite is also used in steel making as

Table 7

Indian consumption of bauxite by industries 1976–1980
(t)

Industry	1976	1977	1978	1979	1980(P)
Abrasive	39 979 (6)	40 031 (6)	68 849 (7)	74 258 (7)	74 824 (7)
Aluminium	1 343 323 (6)	1 197 192 (6)	1 395 550 (5)	1 403 636 (6)	1 341 053 (6)
Alloy Steel	610 (5)	586 (5)	766 (5)	767 (4)	647 (5)
Chemical	33 665 (16)	31 100 (17)	28 655 (15)	28 049 (15)	28 548 (14)
Foundry	60 (1)	51 (1)	Nil	Nil	Nil
Iron & Steel	22 130 (4)	22 149 (5)	21 634 (4)	20 504 (5)	18 646 (4)
Oil	108 (1)	66 (1)	85 (2)	64 (1)	40 (1)
Paint	20 (3)	20 (3)	10 (2)	10 (2)	10 (2)
Refractory	60 920 (21)	63 113 (23)	64 748 (22)	72 095 (17)	77 921 (16)
All industries	**1 593 873 (80)**	**1 425 634 (84)**	**1 666 393 (84)**	**1 690 537 (79)**	**1 650 839 (79)**

Notes:

P = Preliminary.
Figures in parentheses indicate the number of consuming units .

Source:
Indian Minerals Year Book 1980, Indian Bureau of Mines, Nagpur, 1983, p 2.6.10.

a flux and can replace fluorspar to a large extent. The quantity of bauxite consumed in six units of aluminium industry, five units of alloy steel industry and four units of iron & steel industry was 1.360 Mt in 1980.

Depending upon the alumina and silica content, the Indian Standards Institution has specified three grades of bauxite for use in alumina production as follows Table 9.[21]

Chemical Industry

Bauxite is used as the main raw material for the manufacture of aluminous chemicals viz aluminium sulphate, aluminium fluoride, aluminium acetate, aluminium hydroxide, aluminium chloride and sodium aluminate. Aluminium sulphate has a wide field of application in paper making, sewage precipitation, water purification and decolorisation of mineral oils. Aluminium sulphate can be produced from clay also but bauxite is preferred as it is easier to dissolve and needs no calcination. The amount of bauxite consumed in chemical industry was 28.548 kt in 1980.

The trihydrate variety of bauxite is preferred to monohydrate because the absorptive capacity of trihydrate is 3–4 times more than that of monohydrates. The Indian standard specifications for bauxite in chemical and petroleum industries have been given in Table 2. A high alumina requirement of 58 per cent is to be noted.

Abrasive industry

The consumption of bauxite in the abrasive industry in India was 74.824 kt in 1980. Bauxite of both monohydrate and trihydrate varieties is used for abrasive making. The presence of silica in excess is highly undesirable as it is the chief consumer of power and carbon, causes erratic furnace operations and poor control of the chemical reactions. It also forms ferro-silicon alloy with iron which is non-magnetic. Otherwise iron reduces to a metallic state and can be magnetically separated from the finished products. The presence of titanium helps in getting sharp points in the crystalline products and in providing toughness to the product. The specifications for bauxite for abrasive products are in Table 2.

Refractory industry

Bauxite is consumed as raw material in making refractory products since it has a high melting point from 1 740°C–1 820°C mainly depending upon the mineralogical composition. Monohydrate bauxite is preferred to trihydrate variety. Diaspore having a density of 3–4 is considered to be the most suitable aluminous oxides. All impurities except silica present in excess cause deformation in the refractory products. The specification have been given in Table 2.

The country has a shortage of refractory grade bauxite and imports it from

Table 8

Installed capacity and production, company-wise for 1979–1982

Company	Date of registration	Installed licenced smelting capacity	Production (t) 1979–80	1980–81	1981–82
INDALCO	1938-12-17	96 170	63 852	72 919	85 474
			(33.28)	(36.64)	(40.75)
HINDALCO	1958-12-15	100 000	76 173	75 294	75 675
			(39.70)	(37.83)	(36.07)
MALCO	1960-08-31	25 000	22 349	22 027	13 863
			(11.65)	(11.07)	(6.61)
BALCO	1965-11-27	100 000	29 499	28 778	34 754
			(15.37)	(14.46)	(16.57)
NALCO	1981-01-07	..	..	..	..
Total		**321 170**	**191 873**	**199 018**	**209 766**

Note:
Figures in parenthesis indicate per cent share in production of each company.

Source:
Government of India, Ministry of Steel & Mines, Department of Mines, Annual Report 1982–83, p 102.

Table 9

Classification of bauxite according to Indian Standard specifications
(Percentage by weight)

Constituent		Grade I	Grade II	Grade III
Alumina	Min.	51.0	48.0	44.0
Silica	Max.	3.5	5.0	5.0
P_2O_5	Max.	0.2	0.2	0.2
V_2O_5	Max.	0.2	0.2	0.2
$Fe_2O_3+TiO_2$	Max.	30.0	30.0	30.0
LoI at 1100°C	Min.	20.0	20.0	20.0

Guyana. The amount of bauxite consumed in this industry was 77 kt in 1980.

Cement industry

There are no specifications for bauxite in the cement making industry. The presence of silica in excess affects the setting property. Cement produced with more than 70 per cent of alumina and less than 1 per cent of silica and iron oxide has a higher melting point, up to 1 800°C. Bauxites with very high iron and silica are also used for cement making. The bauxite consumption in the country for cement production in 1980 was 103 kt.

Absorbent industry

Bauxite is used for kerosene refining. During the process of absorption, no chemical reaction occurs. It can be reused as an absorbent after reheating.

Other industries

Bauxite has also found application in rubber, plastics, cosmetics and paint industries as filler. The amount consumed in some of these industries in 1980 was 5442 t in ceramics, 40 t in oil industry and 10 t in the paint industry. Bauxite of low quality is used as road making material, and building making material as well.

Conclusion

Concluding the review of the status of bauxite reserves in India in the context of the importance of bauxite for a modern industrial economy, we would like to emphasise that India in view of its large reserves (which are estimated to last for another 250 years, assuming a progressive growth of aluminium consumption to 1 kg per capita by the turn of the century), relatively better technological capabilities, a well developed industrial infrastructure and the potential for developing a vertically integrated aluminium industry with large internal market, seems destined to play a major role in restructuring the international aluminium industry to a more equitous order for developing countries.

Notes:

[1] Altenpohl, D: *Materials in World Perspective.* Material Research and Engineering, Springer verlag Berlin, Heidelberg, New York, 1980.

[2] Encyclopaedia Britannica, 1973–74.

[3] *The World Aluminium Industry,* Vol I. Australian Mineral Economics Pvt. Ltd. Sydney, February 1982.

[4] *Export Possibilities of Minor Minerals.* Federation of Indian Mineral Industries, New Delhi, 1974.

[5] *Studies in Economics of Industry.* Preinvestment data for the aluminium industry, UN, 1966.

[6] Mineral Facts and Problems: No 5 Monograph on Bauxite. Indian Bureau of Mines. Nagpur, November, 1977.

[7] Note 3, p 7.

[8] The latest Report (February 1984) of Sub Group IV (exploration) of the Working Group on Non-Ferrous Metals constituted by the Department of Mines, Government of India to report on the situation during the Seventh Five Year Plan and projection up to 2000 AD assesses the total bauxite reserves in India to be equal to 2.66 Gt as of 1982-01-01. Out of this quantity 1.96 Gt is of metallurgical grade of which 395 Mt is in proved category and an almost equal amount in the probable category. The position regarding chemical, refractory and abrasive grade is considered as alarming. The estimated reserves of this grade are only 34 Mt essentially in Gujarat. All the other states put together have only 7.5 Mt of the non-metallurgical grade bauxite in the proved category and 1.9 Mt in probable category.

[9] Note 3, p 28.

[10] Vinayak, M: *Nalco – The birth of a giant.* Business India, 1983-07-18/31, p 52.

[11] Raman, P K: *Bauxite resources in Andhra Pradesh.* Proceedings of All India Seminar on Aluminium, October 20–21, 1978, Delhi Chapter and The Indian Institute of Metals, Volume 2, p 31, 1–7.

[12] *First All India Mineral Conference,* 1977-07-03, Council of State Mineral Corporation, New Delhi, p 96.

[13] *Ibid.*

[14] Krishnaswamy, S: *India's Mineral Resources.* Oxford, New Delhi, 1979, p 8D.

[15] *Ibid,* p 81.

[16] *Geology and Mineral Resources of the States of India* – Rajasthan, Miscellaneous Publication No 30, Geological Survey of India, Calcutta, 1977, p 23.

[17] *Indian Minerals Year Book 1980.* Indian Bureau of Mines, Nagpur, 1983, p 2.6.2.

[18] Note 6, p 209.

[19] *Processing and Marketing of Bauxite/Alumina/Aluminium:* Areas for International Cooperation. UNCTAD, 1981. TD/B/C.1/PSC/19.

[20] Note 3, p 6.

[21] Note 6, p 18. ■