IBAAS-JNARDDC 2022
TECHNICAL LECTURE SERIES

WORLD - WIDE BAUXITE DEPOSITS & MINES AND OPPORTUNITIES FOR INDIA

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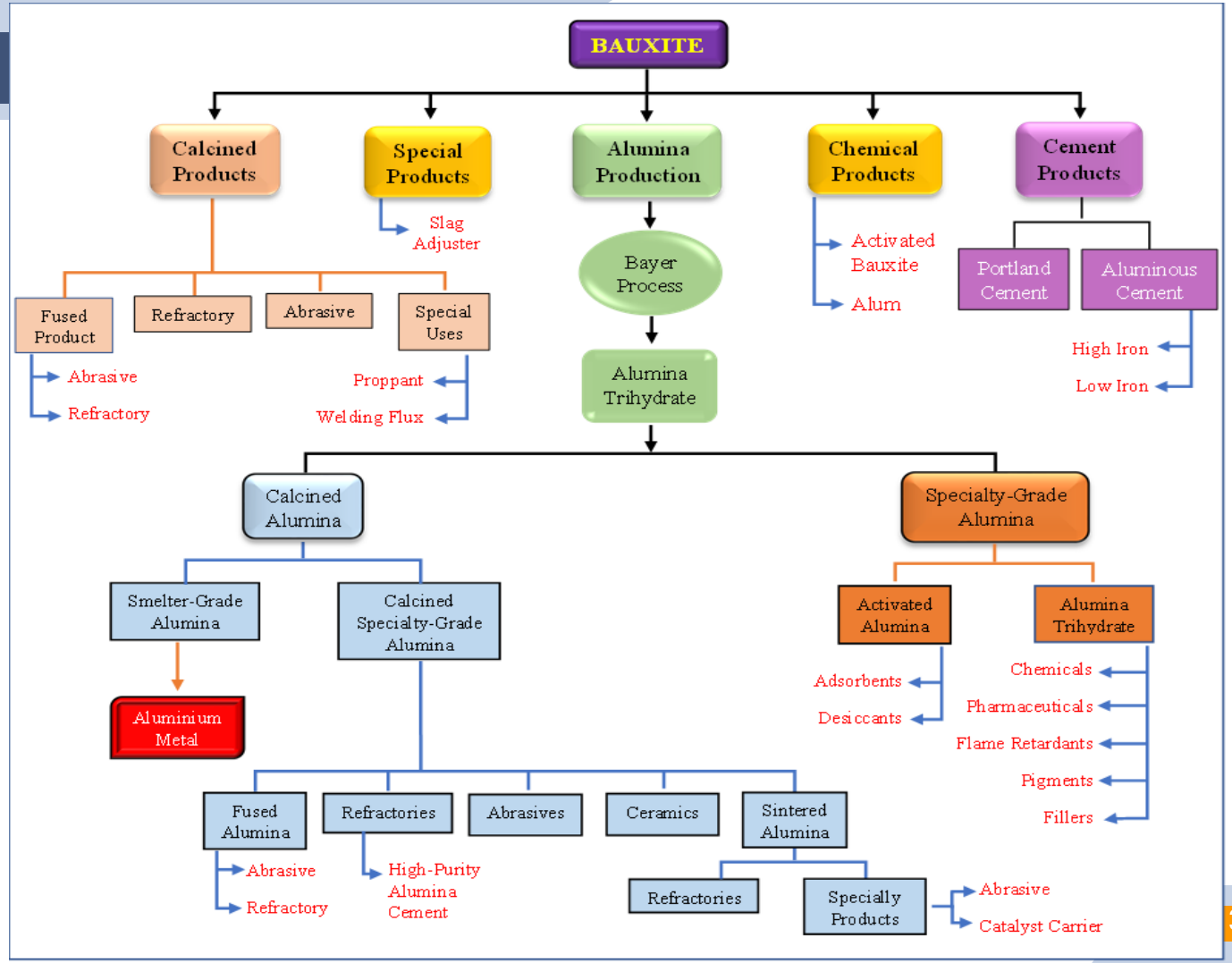
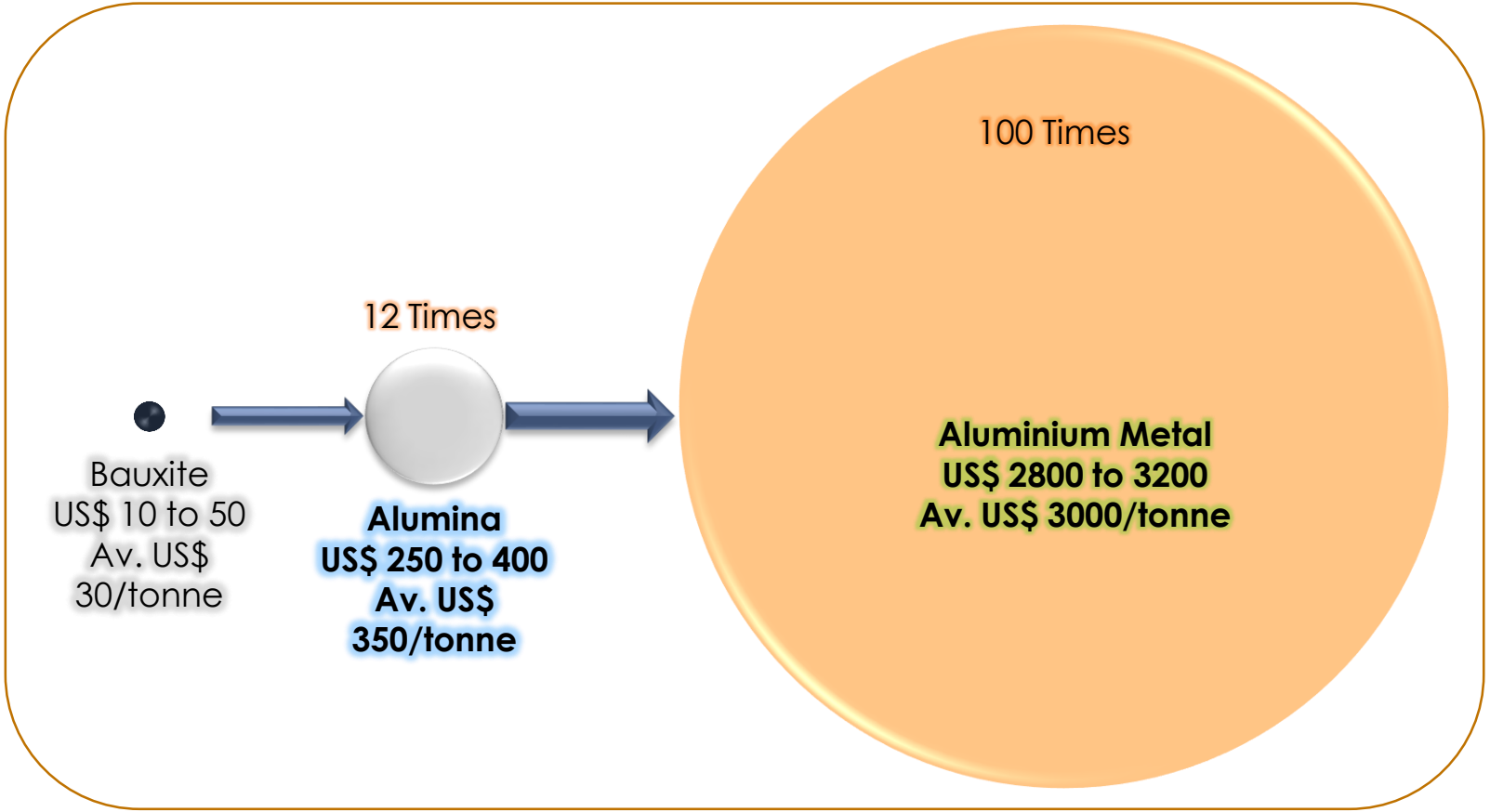
BAUXITE BASIC FACTS

- Bauxite is considered comparatively low value bulk ore.
- Some of the pit head alumina plants receive bauxite as low as US$9 per ton.
- Normally the transportation cost of bauxite is higher than the actual mining and processing cost. Therefore, some plants receive imported bauxite at prices higher than US$ 60 per ton.
- Normally 2.5 to 3 tons bauxite is required to produce 1 ton of alumina.
- There are now well-established processes to upgrade low quality bauxites.

BAUXITE USES

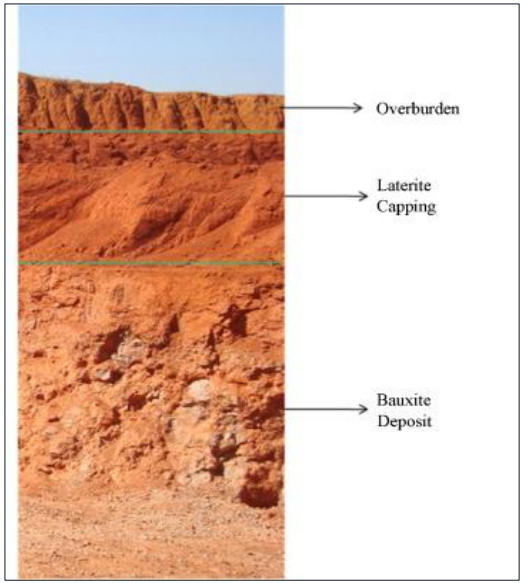


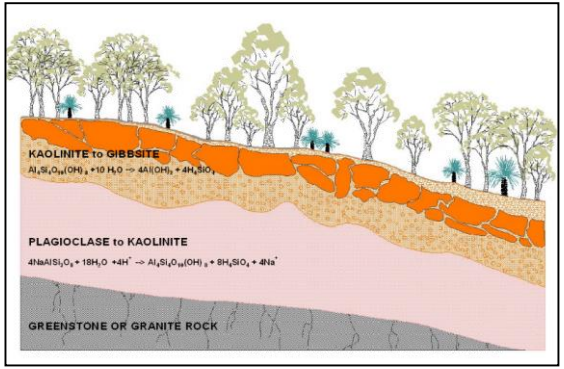
BAUXITE – ALUMINA AND ALUMINIUM VALUE CHAIN

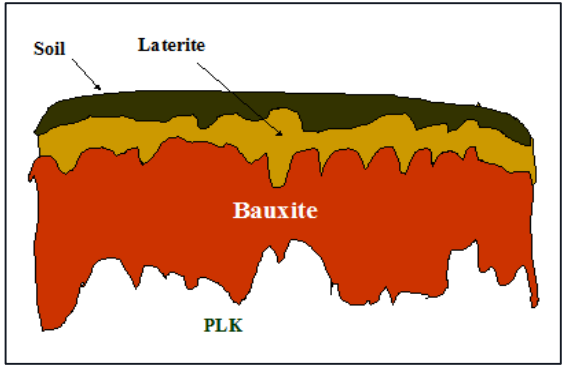


1. LATERITIC BAUXITES

- Developed in situ on alumo-silicate rocks
- Lateritic bauxite of residual origin occurs as capping's over plateaus and occur in tropical countries.
- Lateritic bauxites main occur in Australia, Brazil, Guinea, India, Indonesia, Vietnam & Venezuela.
- More than 80% bauxite in the world are of lateritic origin.

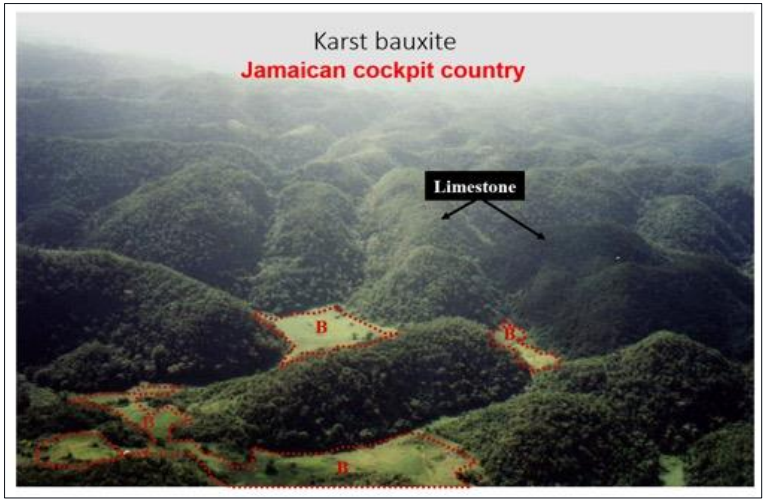




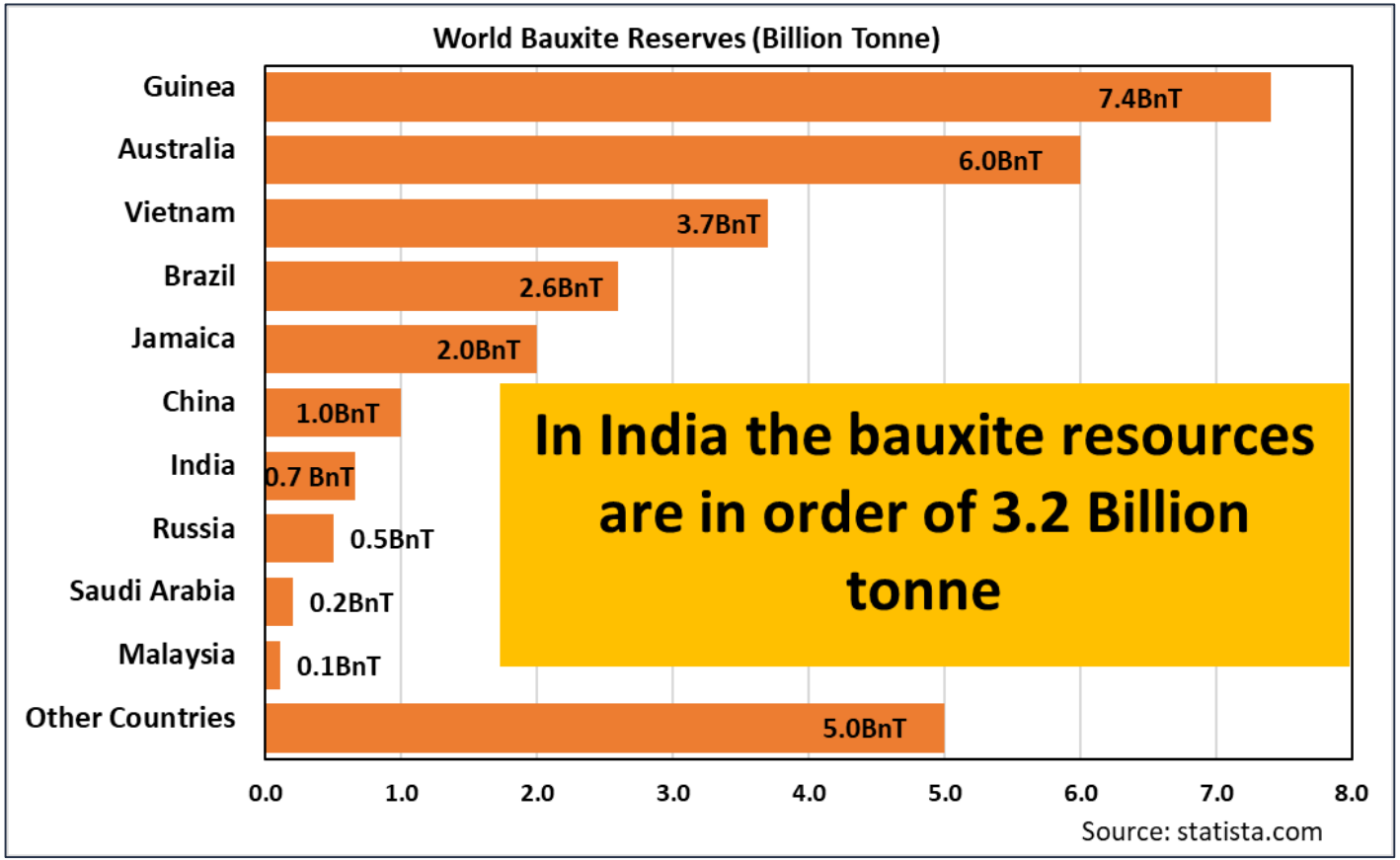


2. KARST BAUXITES

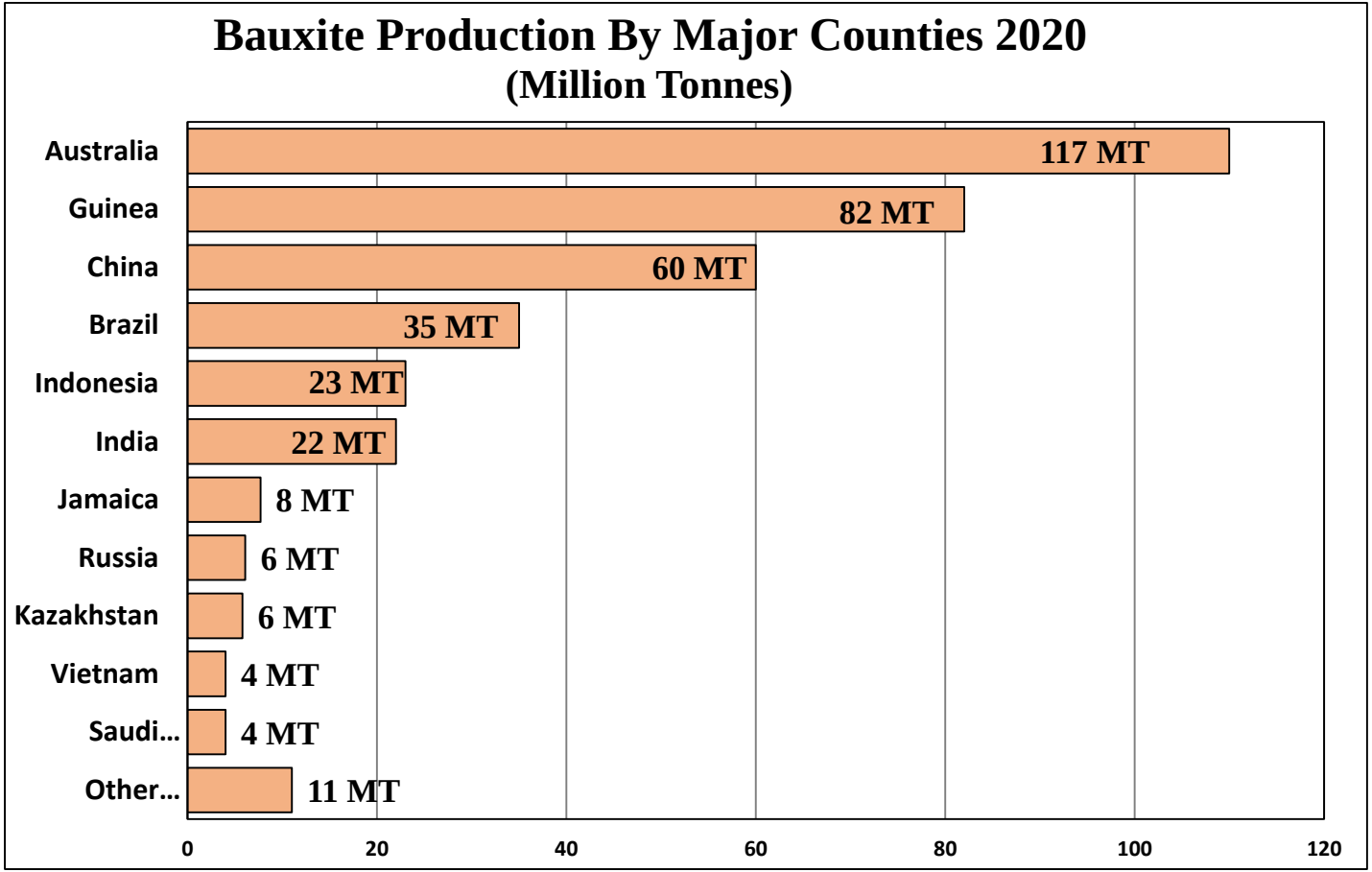
- Karst bauxites predominantly associated with carbonate rocks (limestone and dolomite).
- The processes involved in formation of karst bauxites and lateritic bauxites are much similar except the karstified topography.
- Examples - Bauxite Deposits of Europe, Jamaica & Dominique Republic.



WORLD BAUXITE RESERVES



WORLD BAUXITE PRODUCTION



BAUXITE DEPOSITS & MINES OF WORLD

- World bauxite resources are in the order of 100 billion tons, however, bauxite proved reserves are much lower.

- About 300 million tons of bauxite are mined each year. The leaders in bauxite productions are Australia, Guinea, China, Brazil, India, Indonesia and Vietnam.

- From quality point of view, Guinea bauxite is considered the best in the world, followed by Brazilian bauxite, however, this requires washing. Australian and Indian bauxite are gibbsitic as well mixed gibbsitic-boehmitc ore. Chinese bauxite is mostly diasporic and requires quite high temperature of digestion.

GUINEA BAUXITE

- Guinea > 40 Billions Tonnes of Bauxite Resource

GUINEA BAUXITE – BASIC FACTS

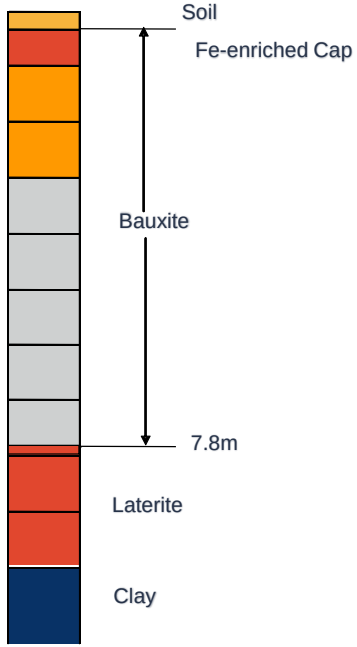
- Low-lying flat topped bauxite plateaus at elevation of 200 to 400m above MSL.
- Bauxite occurs from the surface with thin soil cover (<0.5m) and low overburden (about 1m).
- Average thickness of lateritic bauxite about 8 to 10m.
- A natural low silica (2.5%) Gibbisitc Bauxite, where reactive part is only 50%.

GUINEA BAUXITE – BASIC FACTS (CONTD.)

- Silica content almost remains constant in laterite-bauxite profile does not go down with lowering of alumina.
- In the lateritic bauxite boehmite is, in general, lower than 3%.
- Easy to mine by surface miner or drilling – blasting.
- Raw bauxite after simple crushing can be exported.
- Guinea has about 9 to 10 well developed operating bauxite mines and each mine is different with specific bauxite quality, infrastructure, road/rail network and port / river jetty.

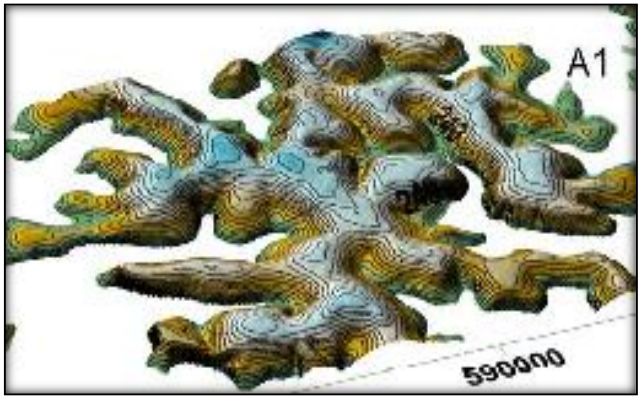
TYPICAL LATERITIC BAUXITE PROFILE

Depth m	TAl_2O_3%	Fe_2O_3%	$TSiO_2$
1	37.94	33.4	3.32.
2	41.30	29.88	2.04
3	43.33	27.53	1.25.
4	46.02	23.44	1.44
5	48.52	20.32	1.59
6	49.22	19.01	1.55
7	49.15	19.05	1.52
8	46.83	22.78	1.56
9	35.02	34.71	7.14
10	34.70	36.24	7.81
11	33.95	16.93	31.84



GUINEA BAUXITE PLATEUAS AND MINING

Bauxite Plateaus Guinea



Drill Blast vs Surface Miner

Typical Chemical and Mineralogical Composition of Guinea Bauxite

Chemical Constituent	Typical Value%
Total Al_2O_3	**45.2**
Total SiO_2	**2.2**
Fe_2O_3	**23.5**
TiO_2	**2.0**
LOI (105 to 1000^0C)	**24.6**
Available Alumina	**40**
Reactive Silica	**1.2**
Organic Carbon	**0.09**
Moisture (105^0C)	**9.5**

Constituent	Mineral Phases	Distribution%
%Al_2O_3	Gibbiste	**40.5**
	Boehmite	**2.1**
	Kaolinite	**0.6**
	Alumogoethite	**1.9**
%SiO_2	Kaolinite	**0.7**
	Quartz	**1.5**
%Fe_2O_3	Hematite	**4.5**
	Alumogoethite	**19.0**
%TiO_2	Rutile	**0.5**
	Anatase	**1.5**
%LOI	Gibbiste	**21.5**
	Boehmite	**0.4**
	Kaolinite	**0.2**
	Alumogoethite	**2.5**

CBG: Compagnie des Bauxites de Guinee

- Guinea's oldest Bauxite Mine, with resources of about 8 billion tons of high-grade bauxite (Alumina 48-50% and SiO2 18-2.2%)

- Alcoa, Rio Tinto Alcan, Dadco and Govt. of Guinea are shareholders with 49% by GoG. The GoG also owns the transport infrastructure including railway, through ANAIM, and SOGUIPAMI has the right to market about 300,000 tons bauxite per annum.

- Well developed mines, rails and Kamsar port infrastructure slowly increasing production and likely to reach 22.5 million tons bauxite per annum by 2022.

- Bauxite quality, shipment size and prices are well known by alumina refineries all over the world.

- Bauxite is mainly exported to North American and European Alumina refineries and occasional shipments are traded to India, China and other countries.

- Only company in Guinea that can dry bauxite and supply ore with 6% moisture content throughout the year.

- CBG's mines may run for decades or more, although high grade Sangaredi sedimentary bauxite has been depleted.

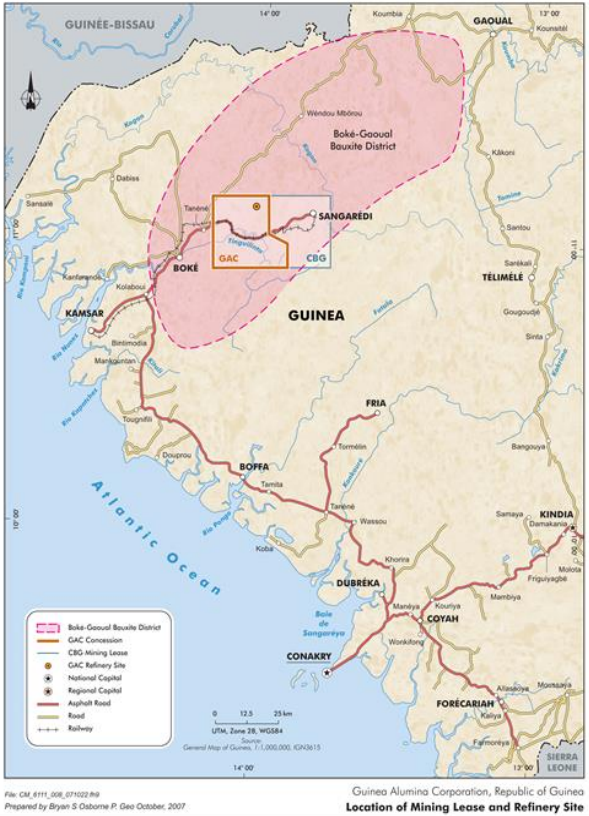
CBK: Compagnie des Bauxites de Kindia

- Second oldest bauxite mine, 100% owned and operated by RUSAL.
- Kindia bauxite is slightly different from Boke bauxite: lower alumina (44-45%) and higher silica (about 3%); however, this is a soft bauxite, devoid of any boehmite.
- Annual production capacity of 3.1 million tons of bauxite. 65 percent of total bauxite output supplied to the Nikolaev alumina refinery in Ukraine. The rest is exported to other locations.
- The high-grade bauxite resources are depleting. However, CBK has a large license area and is exploring new deposits.
- Bauxite is transported by railway to Conakry, then exported from the port through maximum shipment sizes of 60,000 tons.
- The Conakry port would require important improvements to welcome large capsized vessels.
- RUSAL has a 25-year term to operate CBK mines, until 2026.

FRIA BAUXITE MINE & ALUMINA REFINERY

- This is also one of the oldest bauxite mines and only alumina refinery of Guinea, presently run by RUSAL.
- Fria's bauxite mine has resources of more than 700 MT. However, the requirement of alumina refinery is only about 1 million tons per annum.
- Fria alumina refinery was built in 1960 by Aluminium Pechiney (AP), France and alumina is produced by atmospheric digestion process, which is now obsolete. Present plant capacity is only 0.40 MTPA.
- AP had built one of the alumina plants in India (NALCO) based on the same technology in 1982. The technology has since improved and NALCO now produces 2.1 MTPA, expanding to 3.1 MTPA Alumina.

GAC: Guinea Alumina Corporation / EGA: Emirates Global Aluminium'



- GAC/EGA now owns a former part of the CBG concession, initially developed by Global Alumina and temporarily by BHPB to build a large alumina refinery.
- The bauxite resources of GAC deposits are in the order of 1.4 billion tons. GAC currently exports about 3 MTPA with 46-47% alumina and 2.5% silica.
- GAC has developed a multi-user port terminal and a commercial quay in Kamsar. It improved the rail network connecting the mining sites.
- GAC began bauxite exports to India and China in August 2019, and is expected to produce 12 MTPA.
- EGA has built a 2MTPA alumina refinery in Abu Dhabi based on bauxite from CBG.

COBAD: Compagnie des Bauxites de Dian Dian

- The large Dian-Dian bauxite deposit (~2 Billion Tons) of Boke area, developed by RUSAL, produces high-grade bauxite with 47-48% alumina and <2.5% silica.
- RUSAL plans to increase bauxite production to 7 MTPA and has negotiated an agreement with CBG and GAC to share their rail and port infrastructure.
- This is the 3rd and newest RUSAL operation in Guinea after CBK and Fria. It has a lot more potential.
- Most of COBAD's bauxite is exported to RUSAL's refineries in Russia and Ireland.

ALUFER Mining Company

- Alufer has developed the Bel Air bauxite deposit of about 180 MT near the Boffa coast.

- The bauxite quality of Alufer is quite low: about 45-46% alumina and 5% silica with andalusite mineral, which locks up alumina and silica. The available alumina is in the range of 38-39% (inferior to other Guinea bauxite) and reactive silica is about 1.4%.

- Alufer’s bauxite has limited demand in the world market and is sold at a lower price than other Guinea bauxites.

SMB: Société Minière de Boké

- Founded in 2014, the SMB Winning Consortium has completely changed the landscape of bauxite mining in Guinea.
- SMB has developed 3 large river jetties and today exports more than 30 MTPA.
- SMB started with low grade bauxite and now exports 45-46% alumina and <2% silica bauxite at the lowest production, transportation and freight costs. Acquiring high grade deposit (Houda).
- Thanks to economies of scale and the use of large cape size vessels, it is estimated that their FOB bauxite cost may not exceed US$ 12 per ton.
- SMB mainly supplies bauxite to Weiqiao's own alumina refineries, but also third-party alumina refineries in China.

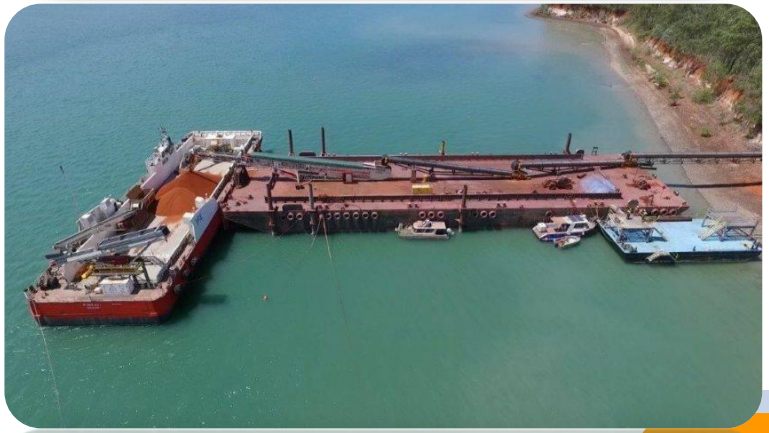
CHALCO

- CHALCO built bauxite mining and export operations in Boffa after taking over mining licenses formerly developed by BHP Billiton.

- CHALCO started bauxite mining in 2018 and plans to export about 12 MTPA to their Chinese alumina refineries.

- CHALCO is also using large capsized (about 200,000 tons) time charter vessels and exporting good quality bauxite (Alumina 45% and <2% silica).

- Its large river jetty is located near the bauxite mines, so the FOB cost of bauxite should be quite low.



AGB2A: Association Guinéenne de Bauxite, d'Alumine et d'Aluminium

- AGB2A, a Guinea based company, produces one of the best metallurgical grade bauxite (46-48% Alumina and <3% silica) by dry beneficiation process involving crushing and screening of ore.

- In the process of beneficiation about 50% high silica fines are generated and thus mining cost of this bauxite is quite high compared to other operations.

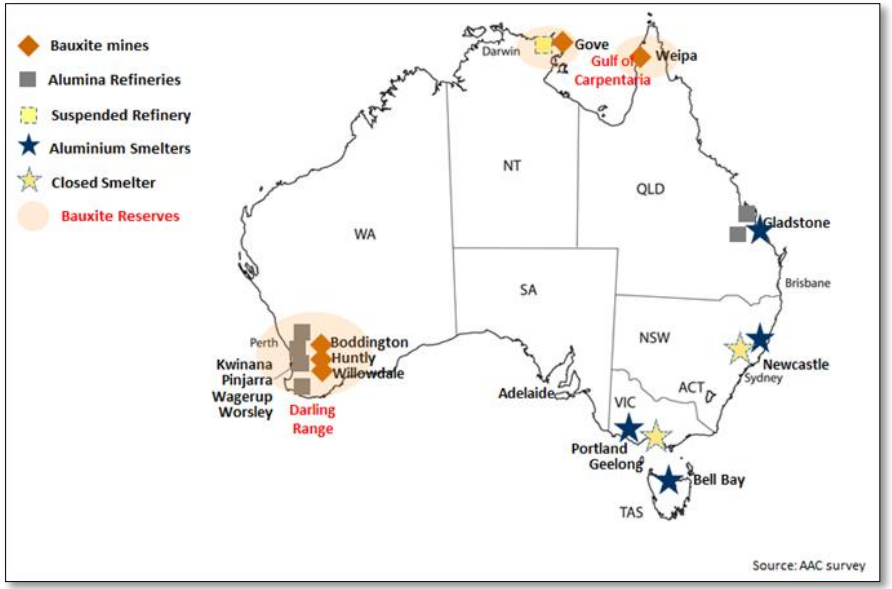
- AGB2A has started bauxite export from its Kokaya port (Boffa) and is likely to produce 3 MTPA, with an agreement to extract minerals from the nearby concession of GBT and Axis Minerals.

GUINEA BAUXITE MINES

S.No.	Bauxite Mine	Resources (Approx.)	Present Mining Capacity in Mt/annum	Quality ROM %Al2O3/ %SiO2	%Available Alumina / %Reactive Silica	Infrastructure	Shipment Sizes in Tonnes	Market Value / FOB Cost/Present Selling Price US$/tonne (Approx.)
1	CBG, Sangareddi	8000	18.0	48-50/1.5-2.0	42-46/1.2-1.6	Rail Line & Port	60,000	High value/23/34
2	CBK, Kindia	200	3.1	44-45/3-3.5	40-41/1.5-1.8	Rail Line & Port	50,000	Medium value/20/31
3	Fria Bauxite Mine	700	1.0	44-45/2-2.5	41-42/1.4-1.6	By Trucks to Plant	Alumina	Reserved for Alumina Plant
4	GAC/EGA, Boke	1400	3.0	45-47/1.8-2.2	41-43/1.2-1.6	Rail Line & Port	60,000 to 100,000	Medium value / 16/32
5	COBAD, Boke	2000	3.0	46-48/1.8-2.2	42-44/1.4-1.6	Barges & Rail Line	60,000 to 100,000	High value/22.7/33
6	Alufer, BelAir	200	3.0	45-45/5-6	38-39/1.4-1.6	Near sea coast, loading by barges	100,000 to 200,000	Low value/16/30
7	SMB, Winning Group	700	30	44-45/1.8-2.4	40-42/1.2-1.6	Road & River jetty with large barges	180,000 to 300,000	High value /12/31
8	CHALCO	500	12	44-45/1.8-2.4	40-42/1.2-1.6	Road & River port	180,000 to 300,000	Medium value/18/32
9	AGB2A	320 (GBT+Axis)	3	46-48/3.0-3.5	43-45/1.2-1.4	Trucks & River Port	100,000 to 220,000	Medium value/20/30

%Available Alumina / %Reactive Silica At low Temperture & Medium Pressure

AUSTRALIA BAUXITE

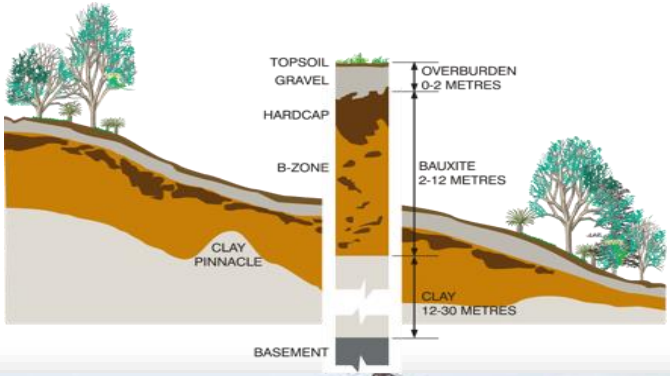


1. Boddington – South 32 – Worsley Alumina
2. Gove – Pacific Aluminium – Now shut down and Bauxite is exported.

1. Huntly – Alcoa of Australia
2. Willowdale - Alcoa of Australia
3. Weipa – Rio Tinto Alcan

- Australia is the world's biggest bauxite producer, about 117 million tonnes (MT) of bauxite was mined in 2019.
- 34.5 MT is exported mainly from Weipa and Gove mines of Northern Territory.
- Cheap open cast mines and developed infrastructure.
- Five major companies, engaged in bauxite mining and alumina production in Australia.

AUSTRALIAN BAUXITE



ALCOA (Alcoa Worldwide Alumina and Chemicals (AWAC)

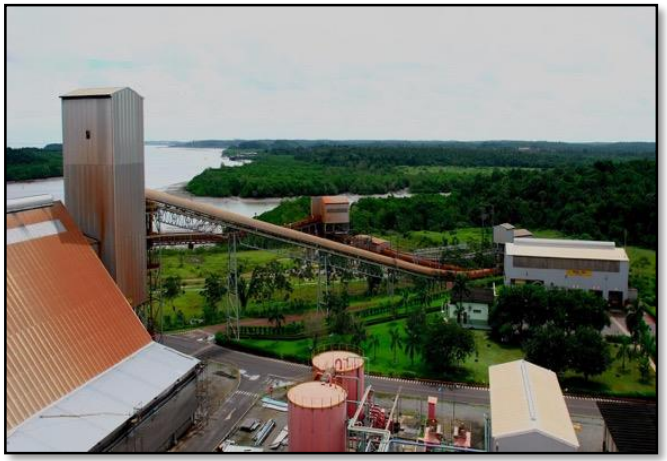
Bauxite Export – Australia-Weipa

BRAZIL BAUXITE

- Brazil produced about 30 Million tonnes of bauxite during 2019.
- Brazil bauxite resources are estimated as 26 Billion tonnes. However, has high silica (8 to 15%) & requires washing: costlier compared to DSO (Direct Shipping Ore), however, preferred by refinery.
- **Mineração Rio do Norte** (MRN) owns the biggest mine of Brazil and has largest alumina refinery of world having capacity of 6Mtpa.
- Second largest mine **Paragominas mine** operated by Vale and has a capacity of 5.4 million tonne per year. Following that is **Juruti mine** operated by Alcoa and has capacity of 2.6 million tonne per year.

Brazil-Surface Mining

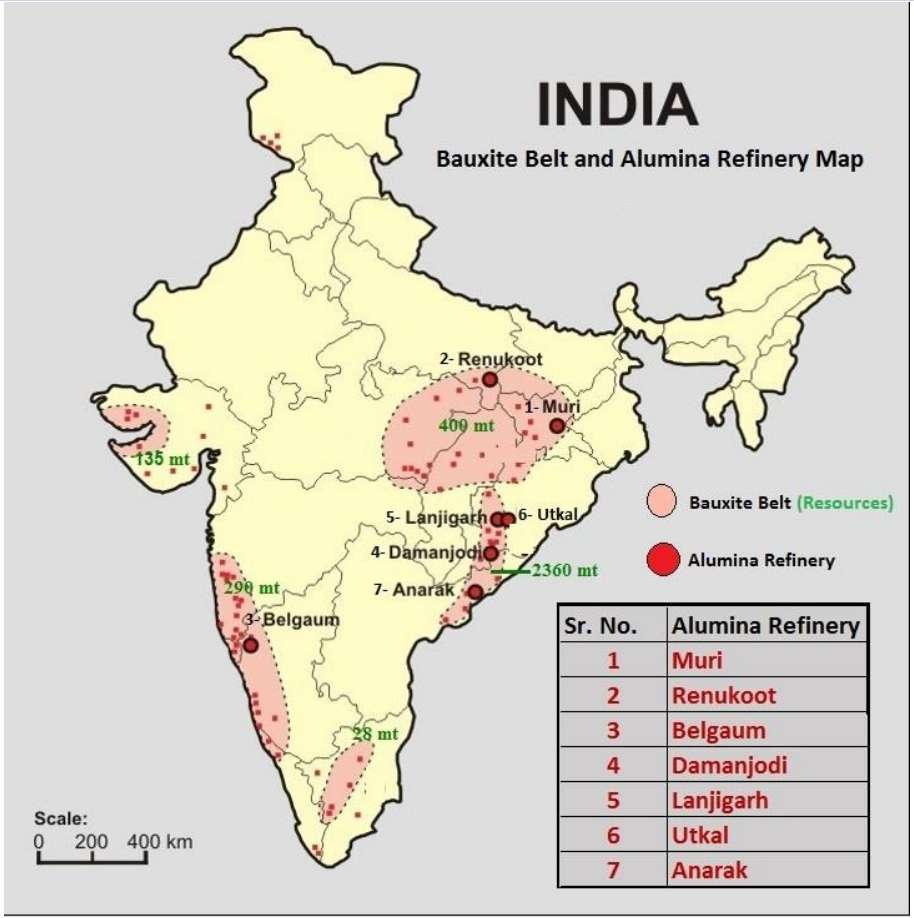
Mining and Refining Trombetas, Brazil



Brazil Alumina

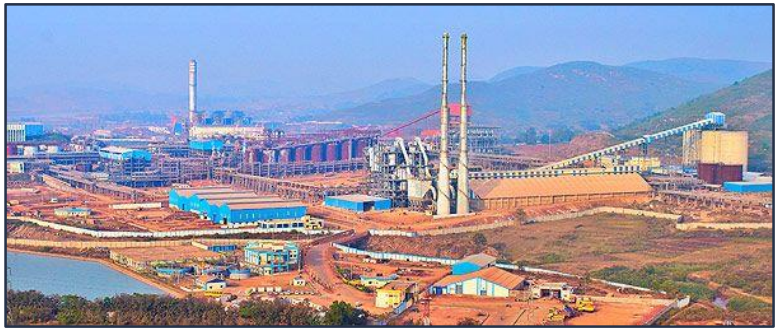
Paragominas mine in Northern Brazil

BAUXITE DEPOSITS & ALUMINA REFINERIES INDIA



Sr. No.	Alumina Refinery
1	Muri
2	Renukoot
3	Belgaum
4	Damanjodi
5	Lanjigarh
6	Utkal
7	Anarak

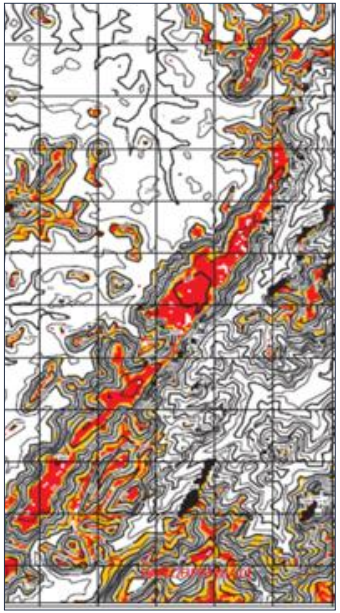
Panchpatmali Bauxite Mine of NALCO



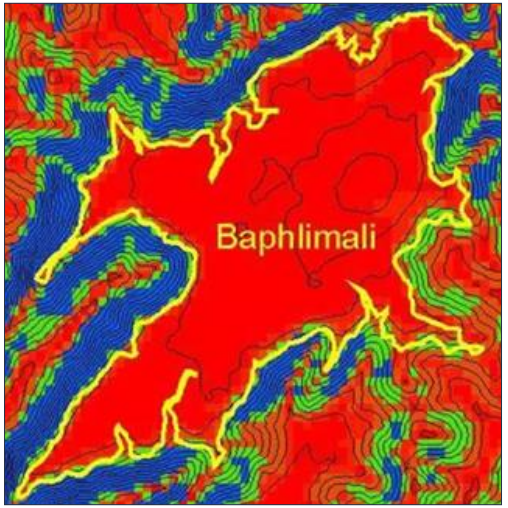
Utkal Alumina Plant of HINDALCO

Eastern Ghats Bauxite Deposits / Mines, India

Panchpatmali Lateritic Bauxite Plateau, India



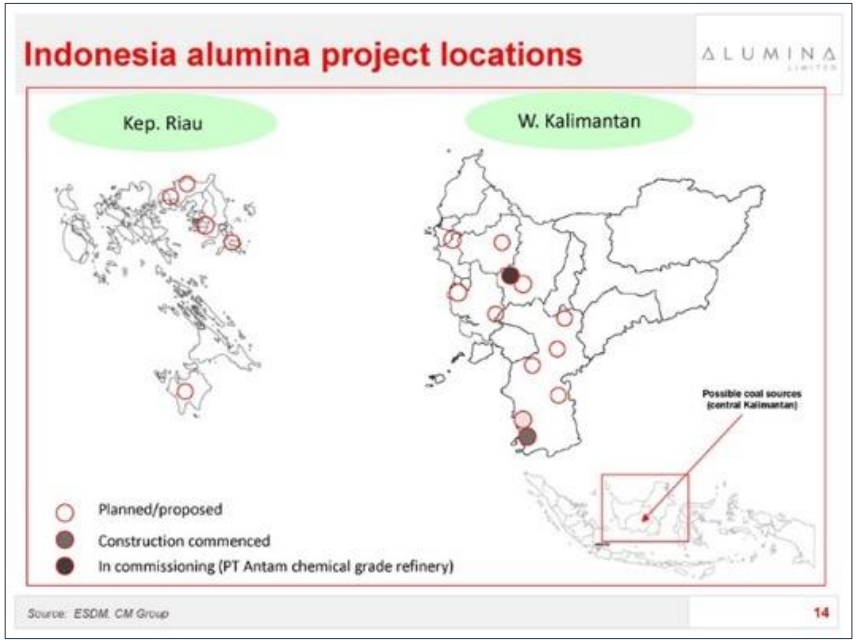
NALCO Panchpatmali Bauxite Deposit of Odisha



Baphlimali Bauxite Deposit of UTKAL Alumina HINDALCO

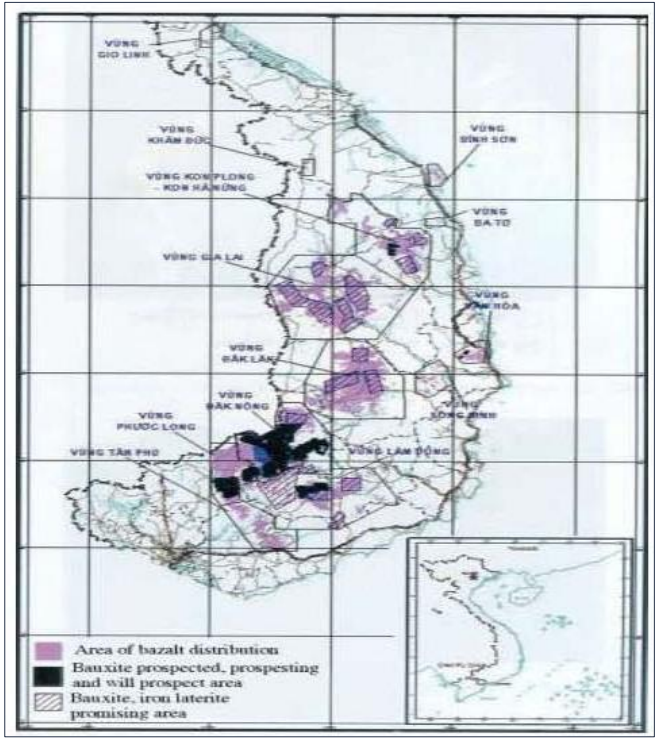
INDONESIA BAUXITE

- Indonesia produced 6.5 million tons of bauxite during 2019 and resources estimated at 12 Billion tons. Bauxite mining is cheap, however, ore requires washing to partly eliminate silica. Primitive wet beneficiation process is employed.
- Bauxite export was restricted in 2014 and requested companies to set up alumina refineries in the country
- Kendawangan mine- large mine located in Indonesia in the province of West Kalimantan
- Tayan mine- large mine located in the eastern part of Indonesia in West Kalimantan.



BAUXITE MINING IN WEST KALIMANTAN

VIETNAM BAUXITE



- Vietnam produced 3.6 Million tonnes of bauxite during 2019. They have huge bauxite resources, however, this ore requires washing, which increases the cost of bauxite.
- The majority of Vietnam's reserves are located in the Central Highlands (Tây Nguyên) and have only been minimally mined.
- The Vietnamese government plans to develop an integrated bauxite, alumina, and aluminium industry. Vinacomin is running about 0.65Mtpa of Tan Rai Alumina Refinery in Lam Dong province.

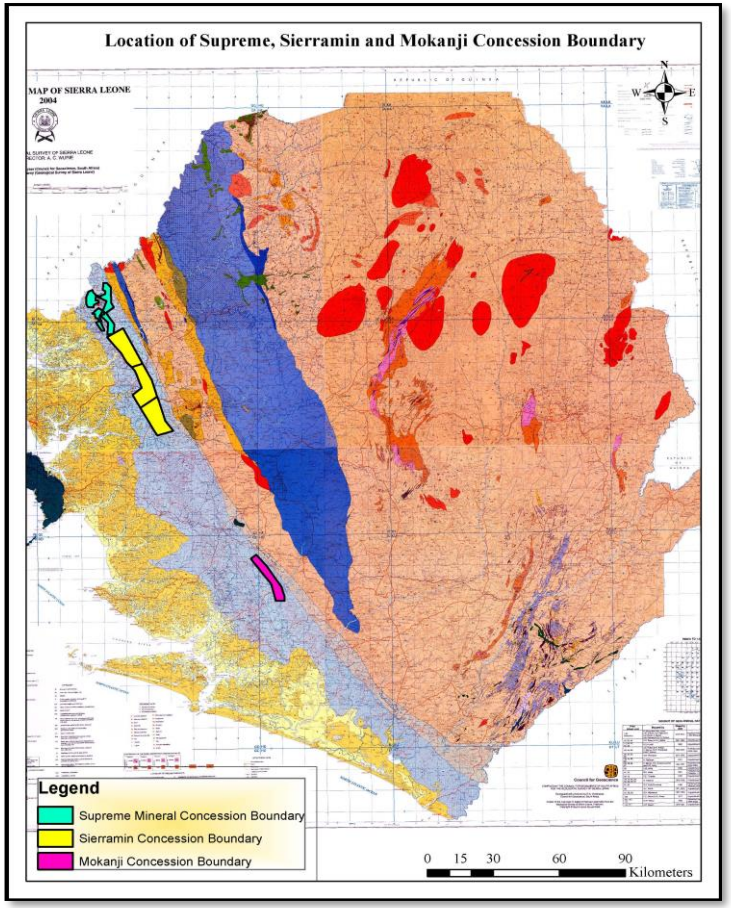
VIETNAM (CONTD.)

Tan Rai bauxite mining in Central Highlands, Vietnam

Central Highlands bauxite mines

Bauxite Mining in Vietnam

SIERRA LEONE BAUXITE



- Total resources in Sierra Leone are estimated to be about 500 MT.
- Total production of bauxite in Sierra Leone in year 2020 was approximately 1.77 million tonnes of washed bauxite.
- The Sierra Leone bauxite requires washing and this produces one of the best quality ore in the world.
- There are several known bauxite deposits like Gondama-Mokanji, Port Loko and Kambia deposits.

GUYANA BAUXITE

- Guyana's reserves of bauxite was known to be 350 million tons.
- The projected bauxite import for 2020 to get a rise by 11.16%, as the total import was recorded at 2.19 million tonnes.
- Major mining sites are at Linden, south of Georgetown, and Kwakwani on the Berbice River.

BAUXITE BENEFICIATION - ISSUES AND OPPORTUNITIES

Issues

- Depletion of high-grade bauxite in the world
- Upgradation of the ore before feeding to alumina refinery
- Limitations of International Maritime Authority for transportation of cargos
- Cost of raw material and energy resources for Alumina plants

Opportunities

- Effective utilization of resources and reserves of medium and low-grade ore
- Control over environmental impact from bauxite residue
- Ensuring safe transportation of ore and Optimization of freight costs
- Development of cheaper energy generating units

OBJECTIVES

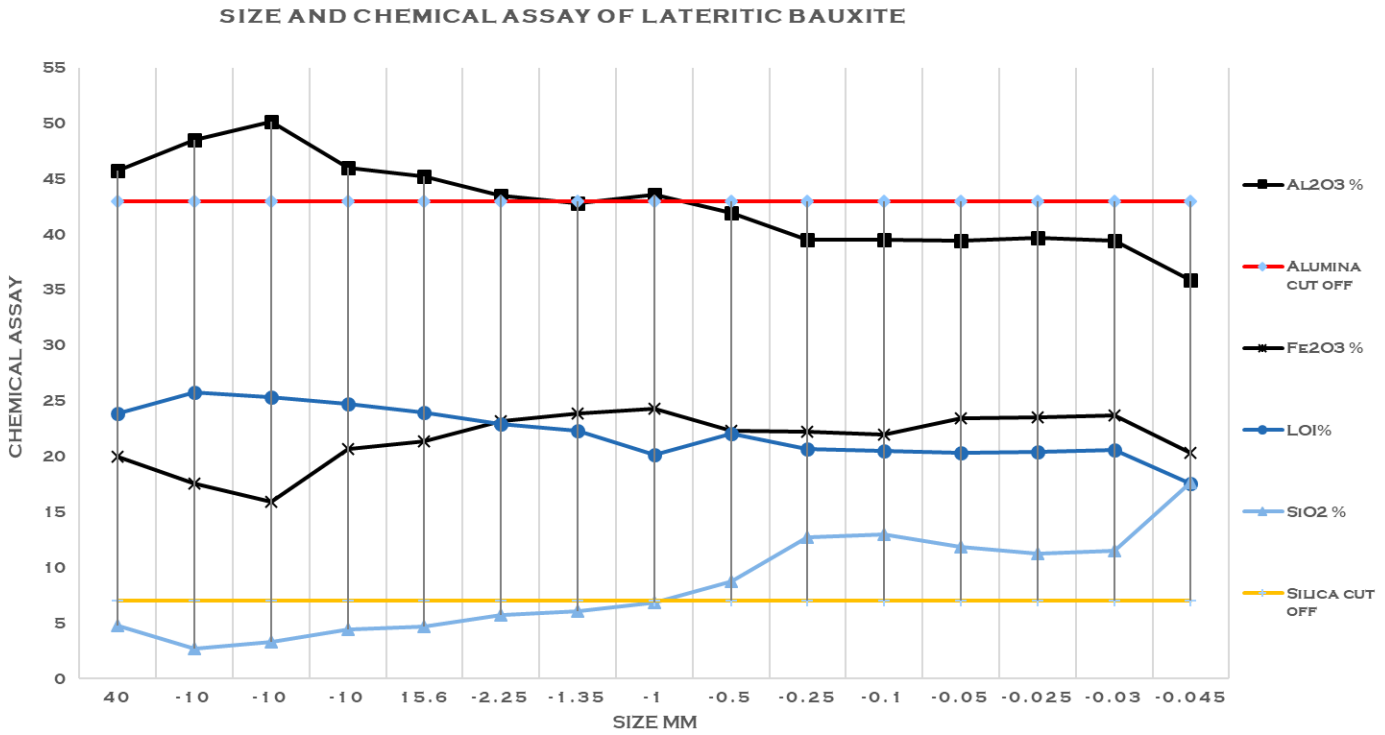
Beneficiation for Metallurgical Industry

- To Increase Value Creation
  - ✓ by reducing/removing the cost for chemicals for leaching
  - ✓ by reducing cost for waste disposal
  - ✓ by separation of iron bearing materials as a product for sales
- To Improve Lifetime of Mine Operations

Beneficiation for Non-Metallurgical Industry

- To Increase Value Creation
  - ➢ by bringing down iron and titanium contents
  - ➢ by enhancing alumina values
  - ➢ by liberating the iron minerals via magnetic separation
- To Effectively Utilize Low Grades of Bauxite

BENEFICIATION – METALLURGICAL BAUXITE



BAUXITE MINERALOGY – UN-WASHED AND WASHED

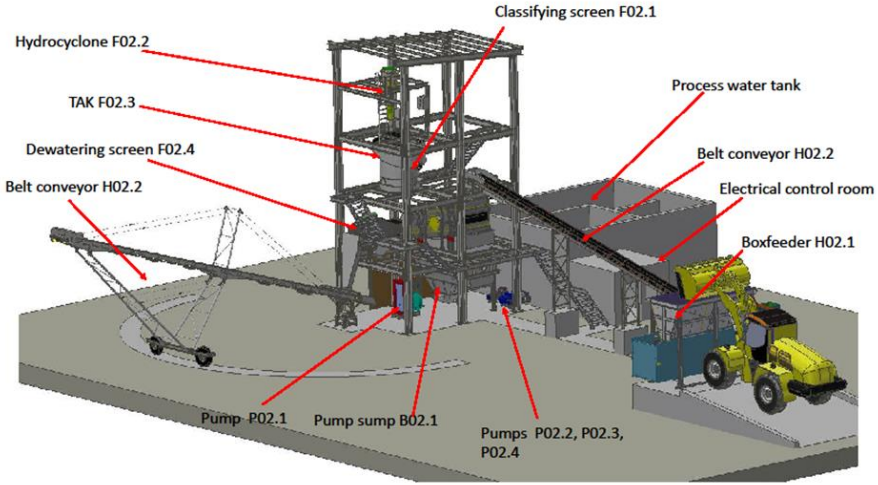
Un-washed

Phase%	SUM 99.40	GibS 56.00	Boeh 0.00	KaoT 10.50	Quar 2.00	Hema 2.50	Goet 23.50	Ilme 4.50	Anat 0.30	Ruti 0.10	Chem Anal	Diff
Fe_2O_3%	23.88					2.50	19.02	2.37			23.88	0.00
TiO_2%	2.77							2.37	0.30	0.10	2.93	0.16
SiO_2%	6.89			4.89	2.00						6.81	-0.08
Al_2O_3%	42.73	36.60		4.15			1.99				42.02	-0.71
H_2O%	23.36	19.40		1.47			2.50					
LOI %	23.36	19.40	0.00	1.47	0.00	0.00	2.50	0.00	0.00	0.00	23.74	0.38

Washed

Phase%	SUM 99.30	GibS 71.50	KaoT 6.00	Goet 17.00	Hema 2.50	Anat 0.20	Ruti 0.20	Ilme 1.50	Quar 0.40	Chem Anal	Diff
Fe_2O_3%	16.45			13.16	2.50			0.79		16.21	-0.24
TiO_2%	1.19					0.20	0.20	0.79		1.22	0.03
SiO_2%	3.19		2.79						0.40	3.20	0.01
Al_2O_3%	51.11	46.73	2.37	2.01						50.55	-0.56
H_2O%	27.45	24.77	0.84	1.84							
LOI %	27.44	24.77	0.84	1.84	0.00	0.00	0.00	0.00	0.00	28.40	0.96

DRY & WET BAUXITE BENEFICIATION PLANTS



INDIAN SCENARIO

- Despite having large resources of bauxite, some of the alumina plants in India are starving for this basic raw material.

- With increasing demand of aluminium metal in the country, there are limited opportunities to enhance the output of alumina for sustaining production in smelters and meet the demand.

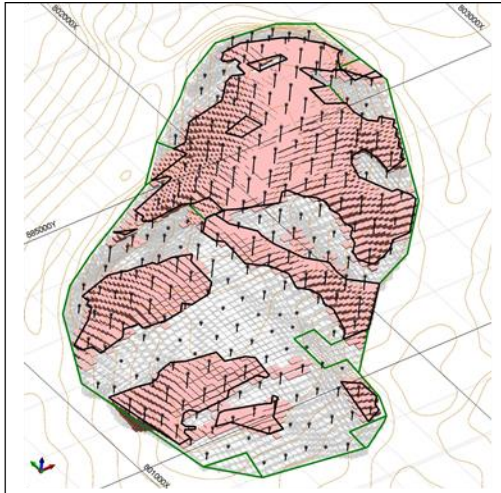
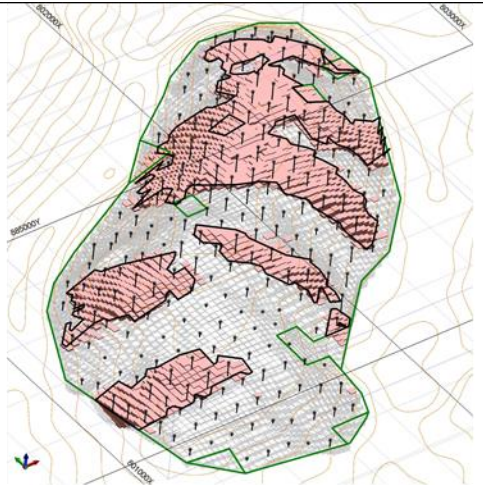
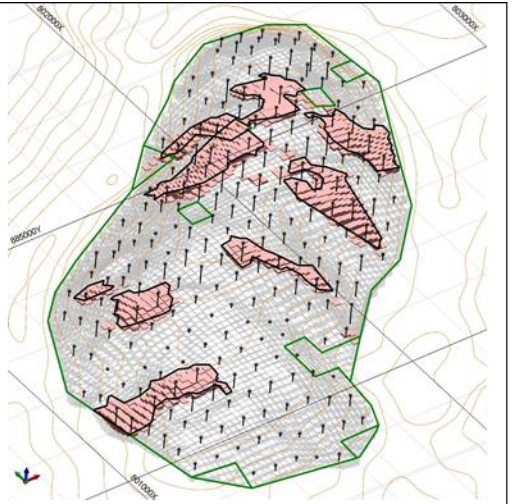
- Delay in bauxite auctioning process and limited availability of local laterites and bauxite further affect the smooth functioning of alumina plants in India. For the last 10 years, no large bauxite deposits were auctioned and plants are compelled to import ore from Africa.

INCREASE RESOURCES IN EXISTING MINES /DEPOSITS

Adopt Natural Cut-off Grade - Bauxite resources of India can be increased by adopting natural cut-off grade of alumina and silica.

Pariculars	Cut-offs Al_2O_3 ≥35%, SiO_2≤10%, ≥1m	Cut-offs Al_2O_3 ≥40%, SiO_2≤9%, ≥1m	Cut-offs Al_2O_3 ≥42%, SiO_2≤6%, ≥1m
No. of Bore Holes	234	234	234
No. of Positive Holes	134	92	56
Av. Bauxite Thickness	5.74m	4.44m	3.63m
Ore Tonnage in MT	9.26	5.43	2.67
Av. % Al_2O_3	41.2	43.23	44.36
Av % SiO_2	6.07	5.47	4.13

INCREASE RESOURCES IN EXISTING MINES (CONTD.)

		
Orebody disposition at 35/10 cut off	**Orebody disposition at 40/9 cut off**	**Orebody disposition at 42/6 cut off**

BAUXITE BENEFICIATION IN INDIA

- Except in Gujarat and Maharashtra, no serious attempts have been made in India to upgrade low grade resources in the mines.

- Some of Eastern Ghats bauxite mines have high silica zones and they are presently rejected during mining. It is necessary to establish resources and grades of low grade bauxite in all the working mines and adopt suitable dry and / or wet beneficiation process to improve the quality.

- All overburden laterites of Eastern Ghats should be beneficiated and used.

OPPORTUNITIES FOR INDIA

- Similar to China, India should consider to set up port-based alumina refinery, which can regularly use imported bauxite as well some of the inland ore. In this case a long-term bauxite import strategy can be developed.

- Countries like Guinea, Sierra Leone, Cameroon, Indonesia, Vietnam and Venezuela have rich bauxite resources and they welcome to set up alumina refineries in their country.

- An alumina refinery and smelter can be planned in one of the Gulf countries having cheap energy and other raw material resources like caustic soda for alumina production.

International Bauxite, Alumina & Aluminium Society (IBAAS)

Jointly with

Jawaharlal Nehru Aluminium Research Development and Design Centre (JNARDDC)

Presents

10th IBAAS International Conference & Exhibition (IBAAS-JNARDDC 2022)

'Sustainability Challenges of Bauxite, Alumina & Aluminium Industry'

With Special Sessions on

Sustainability by Aluminium Stewardship Initiative (September 16)
and
One day Brainstorming on Non-Ferrous Metal Recycling in India to be organized by JNARDDC (September 17)

September 14-17, 2022
Courtyard Marriott
Raipur, India

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Thank You

Dr. Ashok Nandi, President

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