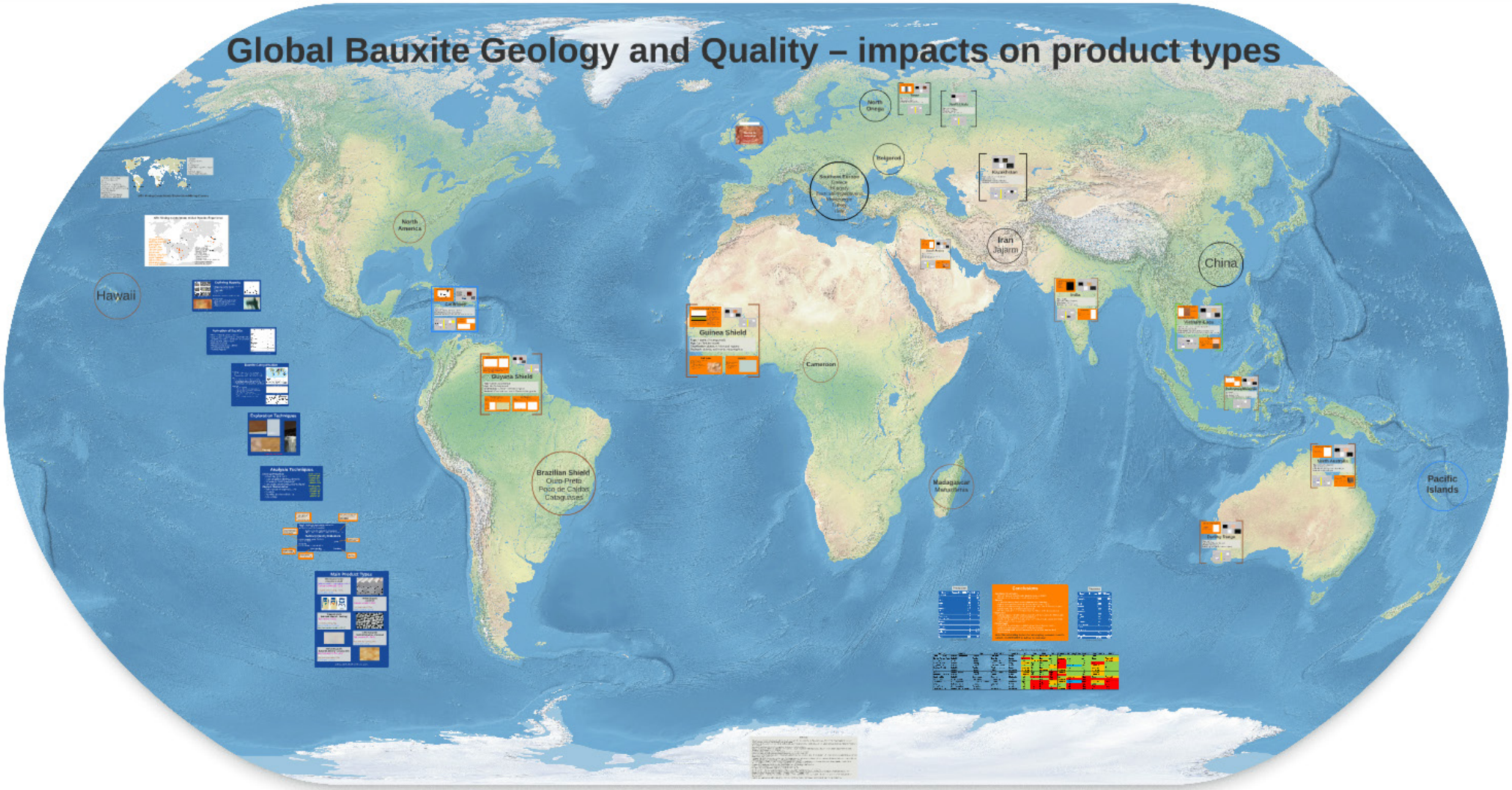
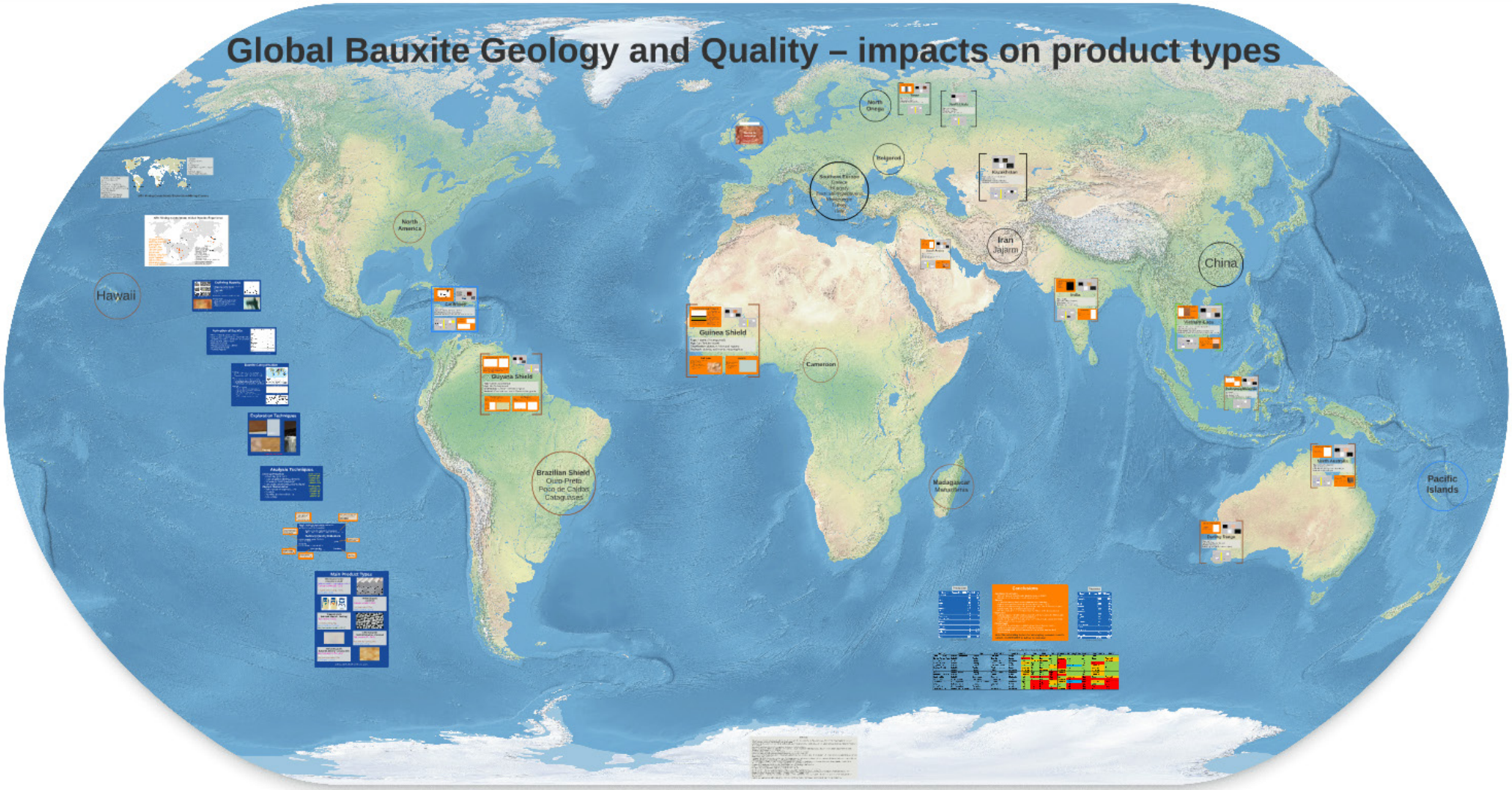
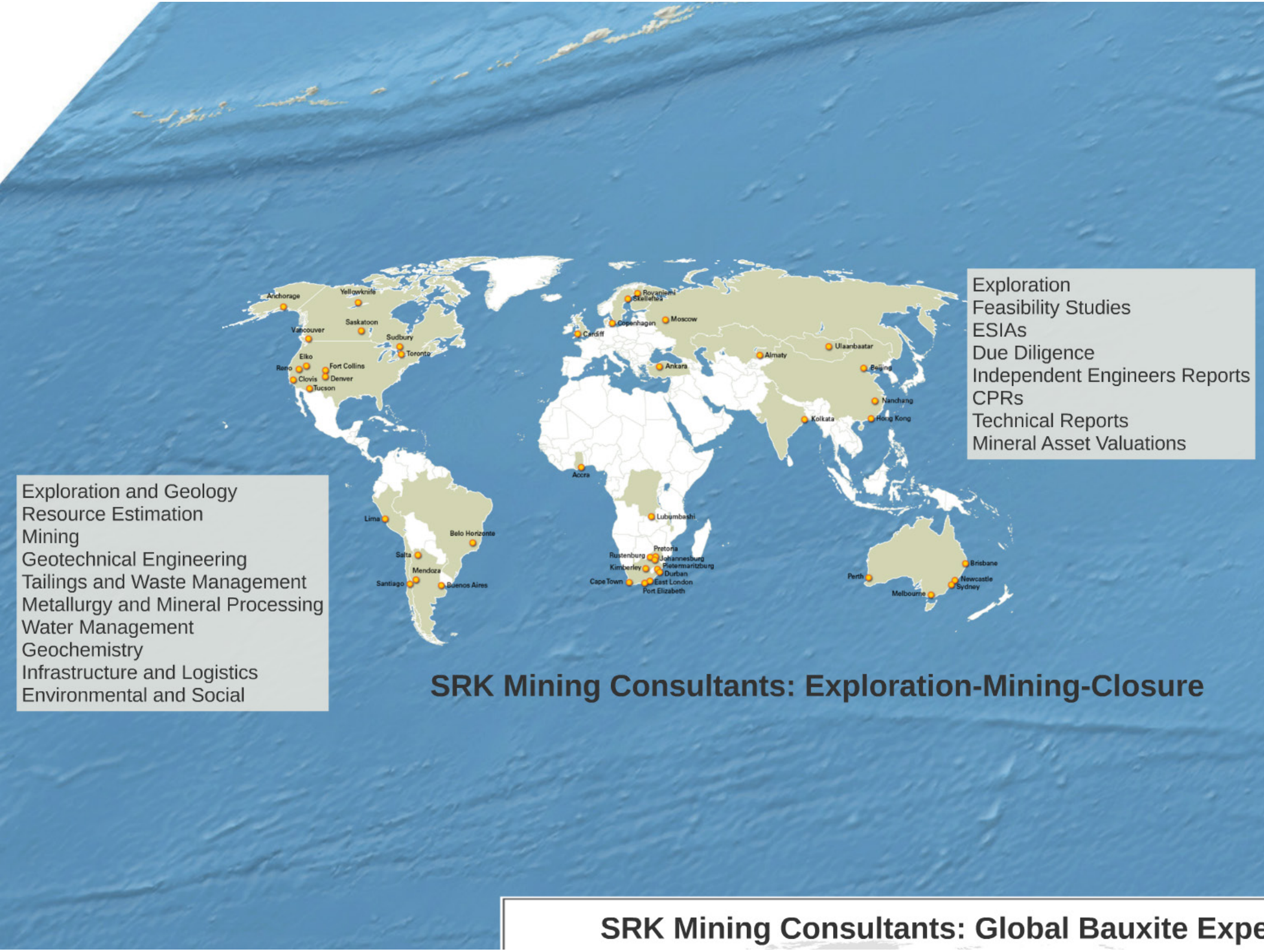

Global Bauxite Geology and Quality – impacts on product types
North America
Hawaii
Guyana Shield
Brazilian Shield
Guinea Shield
Cameroon
Iran
Jajarm
China
Pacific Islands


Global Bauxite Geology and Quality – impacts on product types
North America
Hawaii
Guyana Shield
Brazilian Shield
Guinea Shield
Cameroon
Iran
Jajarm
China
Pacific Islands



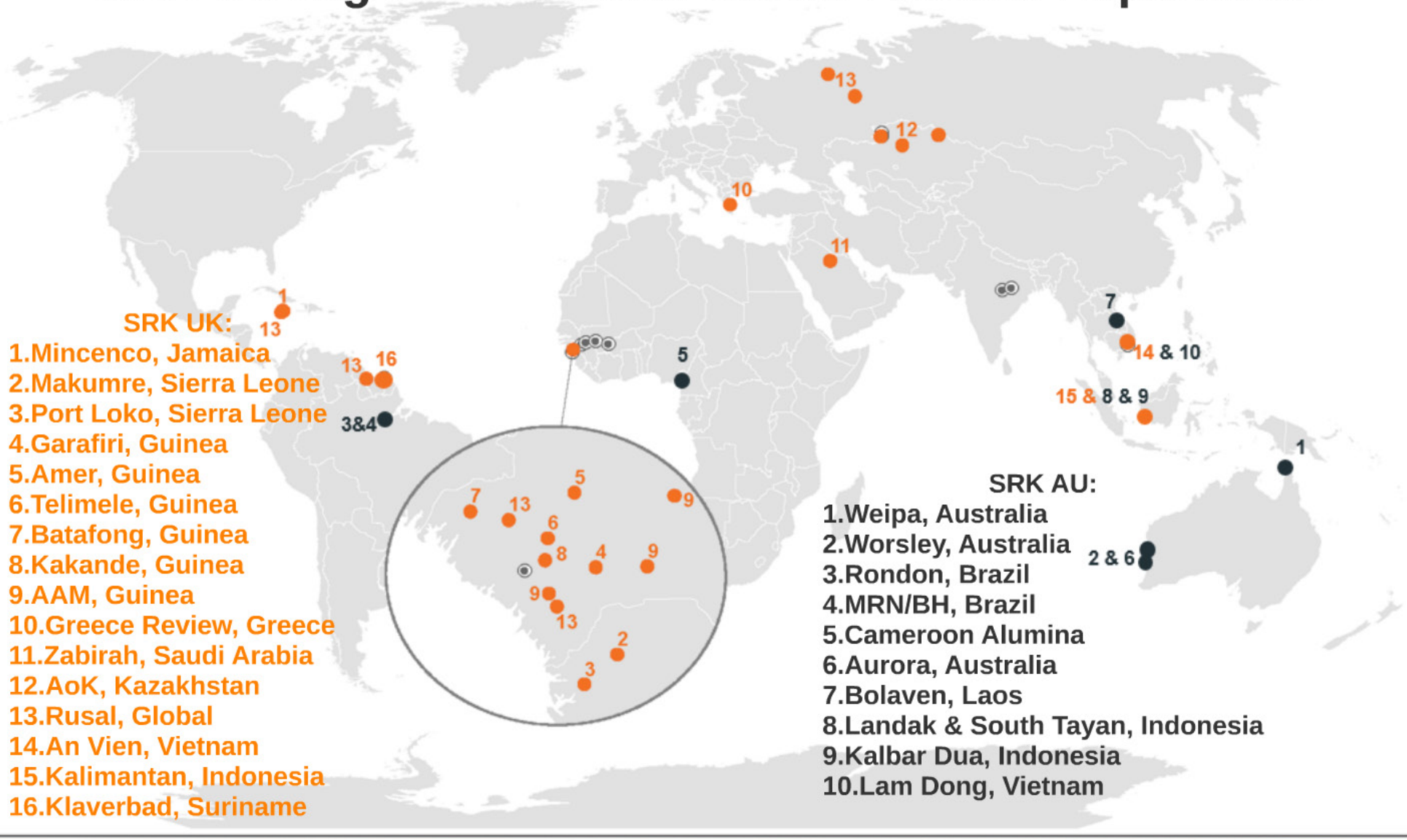
Exploration
Feasibility Studies
ESIAs
Due Diligence
Independent Engineers Reports
CPRs
Technical Reports
Mineral Asset Valuations

Exploration and Geology
Resource Estimation
Mining
Geotechnical Engineering
Tailings and Waste Management
Metallurgy and Mineral Processing
Water Management
Geochemistry
Infrastructure and Logistics
Environmental and Social

SRK Mining Consultants: Exploration-Mining-Closure

SRK Mining Consultants: Global Bauxite Expe

SRK Mining Consultants: Global Bauxite Experience



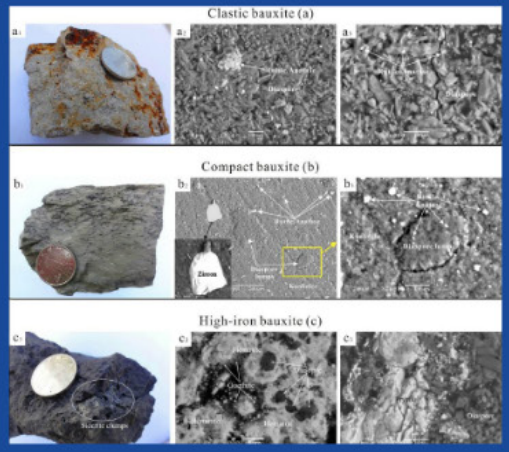
SRK UK:

1. Mincenco, Jamaica
2. Makumre, Sierra Leone
3. Port Loko, Sierra Leone
4. Garafiri, Guinea
5. Amer, Guinea
6. Telimele, Guinea
7. Batafong, Guinea
8. Kakande, Guinea
9. AAM, Guinea
10. Greece Review, Greece
11. Zabirah, Saudi Arabia
12. AoK, Kazakhstan
13. Rusal, Global
14. An Vien, Vietnam
15. Kalimantan, Indonesia
16. Klaverbad, Suriname

SRK AU:

1. Weipa, Australia
2. Worsley, Australia
3. Rondon, Brazil
4. MRN/BH, Brazil
5. Cameroon Alumina
6. Aurora, Australia
7. Bolaven, Laos
8. Landak & South Tayan, Indonesia
9. Kalbar Dua, Indonesia
10. Lam Dong, Vietnam

Defining Bauxite

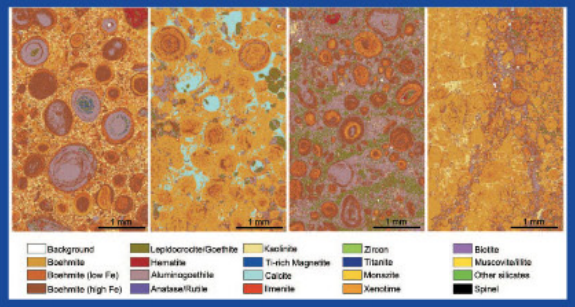


Source: Ling et al (2017)

Aluminium-rich soil comprising oxides and clays:

- Al-oxides: trihydrate + monohydrate
- Fe-oxides: goethite + hematite
- Clays: kaolinite
- Quartz
- Rutile+anatase

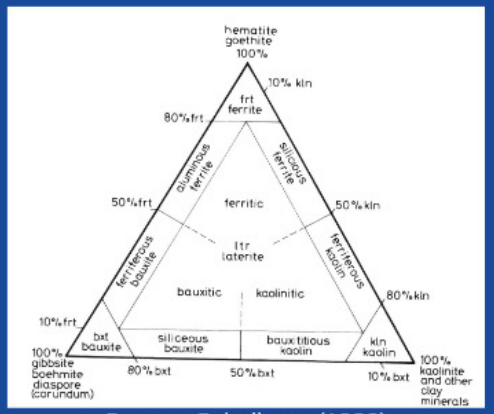
Fresh>kaolinisation>laterisation>bauxitisation



Source: Boni et al (2013)

Economic bauxite:

- Can it be processed to create a product?
- Bx export vs integrated alumina refinery?
- Mineralogy and chemistry ?
- Infrastructure and logistics to market?
- OPEX and CAPEX?



Source: Schellman (1982)

Formation of Bauxite

- Wet and warm (equatorial) climate
- Stable tectonic regime with lack of uplift (lateritic)
- Groundwater regime controlling eH-pH conditions
- Host rock with alumina >10%
- Permeable host rock
- Plateaux / gentle slopes (lateritic)
- Low erosion (hard cap)
- Moderate vegetation

Rock types	Number of bauxite districts or groups of deposits	Percentage of tonnage	
Granite	10	9.0	
Diorite, granodiorite	2	1.3	
Monzonite	1	0.7	
Anorthosite	1	0.2	plutonic rocks
Leucogabbro	1	0.1	15.5%
Gabbro, norite	5	3.0	
Syenite	1	0.1	
Nepheline syenite, foyalite	5	0.8	
Dunite, peridotite	1	0.3	
Dolerite	16	17.1	
Pyroxenite	1	0.1	hypabyssal rocks
Tinguaite	1	0.1	17.3%
Metasomatized dolostone	1	0.1	
Rhyolite	2	0.1	
Trachyte	2	0.1	
Andesite	5	0.9	volcanic rocks
Basalt	22	19.0	20.3%
Phonolite	2	0.1	
Undifferenciated volcanic rocks	1	0.1	
Metavolcanites (basic)	2	0.5	
Greenstone	5	1.5	
Schist (mainly sericitic)	10	1.2	metamorphic rocks
Amphibolite	7	0.3	12.8%
Hornfels	3	0.8	
Gneiss, granite-gneiss	2	0.8	
Granulite (charnockite, khondalite, etc).	6	7.7	
Kaolinitic sandy clay	4	10.6	
Shale, slate	10	10.0	sedimentary rocks
Kaolinitic siltstone, -sandstone	2	0.4	34.1%
Arkosic sandstone, -siltstone	10	12.9	
Graywacke	2	0.2	

Source: Bardossy and Aleva (1990)

Bauxite Categorisation

Bauxite Categorisation

Ore Genesis

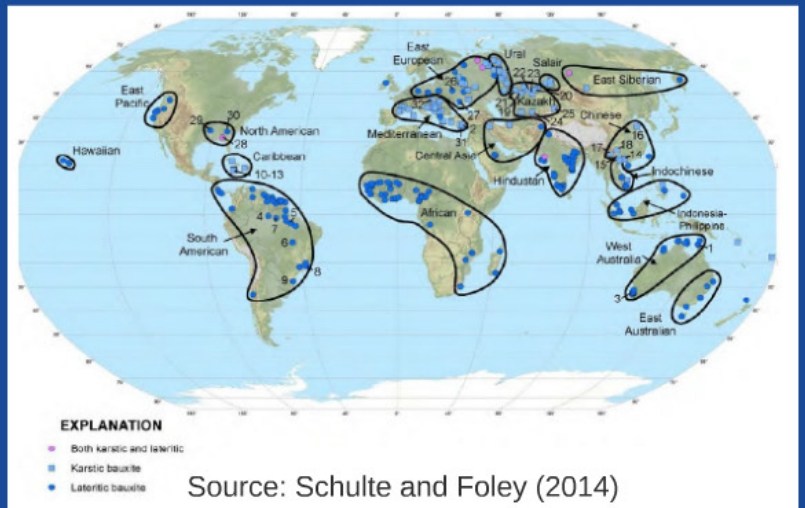
- **Lateritic** = blanket deposits generally plateau-bound
- **Karst** = dissolution + weathering of karstic infill material
- **Sedimentary** (transported) = eroded bauxite re-bauxitised

Age

- Majority mid-Tertiary (Eocene-Miocene ~50 to 5Ma)
- Throughout geologic record - notable periods last for <10Ma
- Ancient bauxites protected by re-silication or ferricrust
- Forming today (e.g. Indochinese peninsula, Pacific Islands)

Mineralogy

- Dominantly monohydrate
  - High seasonality (fluctuation of ground water) = dehydration of primary trihydrate to monohydrate
  - Higher drainage (karst)
  - Burial / compaction = monohydrate
- Dominantly gibbsitic/trihydrate (with <3% monohydrate)
  - Recent
  - Low seasonality with constant high humidity



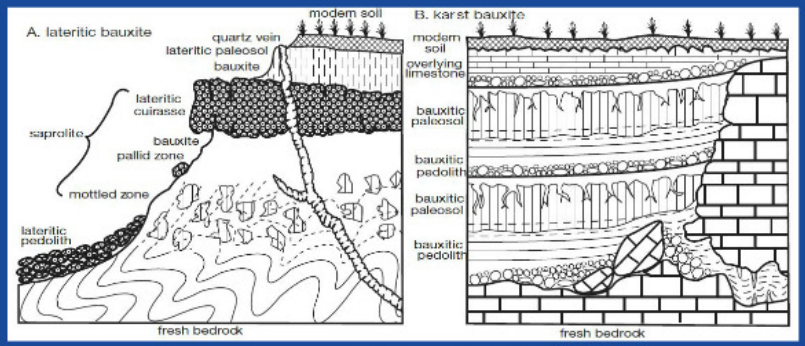
Source: Schulte and Foley (2014)

Figure 1. World map showing distribution of bauxite deposits. Major bauxite provinces are identified. Selected deposits are indicated with numbers: 1–Weipa, Australia; 2–Doğankuzu, Turkey; 3–Darling Range, Australia; 4–Pitinga, Brazil; 5–Tucuruí, Brazil; 6–Paragominos, Brazil; 7–Porto Trombetas, Brazil; 8–Cataguases, Brazil; 9–Poço de Caldas, Brazil; 10–Saint Ann, Jamaica; 11–Saint Catherine, Jamaica; 12–Saint Elizabeth, Jamaica; 13–Manchester, Jamaica; 14–Dajia, China; 15–Xinxu, China; 16–Nanling, China; 17–Kunmin, China; 18–Queyang, China; 19–Arqalyk, Kazakhstan; 20–Eksibatoz-Pavlodar, Kazakhstan; 21–Naurzum, Kazakhstan; 22–Astana, Kazakhstan; 23–Açtas, Kazakhstan; 24–Shimkent, Kazakhstan; 25–Ili, Kazakhstan; 26–Pripyat, Ukraine; 27–Vysokopf'ye, Ukraine; 28–Eufaula, United States; 29–Pulaski-Saline, United States; 30–Hall-Veneer, United States; 31–Maşaldağı, Turkey; 32–Iszkaszentgyörgy, Hungary.

Dominant Mineralogy

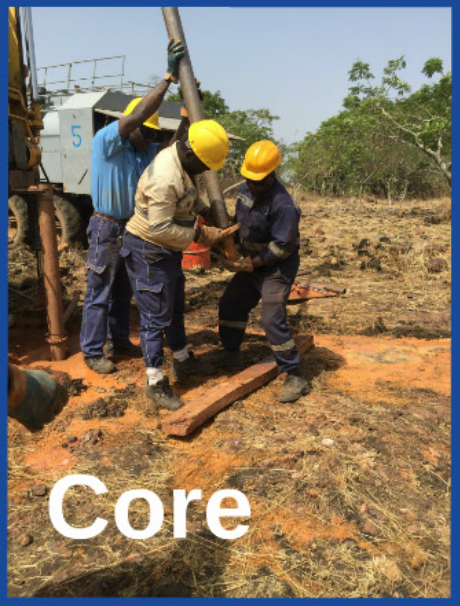
Oxide	Lateritic	Karst
Al_2O_3	Gibbsite, Boehmite, Kaolinite, Aluminogoethite	Boehmite, Diaspore, Kaolinite
SiO_2	Kaolinite, Quartz	Quartz, Kaolinite, Chamosite, Illite
Fe_2O_3	Goethite, Hematite	Hematite, Goethite, Maghemite, Magnetite
TiO_2	Anatase, Rutile	Anatase, Rutile, Ilmenite
CaO	Calcite, Apatite	Calcite, Apatite, Crandallite

Source: Smith (2008)



Source: Retallack (2010)

Exploration Techniques



Lateritic vs Karstic

Analysis Techniques

Chemical Properties

- Chemistry (XRF/ICP)
- Loss on ignition (thermograimetry)
- Mineralogy (XRD/QEMSCAN)
- Extractable alumina/silica (bomb digest)

Physical Characteristics

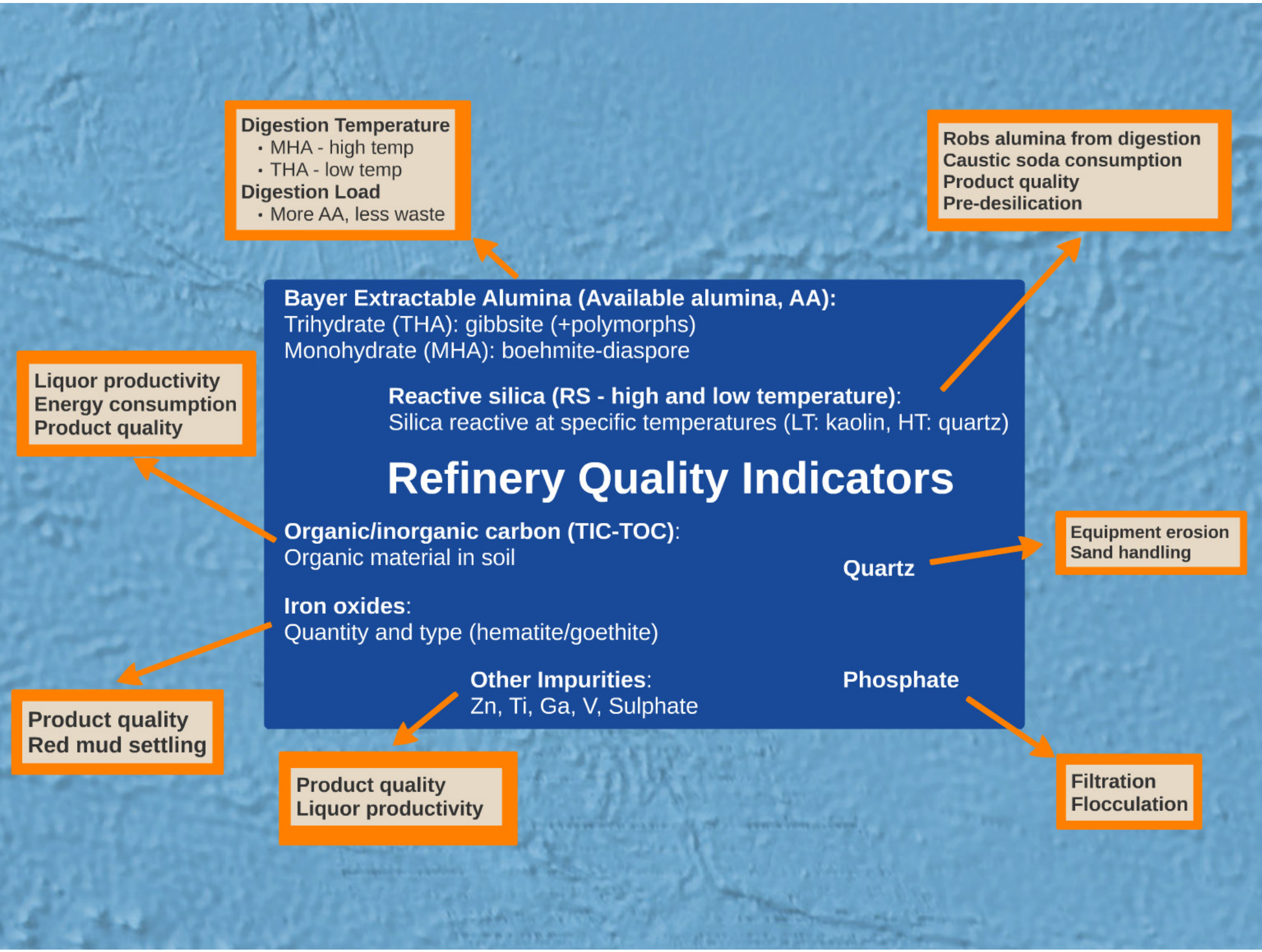
- Bulk Density (in-situ/moist, dry)
- Moisture
- Digability (hardness/friability)
- Washability

Alumina content:

- **Boehmite: 85%**
- **Diaspore: 85%**
- **Gibbsite: 65%**
- **Kaolinite: 39%**
- **Goethite: 0-35%**

Mineral Density:

- **Gibbsite: 2.4**
- **Boehmite: 3.0**
- **Diaspore: 3.4**
- **Kaolinite: 2.6**
- **Goethite: 4.2**
- **Hematite: 5.3**


Digestion Temperature
• MHA - high temp
• THA - low temp
Digestion Load
• More AA, less waste
Robs alumina from digestion
Caustic soda consumption
Product quality
Pre-desilication
Bayer Extractable Alumina (Available alumina, AA):
Trihydrate (THA): gibbsite (+polymorphs)
Monohydrate (MHA): boehmite-diaspore
Reactive silica (RS - high and low temperature):
Silica reactive at specific temperatures (LT: kaolin, HT: quartz)
Refinery Quality Indicators
Liquor productivity
Energy consumption
Product quality
Organic/inorganic carbon (TIC-TOC):
Organic material in soil
Quartz
Equipment erosion
Sand handling
Iron oxides:
Quantity and type (hematite/goethite)
Other Impurities:
Zn, Ti, Ga, V, Sulphate
Phosphate
Product quality
Red mud settling
Product quality
Liquor productivity
Filtration
Flocculation

Main Product Types

Metallurgical Grade
(aluminium metal)
Refinery-specific (mineralogy critical)
Elevated alumina (35 - 55%)
Low silica (<15%)
Elevated iron oxide (5 - 30%)
Low titania (<6%)

Industrial grade
(cement)
Elevated alumina (~50%)
Elevated silica (<20%)
Low iron oxide (<7%)
Moderate titania (<5%)

Proppant grade
(calcined alumina - fracking)
High alumina (>55%)
Very low silica (<5%)
Low iron oxide (<6%)
Moderate titania (>2.5%)
Very low calcium oxide (<0.1%)

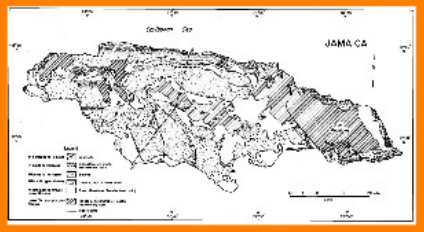
Chemical grade
(calcined alumina - chemical)
High alumina (55 - 58%)
Low silica (5 - 12%)
Very low iron oxide (<2%)
Low titania (<6%)

Refractory grade
(calcined alumina - construction)
Very high alumina (59 - 61%)
Very low silica (1.5 - 5%)
Very low iron oxide (<2%)
Low titania (<2.5%)

Sources: Sehnke (1995), conference papers

Caribbean

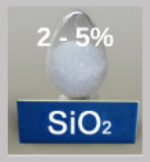
Operations and Projects



Source: Comer (1974)

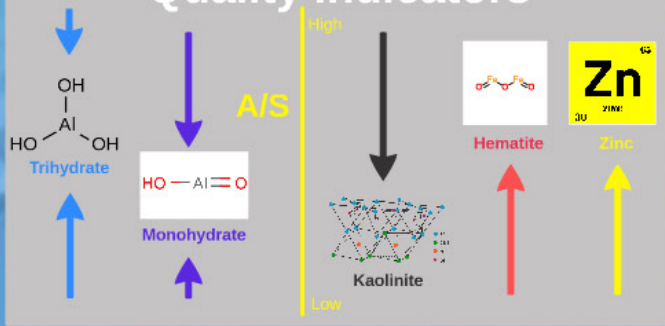
Jamaica: St Ann, Cockpit Country, Essex Valley, Manchester
Dominican Republic: Las Mercedes, Aceitilar

General Chemistry



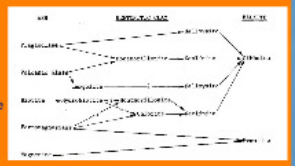
Type: karst
Age: late Tertiary (Miocene) - recent
Distribution: pockets and blankets
Bedrock: karstified limestone with infill volcanic ash

Quality Indicators



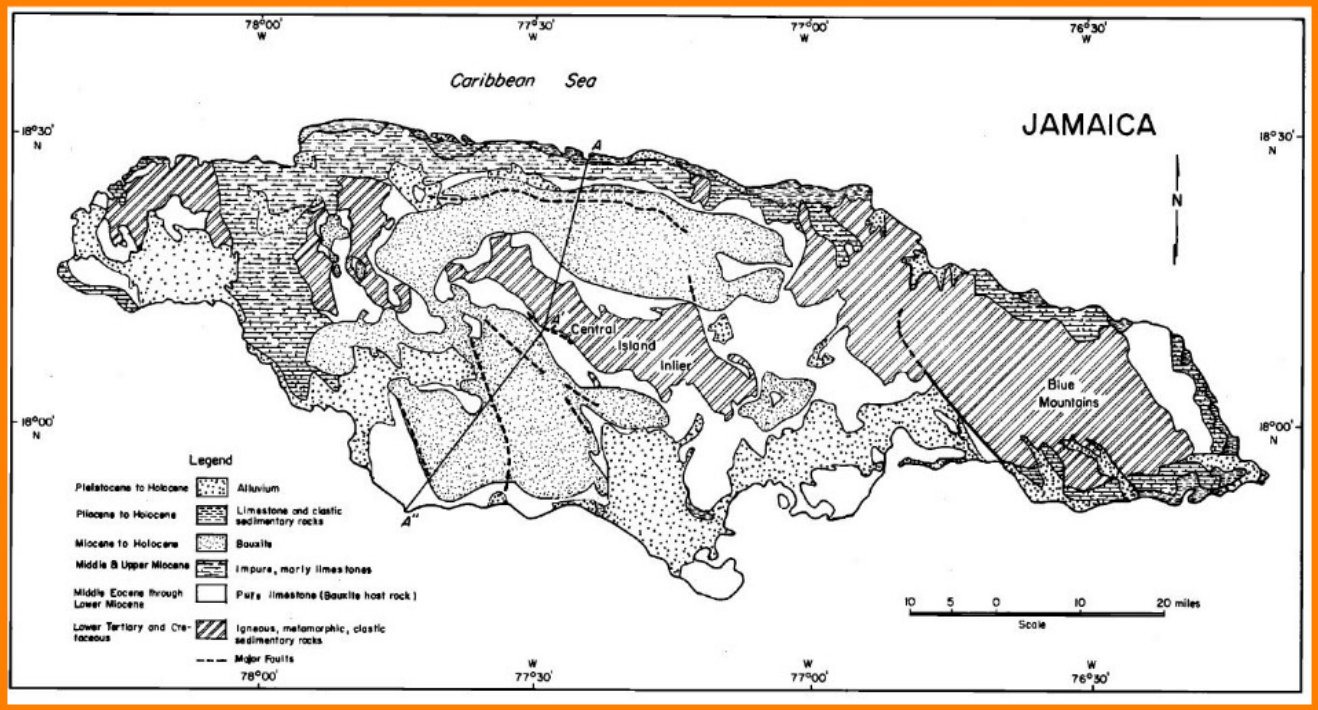
Jamaica

Highest grade at elevation - rainfall and drainage
Lower grade Terra Rosa in valleys
High moisture (~20%)



Source: Comer (1974)

Operations and Projects

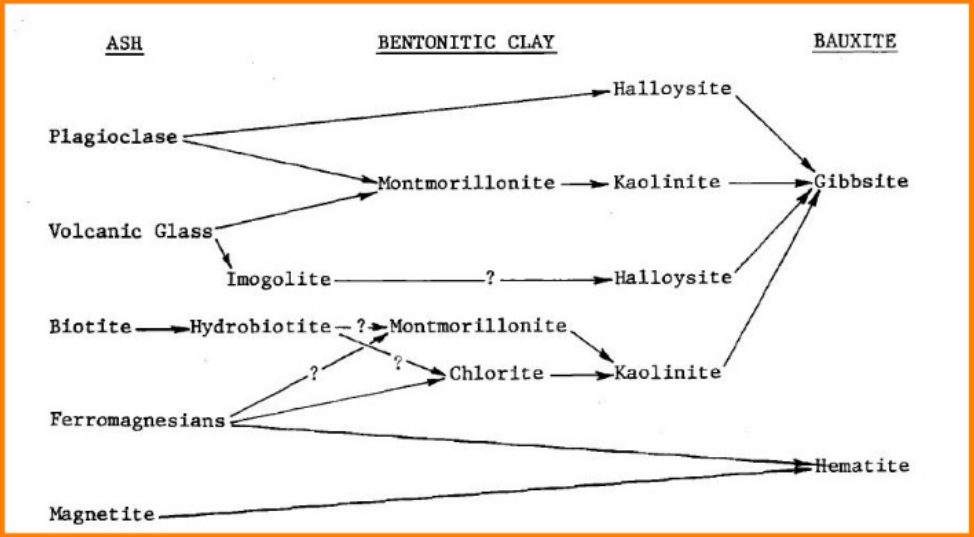


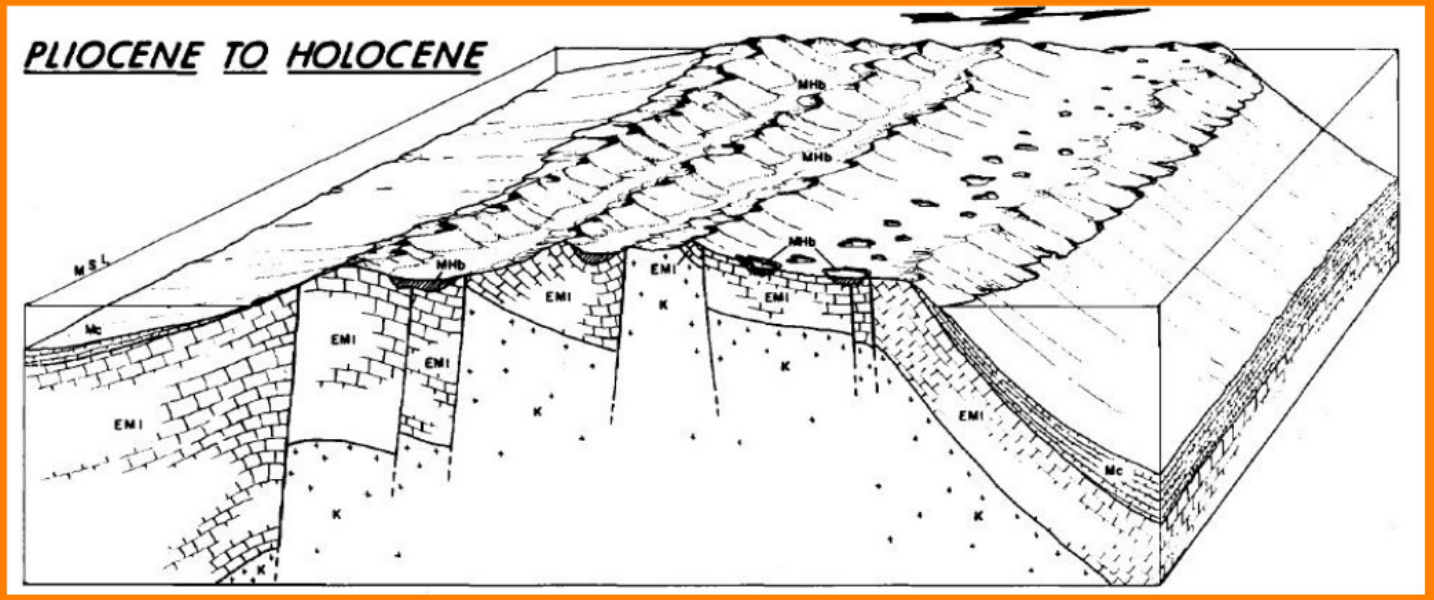
Source: Comer (1974)

Jamaica: St Ann, Cockpit Country, Essex Valley, Manchester
Dominican Republic: Las Mercedes, Aceitilar

Jamaica

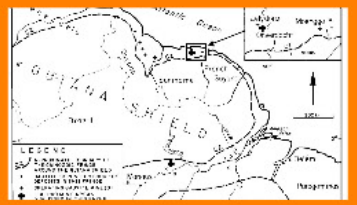
Highest grade at elevation - rainfall and drainage
Lower grade Terra Rosa in valleys
High moisture (~20%)





Source: Comer (1974)

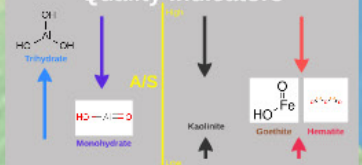
Operations and Projects



Brazil: Trombetas, Juruti, Paragominas, Rondon do Para
Suriname: Onverdacht, Lelydorp, Moenggo, Klaverbad
Guyana: Bosai, Linden, Kwakwani and Ituni
Venezuela: Los Pijiguaos

General Chemistry

Quality Indicators

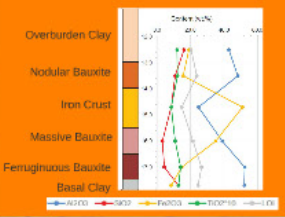


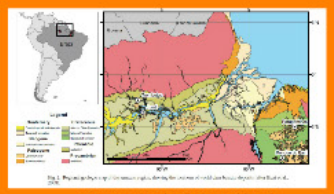
Guyana Shield

Type: lateritic (and buried)
Age: late Tertiary-recent
Distribution: plateaux / elevated regions
Bedrock: Cenozoic sediments, Precambrian granite

Rondon do Para

Geology: Cretaceous arkosic sediments, bauxitised in Tertiary (Eocene-Miocene), covered by late Tertiary sediments (>10m thick)
Type: Lateritic (buried)
Qualities: moderate alumina (gibbsitic), low silica, ave 4m thick

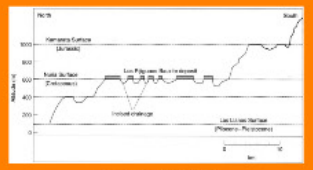




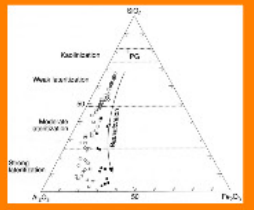
Source: Batista de Oliveira et al (2016)

Los Pijiguaos

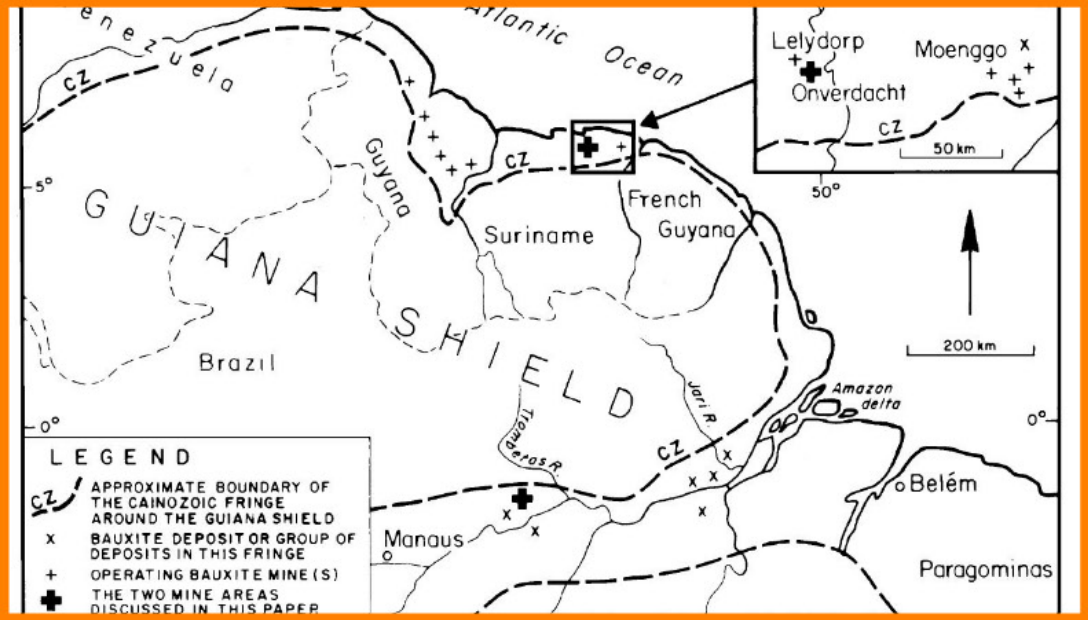
Geology: Precambrian granite bauxitised in early Tertiary (Palaeogene)
Type: Lateritic plateaux
Qualities: high alumina (gibbsitic), moderate silica (mainly quartz, low kaolin), low iron, low titania, moderate moisture, 10-12m thick



Source: Robb (2005)

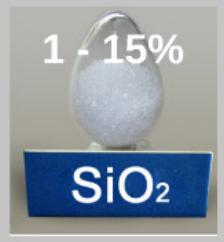


Operations and Projects

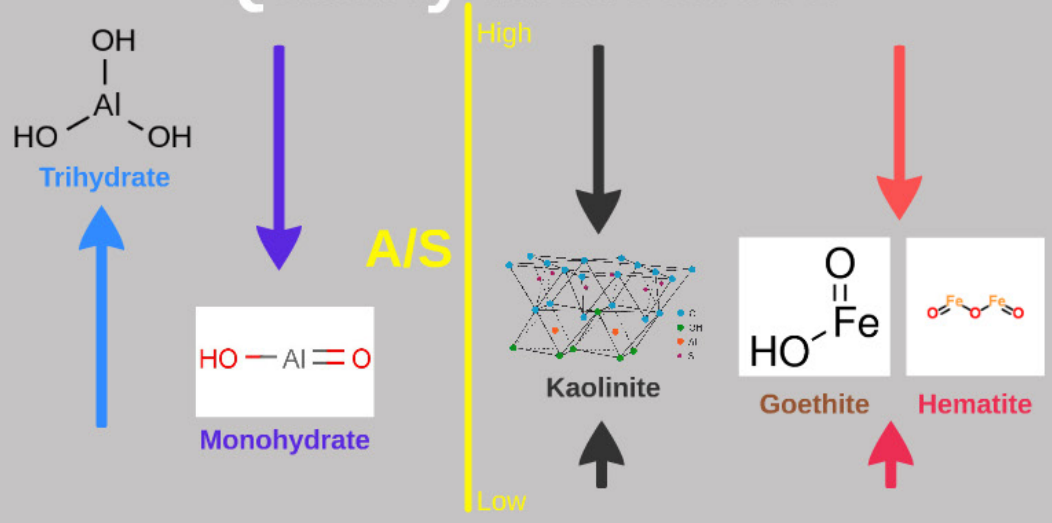


Brazil: Trombetas, Juruti, Paragominas, Rondon do Para
Suriname: Onverdacht, Lelydorp, Moenggo, Klaverbad
Guyana: Bosai, Linden, Kwakwani and Ituni
Venezuela: Los Pijiguaos

General Chemistry



Quality Indicators

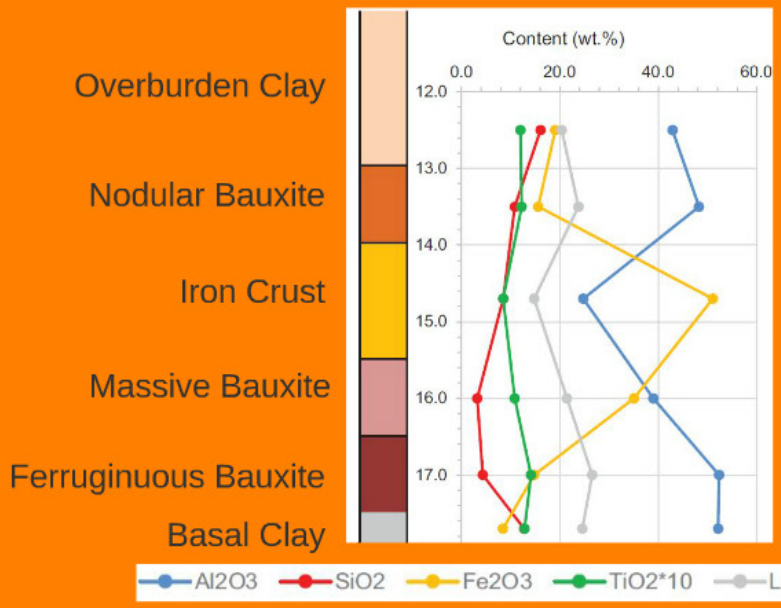


Distribution: plateaux / cli

Bedrock: Cenozoic sedime

Rondon do Para

Geology: Cretaceous arkosic sediments, bauxitised in Tertiary (Eocene-Miocene), covered by late Tertiary sediments (>10m thick)
Type: Lateritic (buried)
Qualities: moderate alumina (gibbsitic), low silica, ave 4m thick



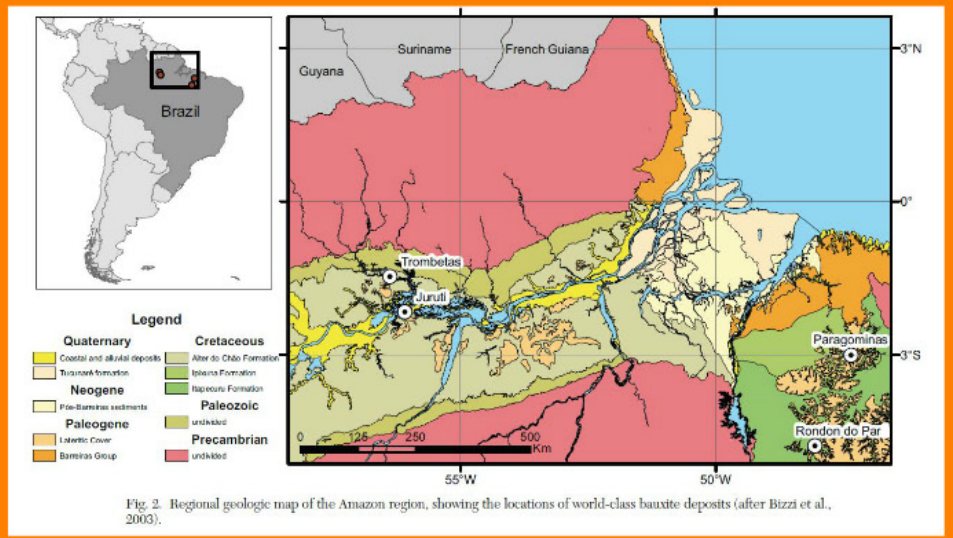
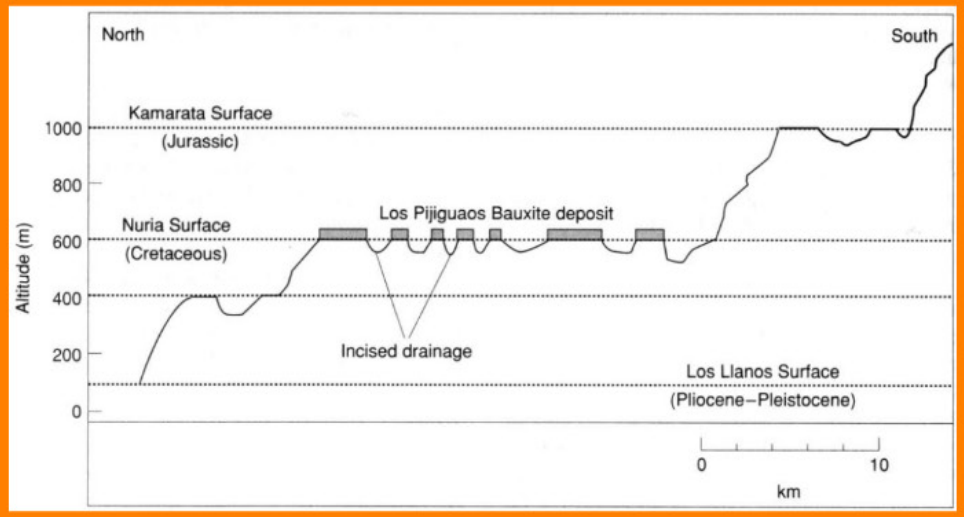


Fig. 2. Regional geologic map of the Amazon region, showing the locations of world-class bauxite deposits (after Bizzi et al., 2003).

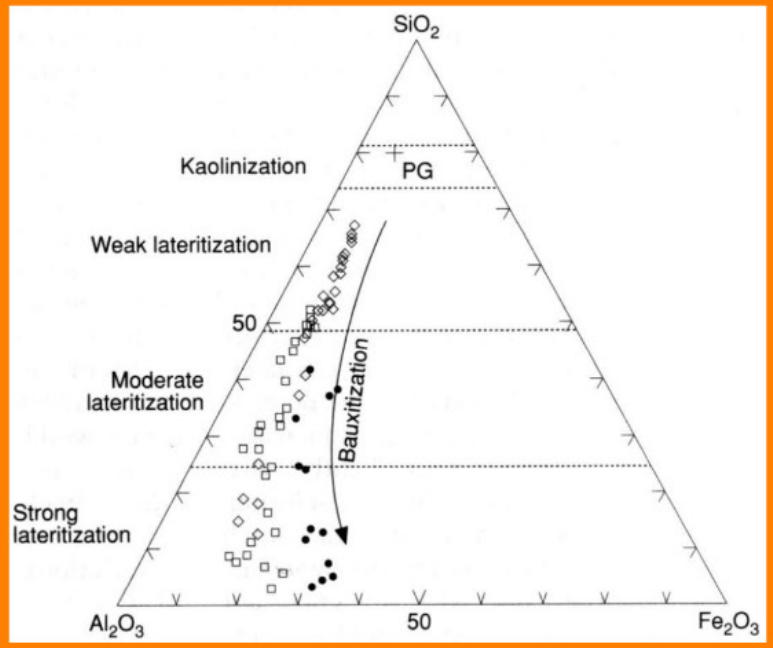
Source: Batista de Oliveira et al (2016)

Los Pijiguaos

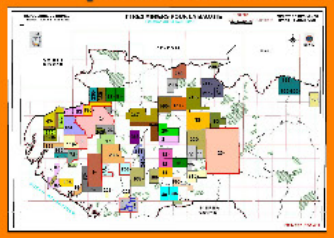
Geology: Precambrian granite bauxitised in early Tertiary (Palaeogene)
Type: Lateritic plateaux
Qualities: high alumina (gibbsitic), moderate silica (mainly quartz, low kaolin), low iron, low titania, moderate moisture, 10-12m thick



Source: Robb (2005)



Operations and Projects

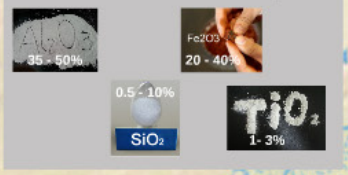


- No currently operating refineries
- Mainly bauxite export projects
- Several close to production

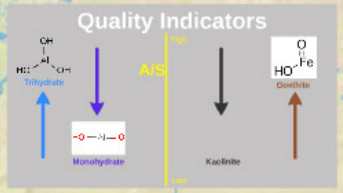
Operations
Guinea - CBG, CBK, SMB
Sierra Leone - Mokanji
Ghana - Awaso

Advanced Projects
Guinea: GAC, Dian Dian, Alufer, Boffa, Fria, SBG, FAR, DMBP
Sierra Leone: Port Loko
Mali: Balea
Ghana: Nyinahin, Kibi

General Chemistry



Quality Indicators



Guinea Shield

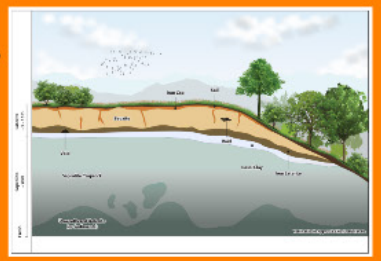
Type: Lateritic (+transported)
Age: late Tertiary-recent
Distribution: plateaux / elevated regions
Bedrock: dolerite, sediments, metamophics

Port Loko

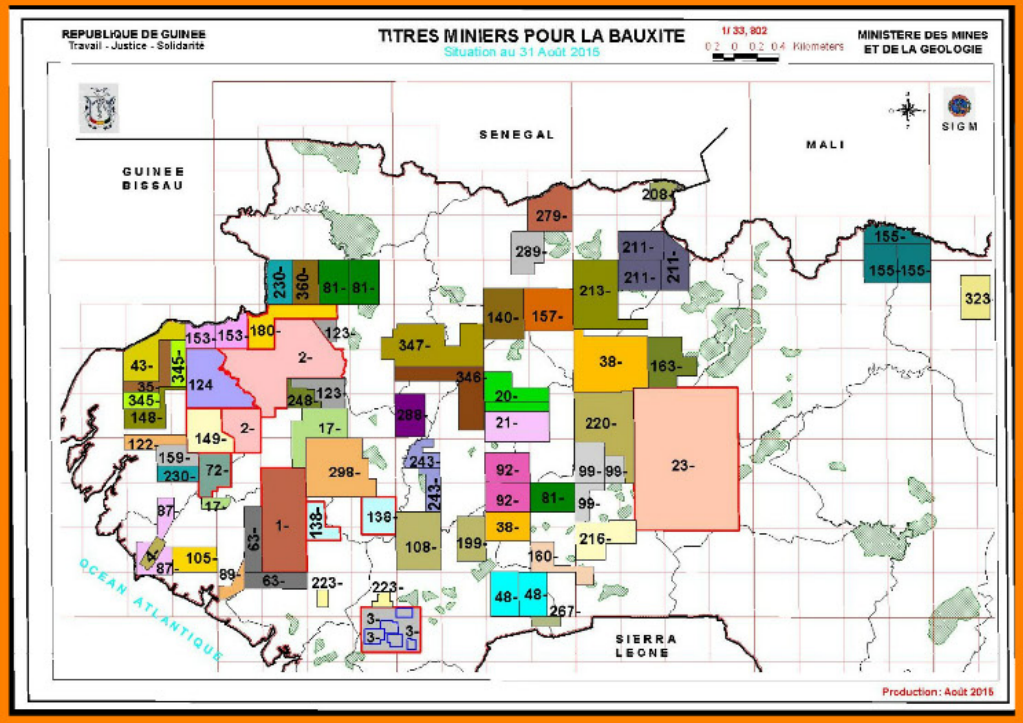
Geology: Archaean gneisss - Tertiary bauxite in pods above al-rich lithologies
Type: Lateritic (elevated areas)
Qualities:
- moderate alumina (gibbsitic)
- high silica (kaolinite) - washing required
- high iron
- 7m ave thickness (thin ovbd)
- high moisture

Garafiri

Geology: Devonian al-rich sediments, Jurassic dolerites - Tertiary bauxite
Type: Lateritic plateaux
Qualities:
- moderate alumina (gibbsitic)
- low silica, high iron
- 9m ave thickness (thin ovb)
- high moisture



Operations and Projects



- No currently operating refineries
- Mainly bauxite export projects
- Several close to production

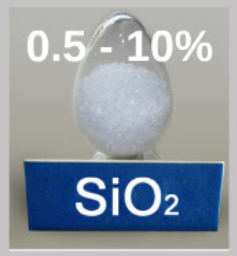
Operations

Guinea - CBG, CBK, SMB
Sierra Leone - Mokanji
Ghana - Awaso

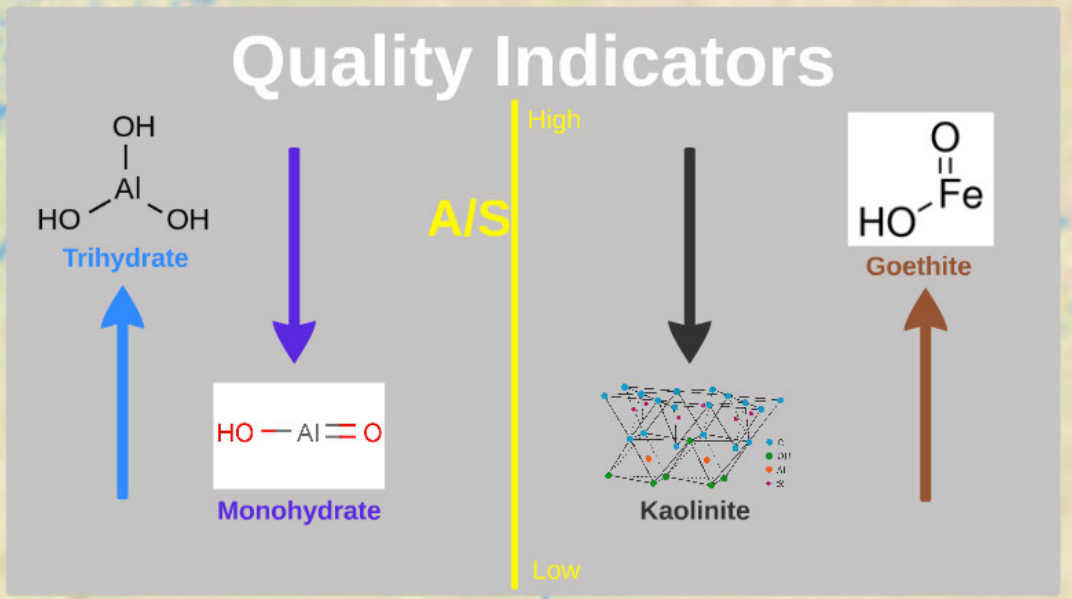
Advanced Projects

Guinea: GAC, Dian Dian, Alufer, Boffa, Fria, SBG, FAR, DMBP
Sierra Leone: Port Loko
Mali: Balea
Ghana: Nyinahin, Kibi

General Chemistry



Quality Indicators



Port Loko

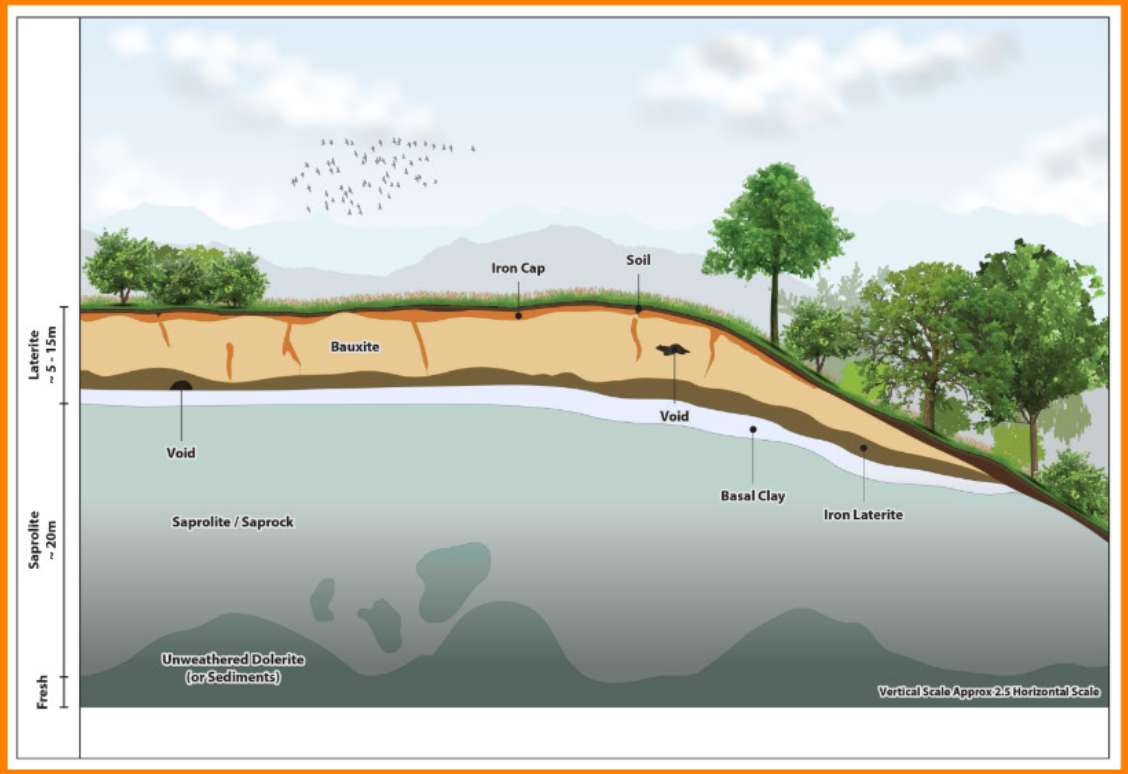
Geology: Archaean gneisss - Tertiary bauxite in pods above al-rich lithologies
Type: Lateritic (elevated areas)
Qualities:

- moderate alumina (gibbsitic)
- high silica (kaolinite) - washing required
- high iron
- 7m ave thickness (thin ovbd)
- high moisture

Garafiri

Geology: Devonian al-rich sediments, Jurassic dolerites - Tertiary bauxite
Type: Lateritic plateaux
Qualities:

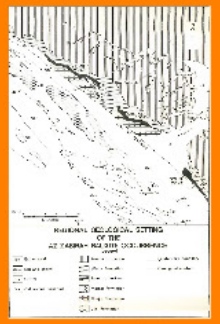
- moderate alumina (gibbsitic)
- low silica, high iron
- 9m ave thickness (thin ovb)
- high moisture



Operations and Projects

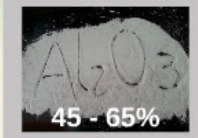
Operations:
- **Zabirah South (Al Ba'itha)**
- **Zabirah Central**

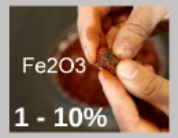
Exploration: Zabirah North



Source: Bowden (1981)

General Chemistry

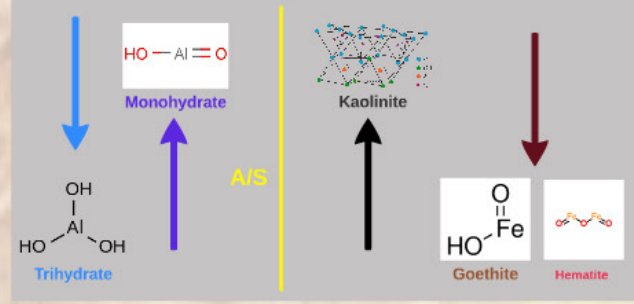




Saudi Arabia

Type: lateritic (buried)
Age: Cretaceous
Distribution: palaeo-weathering surface
Bedrock: al-rich sediments

Quality Indicators



Zabirah

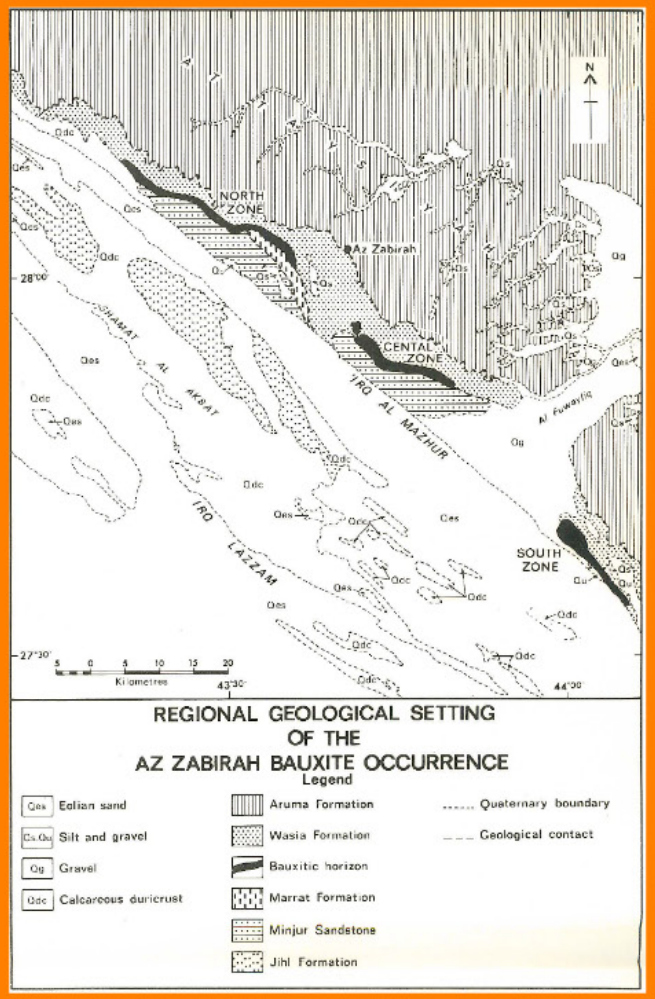
Geology: palaeo-laterite surface Cretaceous kaolinitic sediments. Shallow dipping. Overburden of sand and siltstone.
Type: Lateritic (buried)
Qualities:
- very high grade alumina areas
- boehmitic (low gibbsite)
- high silica (kaolin)
- low iron
- low moisture
- high density

Operations and Projects

Operations:

- **Zabirah South (Al Ba'itha)**
- **Zabirah Central**

Exploration: Zabirah North



Source: Bowden (1981)

Zabirah

Geology: palaeo-laterite surface Cretaceous kaolinitic sediments. Shallow dipping. Overburden of sand and siltstone.
Type: Lateritic (buried)
Qualities:

- very high grade alumina areas
- boehmitic (low gibbsite)
- high silica (kaolin)
- low iron
- low moisture
- high density

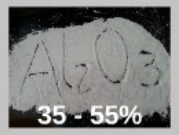
India

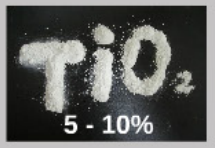
Operations and Projects

Key Operations:
- Panchpatmali
- Baphlimali
- Lohardagar
- Mainpat
- Kawardha
- Idergunj
- Madhya Pradesh

Source: mapsofindia.com

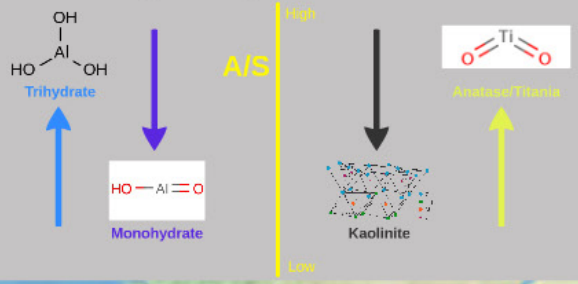
General Chemistry





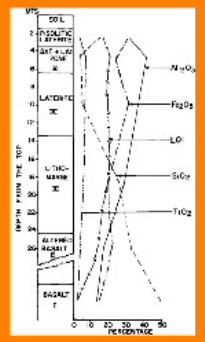
Type: lateritic
Age: late-Tertiary (Neogene)
Distribution: plateaux
Bedrock: Deccan trap basalt

Quality Indicators



Hazaridadar

Geology: Tertiary Deccan traps basalt bauxitised in late Tertiary-recent
Type: Lateritic plateaux
Qualities:
- moderate alumina (mainly gibbsitic but with minor boehmite)
- low silica
- elevated titania
- moderate iron
- 4m ave thickness (<4m ovbd)



Operations and Projects

Key Operations:

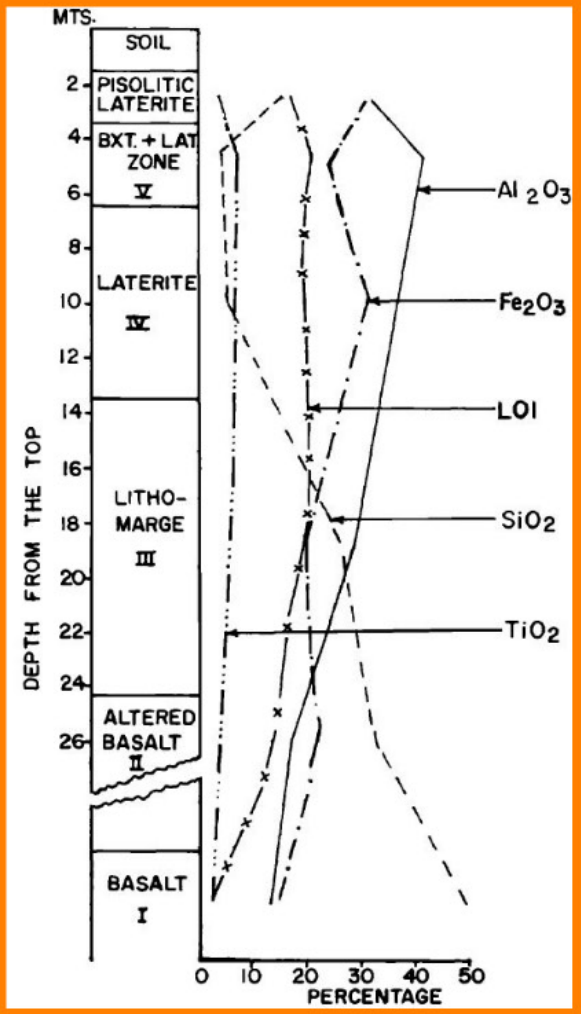
- Panchpatmali
- Baphlimali
- Lohardagar
- Mainpat
- Kawardha
- Idergunj
- Madhya Pradesh

Source: mapsofindia.com

Hazaridadar

Geology: Tertiary Deccan traps basalt bauxitised in late Tertiary-recent
Type: Lateritic plateaux
Qualities:

- moderate alumina (mainly gibbsitic but with minor boehmite)
- low silica
- elevated titania
- moderate iron
- 4m ave thickness (<4m ovbd)



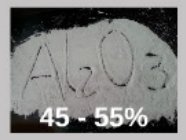
Vietnam-Laos

Operations and Projects

Laos: Champasak

Southern Vietnam: Dac Nong and Lam Dong
Central Vietnam: Lang Son, Cao Bang, Ha Giang

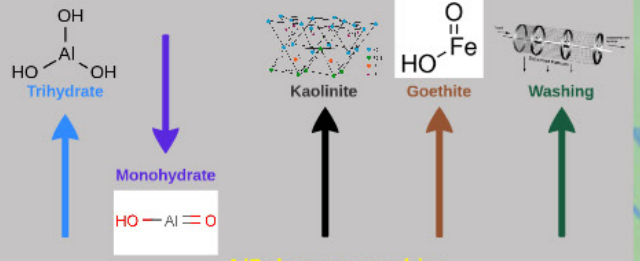
General Chemistry (lateritic)



Washed grades

Type: lateritic (south) and karstic (central)
Age: Pleistocene-recent
Distribution: lateritic blankets and karstic infill
Bedrock: plateau basalt (south) volcanic ash (central)

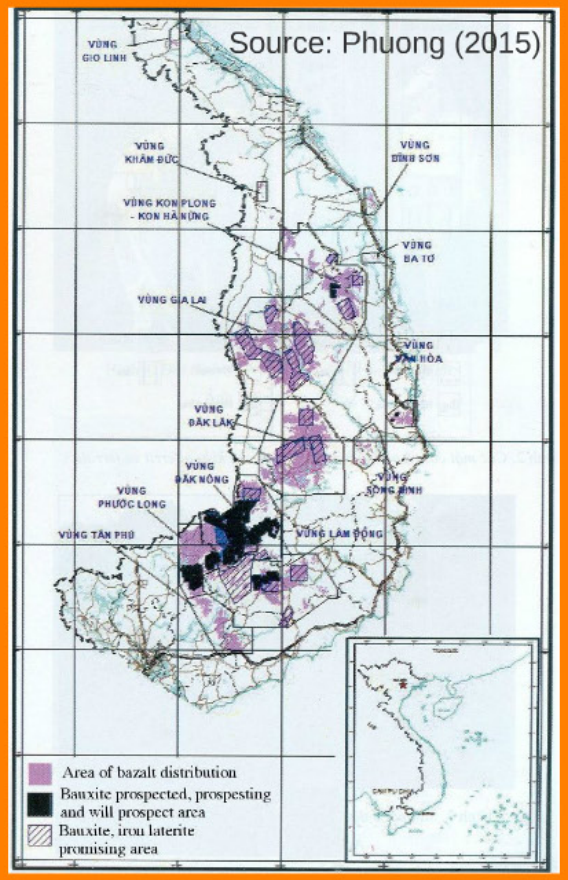
Quality Indicators



Tan Rai

Geology: Tertiary plateau basalts
Type: Lateritic plateau (800m+)
Qualities:
- moderate alumina (gibbsitic)
- high silica (kaolin - requires washing),
- 1-12m thick
- high moisture

Operations and Projects



Laos: Champasak

Southern Vietnam: Dac Nong and Lam Dong
Central Vietnam: Lang Son, Cao Bang, Ha Giang

Tan Rai

Geology: Tertiary plateau basalts
Type: Lateritic plateau (800m+)
Qualities:

- moderate alumina (gibbsitic)
- high silica (kaolin - requires washing),
- 1-12m thick
- high moisture

Source: Phuong (2015)

Operations and Projects

Source: Haji Eki (2015)

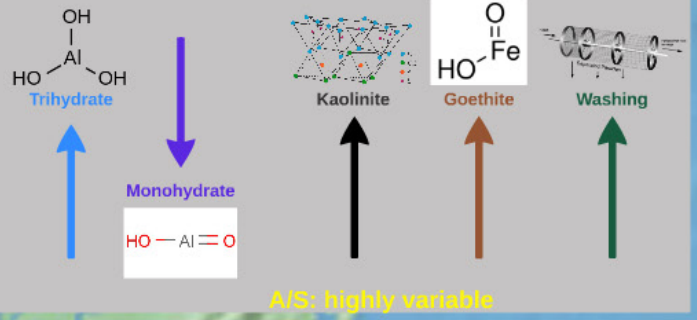
Source: SRK (2008)

General Chemistry

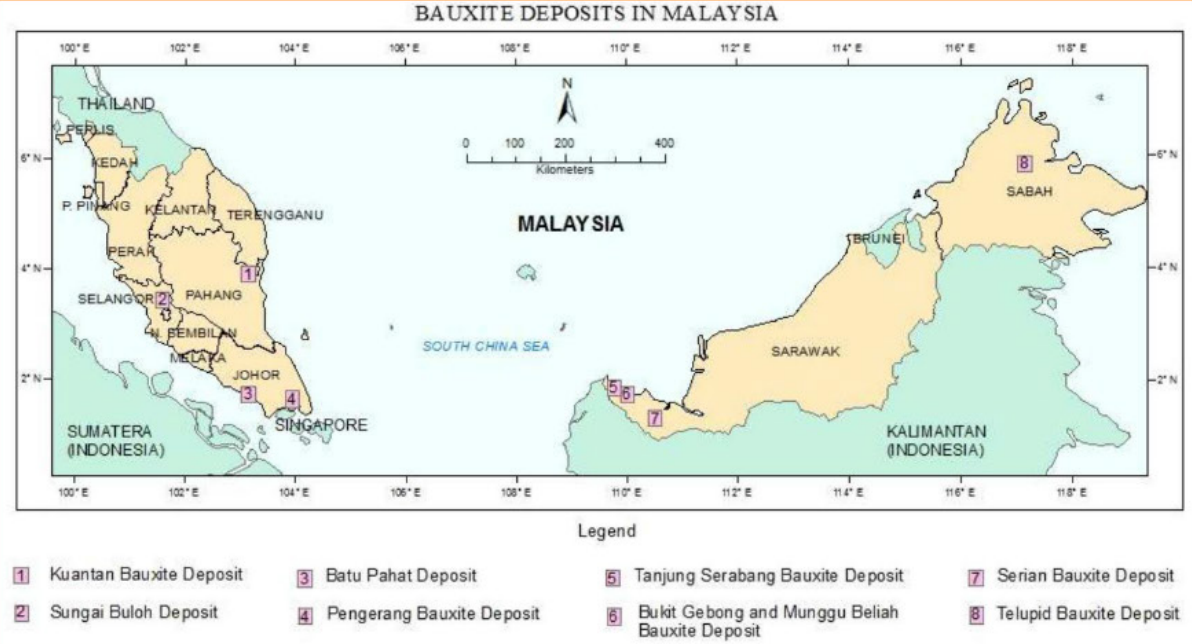
Indonesia-Malaysia

Type: lateritic
Age: late-Tertiary-recent
Distribution: plateaux
Bedrock: basic rocks (basalt, diorite, gabbro)

Quality Indicators

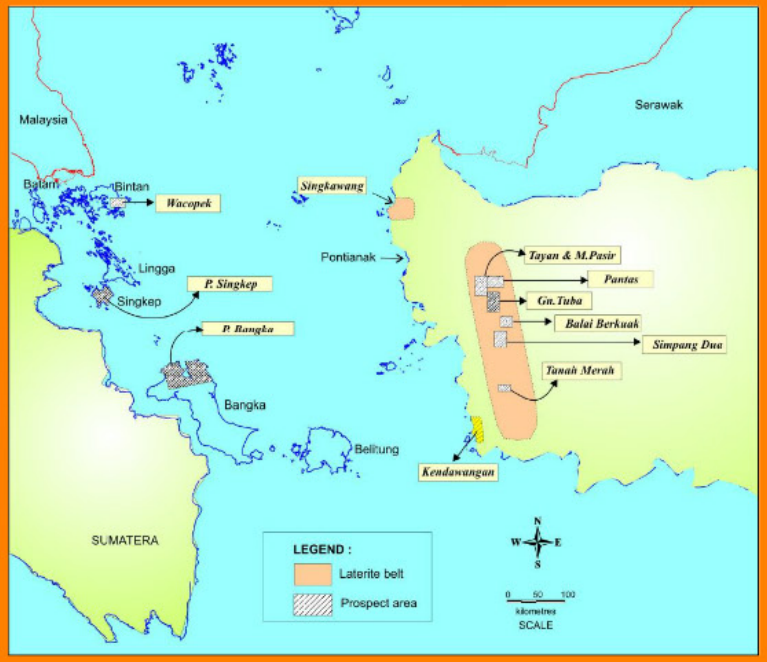


Operations and Projects



Source: Haji Eki (2015)

Source: SRK (2008)



Operations and Projects

Two operations:
- Huntly/Willowdale
- Worseley

Many exploration projects

General Chemistry

Darling Range

Type: lateritic
Age: Tertiary (Eocene-Miocene)
Distribution: plateaux
Bedrock: granite-gneiss (+dolerite dykes)

Quality Indicators

Operations and Projects

Two operations:

- **Huntly/Willowdale**
- **Worseley**

Many exploration projects

Operations and Projects

Two mining operations
Many exploration projects

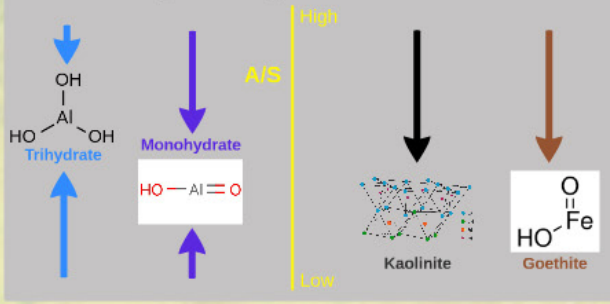
Source: Australian Mines Atlas (2017)

General Chemistry

North Australia

Type: lateritic (+transported)
Age: Tertiary-recent
Distribution: mix of plateaux and valley fill
Bedrock: al-rich sediments

Quality Indicators



Weipa

Geology: Cretaceous sediments laterised then re-deposited as secondary clays and sandstones, then bauxitised further in Tertiary-recent
Type: Lateritic - transported
Qualities:

- high alumina (mainly gibbsitic but significant boehmite)
- low silica
- 1-6m thick (3m ave),
- high filter-speed due to large and uniform grain size

Source: Taylor & Eggleton (2008)

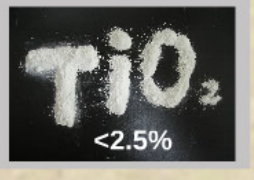
Weipa

Geology: Cretaceous sediments laterised then re-deposited as secondary clays and sandstones, then bauxitised further in Tertiary-recent
Type: Lateritic - transported
Qualities:

- high alumina (mainly gibbsitic but significant boehmite)
- low silica
- 1-6m thick (3m ave),
- high filter-speed due to large and uniform grain size

Source: Taylor & Eggleton (2008)

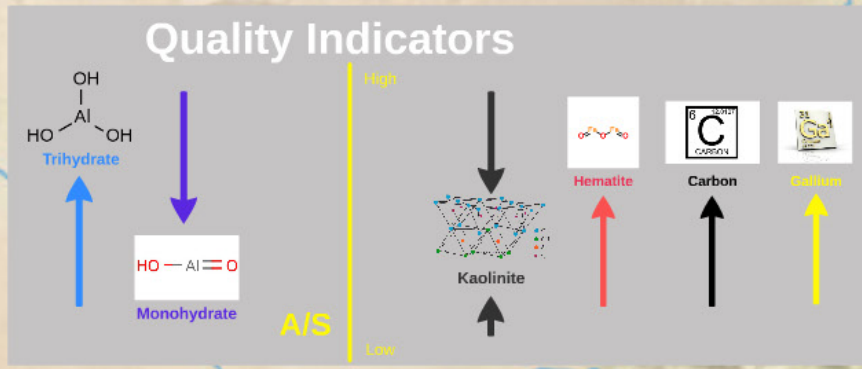
General Chemistry



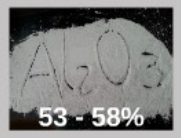
Kazakhstan

Type: polycyclic-karstic (buried)
Age: Cretaceous
Distribution: karstic sink holes
Bedrock: Caboniferous limestone

Quality Indicators



General Chemistry

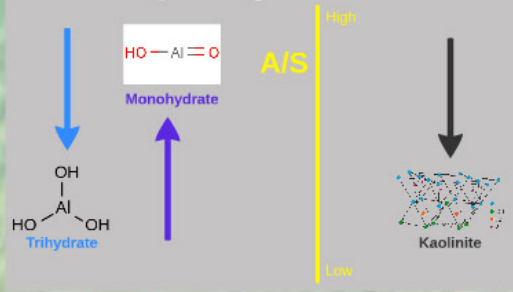


Elevated CaO and S

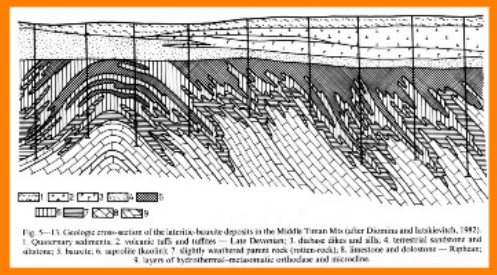
North Urals

Type: karstic (buried)
Age: Devonian (~400Ma)
Distribution: fold belts
Bedrock: Silurian-Devonian limestone

Quality Indicators

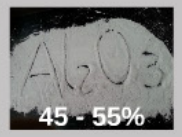


Operations and Projects



Source: Bardossy and Aleva (1990)

General Chemistry

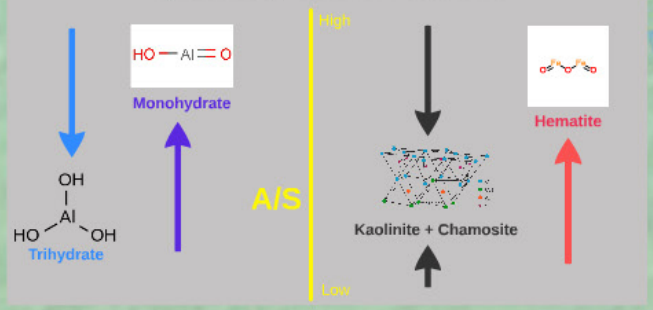


Elevated CaO and MgO

Timan

Type: lateritic (buried)
Age: Devonian (~400Ma)
Distribution: lenses in fold belts
Bedrock: Precambrian metamorphic terrain

Quality Indicators



Operations and Projects

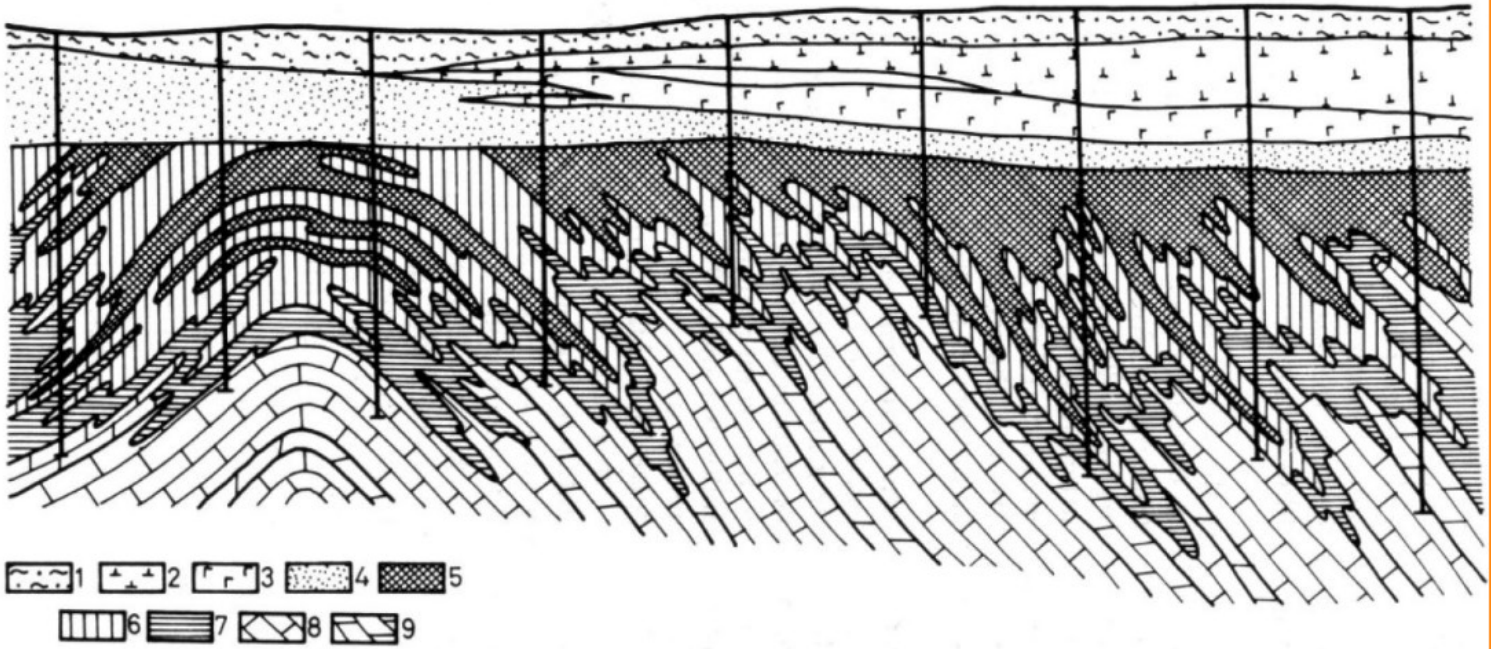


Fig. 5—13. Geologic cross-section of the lateritic-bauxite deposits in the Middle Timan Mts (after Diomina and Iatskievitch, 1982). 1. Quaternary sediments; 2. volcanic tuffs and tuffites — Late Devonian; 3. diabase dikes and sills; 4. terrestrial sandstone and siltstone; 5. bauxite; 6. saprolite (kaolin); 7. slightly weathered parent rock (rotten-rock); 8. limestone and dolostone — Riphean; 9. layers of hydrothermal–metasomatic orthoclase and microcline.

Source: Bardossy and Aleva (1990)

uyana)

ce)

n. Lower

depth.

bauxite

Reserves

Country	Reserves (Mt)	%Global
Guinea	7,400	27%
Australia	6,200	22%
Others	2,700	10%
Brazil	2,600	9%
Vietnam	2,100	8%
Jamaica	2,000	7%
Indonesia	1,000	4%
China	980	4%
Guyana	850	3%
India	590	2%
Suriname	580	2%
Saudi Arabia	210	1%
Russia	200	1%
Kazakhstan	160	1%
Greece	130	0.5%
Malaysia	110	0.4%
Total	**27,810**	**100%**

Source: USGS 2017

Production

Country	Production 2016 (Mt)	%Global
Australia	82	31%
China	65	25%
Brazil	34.5	13%
India	25	10%
Guinea	19.7	8%
Jamaica	8.5	3%
Others	6.9	3%
Russia	5.4	2%
Kazakhstan	4.6	2%
Saudi Arabia	4	2%
Greece	1.8	1%
Guyana	1.6	1%
Vietnam	1.5	1%
Indonesia	1	0.4%
Malaysia	1	0.4%
Suriname	-	-
Total	**263**	**100%**

Source: USGS 2017

- Co
- Ge
- Ex
- Pr

Ne
re

India	25	10%
Guinea	19.7	8%
Jamaica	8.5	3%
Others	6.9	3%
Russia	5.4	2%
Kazakhstan	4.6	2%
Saudi Arabia	4	2%
Greece	1.8	1%
Guyana	1.6	1%
Vietnam	1.5	1%
Indonesia	1	0.4%
Malaysia	1	0.4%
Suriname	-	-
Total	**263**	**100%**

Source: USGS 2017

- All bauxite deposits show variable chemistry and mineralogy
- Highest spec bauxites transported/re-bauxitised (Weipa, CBG)
- Lateritic more likely to be gibbsitic (Guinea, Australia, Brazil, Vietnam, Guyana)
- Karstic more likely to be boehmitic (Jamaica)
- Pre-Tertiary likely to be boehmitic / diasporic (Timan, Urals, Saudi, Greece)

- **Exploration:**
  - Lateritic deposits = greater continuity laterally and more consistent depth. Lower sampling density required for high confidence.
  - Karstic and transported deposits = lower continuity laterally and variable depth. Higher sampling density required.
- **Product Types**:
  - Opportunities exist to produce multiple product types from one source
  - Analyse at early stage of project to understand potential
  - Quantitate high-spec material (by-products, e.g. washed fines for alum)
  - Market studies

Note: The overriding factors for developing economic bauxite remain - CAPEX/OPEX to deliver to customer

Brazil	2,600	9%
Vietnam	2,100	8%
Jamaica	2,000	7%
Indonesia	1,000	4%
China	980	4%
Guyana	850	3%
India	590	2%
Suriname	580	2%
Saudi Arabia	210	1%
Russia	200	1%
Kazakhstan	160	1%
Greece	130	0.5%
Malaysia	110	0.4%
Total	**27,810**	**100%**

Source: USGS 2017

Global Quality Overview by Region

Region	Genesis	Age	Parent Rock	Deposit Size	TAA	THA	MHA	RS	Moisture	Stripping Ratio	Hardness	Infrastructure	Market
Cape York (Aus)	Lateritic/transported	Tertiary	Sediment	Large	High	High	Moderate	Low	Low	Low	Low	Good	Global
Darling Range (Aus)	Lateritic	Tertiary	Granite	Large	Low	High	Low	Low	Moderate	Low	Low	Good	Regional
Caribbean	Karstic	Tertiary	Volcanic ash	Moderate	High	Moderate	Moderate	Low	High	Low	Low	Good	Regional
Guinea Shield	Lateritic/transported	Tertiary	Dolerite/Sediment	Large	Moderate	High	Low	Low	High	Low	Low	Poor	Global
Guyana Shield	Lateritic	Tertiary	Sediment/Granite	Large	High	High	Low	Moderate	High	Variable	Low	Moderate	Global
Brazilian Shield	Lateritic	Tertiary	Alkaline intrusive	Large	Moderate	High	Low	Moderate	High	Low	Low	Moderate	Global
India	Lateritic	Tertiary	Basalt	Moderate	Moderate	High	Moderate	Low	Moderate	Low	Low	Moderate	Global
Vietnam-Laos	Lateritic/Karstic	Tertiary	Basalt/Volcanic Ash	Moderate	Moderate	High	Low	High	Moderate	Low	Low	Moderate	Global
Indonesia-Malaysia	Lateritic	Tertiary	Basalt	Small	Moderate	High	Low	High	High	Low	Low	Moderate	Global
Saudi Arabia	Lateritic	Cretaceous	Sediment	Moderate	High	Low	High	High	Low	Moderate	High	Good	Regional
Kazakhstan	Karstic (buried)	Cretaceous	Volcanic ash	Small	High	High	Low	High	Moderate	High	High	Poor	Local
Southern Europe	Karstic (buried)	Jurassic/Cretaceous	Volcanic ash	Moderate	High	Low	High	Moderate	Moderate	Variable	High	Moderate	Local
China	Lateritic/Karstic (buried)	Permian	Sediment	Small	High	Low	High	Moderate	Low	High	High	Good	Local
Urals (Rus)	Karstic (buried)	Devonian	Sediment	Small	High	Low	High	Low	Low	High	High	Poor	Local
Eastern Europe	Lateritic/karstic (buried)	Devonian	Metamorphic	Moderate	High	Low	High	High	Moderate	High	High	Poor	Local

Conclusions

- **Conditions for Formation**:
  - Duration, location, ground water, geomorphology, tectonics
  - Bauxites can form on any al-enriched parent rock
- **Genesis**:
  - All bauxite deposits show variable chemistry and mineralogy
  - Highest spec bauxites transported/re-bauxitised (Weipa, CBG)
  - Lateritic more likely to be gibbsitic (Guinea, Australia, Brazil, Vietnam, Guyana)
  - Karstic more likely to be boehmitic (Jamaica)
  - Pre-Tertiary likely to be boehmitic / diasporic (Timan, Urals, Saudi, Greece)
- **Exploration:**
  - Lateritic deposits = greater continuity laterally and more consistent depth. Lower sampling density required for high confidence.
  - Karstic and transported deposits = lower continuity laterally and variable depth. Higher sampling density required.
- **Product Types**:
  - Opportunities exist to produce multiple product types from one source
  - Analyse at early stage of project to understand potential
  - Quantitate high-spec material (by-products, e.g. washed fines for alum)
  - Market studies

Note: The overriding factors for developing economic bauxite remain - CAPEX/OPEX to deliver to customer

srk consulting

References

- Batista de Oliveira, S., Lima da Costa, M., dos Prazeres Filho, H.J. (2016). The Lateritic Bauxite Deposit of Rondon Do Pará: A New Giant Deposit in the Amazon Region, Northern Brazil. Economic Geology, v. 111, p. 1277-1290
- Bardossy, G. (1983). A comparison of the main lateritic bauxite regions of our globe. In A. J. Melfi and A. Carvalho (eds.) Laterization Processes. University of São Paulo, Brazil. p. 15–51.
- Bardossy, G. and Aleva, G.J.J. (1990). Lateritic Bauxites. Elsevier, Amsterdam. 624 pp.
- Boni, M., Rollinson, G., Mondillo, N., Balasone, G. and Santoro, L. (2013). Quantitative Mineralogical Characterization of Karst Bauxite Deposits in the Southern Apennines, Italy. Economic Geology, v.108, p.813-833.
- Bowden, R. (1981). Geology of the Az Zabirah Bauxite Occurrence. Riofinex internal report.
- Comer, J.B. (1974). Genesis of Jamaica Bauxite. Economic Geology, v. 69, p. 1251-1264
- Hill, V.G. (1980). The Rational Development of Bauxite Resources. In: Proceedings of Bauxite/Alumina symposium IV, Kingston, Jamaica. Geological Society of Jamaica Journal, Special Issue 5, p.3-19
- Lillehagen, N.B., 1979, The estimation and mining of Gove bauxite reserves—Estimation and statement of mineral reserves: Melbourne, Australasian Institute of Mining and Metallurgy, Symposia Series, October 1, 1979, Sydney, Australia, p. 19–32.
- Ling, K-Y., Zhu, X-Q., Tang, H-S., and Li, S-X. (2017). Importance of hydrogeological conditions during formation of the karstic bauxite deposits, Central Guizhou Province, Southwest China: A case study at Lindai deposit. Ore Geology Reviews, v.82, p.198-216.
- Retallack, G.J. (2010). Lateritization and Bauxitization Events. Economic Geology, v. 105, p. 655–667.
- Robb, L. (2005). Introduction to Ore Forming Processes. Blackwell. 373p.
- Schellman, W. (1982). Eine neue Lateritdefinition. Geol. Jb. v. 58, p.31–47
- Schellmann, W. (1994). Geochemical differentiation in laterite and bauxite formation: Catena, v. 21, p. 131–143
- Schulte, R.F. and Foley, N.K. (2014). Compilation of gallium resource data for bauxite deposits: U.S. Geological Survey Open-File Report 2013–1272, p. 14.
- Sehnke, E.D. (1995). Bauxite—A global review: Industrial Minerals, no. 335, August, p. 39-51.
- Smith, P. (2008). Economic Processing of High Silica Bauxites – Existing and Potential Processes. Asian-Pacific Partnership on Clean Development and Climate, technical paper.
- Taylor, G. and Eggleton, R.A. (2004). "Little Balls": The origin of the Weipa bauxite. Proceedings of the CRC LEME Regional Regolith Symposia.