IBAAS 2023
TECHNICAL LECTURE SERIES

QEMSCAN Based mineralogical characterization of bauxite & intermediate solids of bayer process

Dr Vilas Tathavadkar

Content

- Why mineralogical characterisation required ?
- What is mineralogical characterisation ?
- What is QEMSCAN ?
- QEMSCAN of Bauxite
- Use of QEMSCAN results in Bayer process
- Conclusion & way forward

WHY Mineralogical Characterisation ?

- Bauxite is only major commercial source of alumina
- It is complex mixture of various minerals of Al, Fe, Si & Ti
- Bauxite is classified as Lateritic (86%) & Karstic (14%)

Bauxite Mineralogy

Element	Lateritic	Karstic
Al	Gibbsite, boehmite	Boehmite, diaspore
Si	Kaolinite, quartz	Kaolinite, quartz, chamosite, illite
Fe	Goethite, hematite	Hematite, goethite maghemite, magnetite
Ti	Anatase, rutile	Anatase, rutile, ilmenite
Ca	Calcite, apatite, crandallite	Calcite, apatite, crandallite

- Bauxite properties controls the raw material consumption, process economics and product quality for Alumina Plants

WHY Mineralogical Characterisation ?

- Mineralogical characterisation of Bauxite is generally carried out during exploration and process designing
- In regular production ,chemical (MHA, THA, R-silica, LoI) & physical characterisation (Size distribution) is carried out to design blends & control the process parameters
- In some plants, phase analysis by X-Ray Diffraction is also employed
- The phase association & texture are not measured on regularly basis. However, these properties varies significantly within pit / band and mine to mine and also impact performance of Bayer process

WHAT is Mineralogical Characterisation ?

- Typical techniques
  - ❑ Hand inspection
  - ❑ Chemical characterisation – elemental analysis,
  - ❑ Physical characterisation – hardness, bond index, size distribution
  - ❑ Phase analysis – XRD,
  - ❑ Microstructural characterisation - optical & electron microscopy, SEM-EDAX, EPMA, TEM-SAD

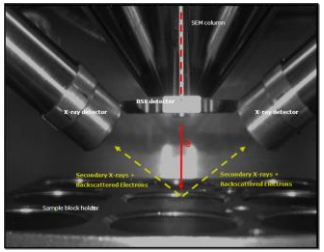
These methods are slow & depends on human expertise & sophisticated instruments for quantification

WHAT is QEMSCAN ?

" QEMSCAN is a scanning electron microscope (SEM) system to provide rapid automated quantitative mineral analyses"

The Instrument

- Based on a Scanning Electron Microscopy;
- Up to **4** light-element X-ray detectors.



The Technology

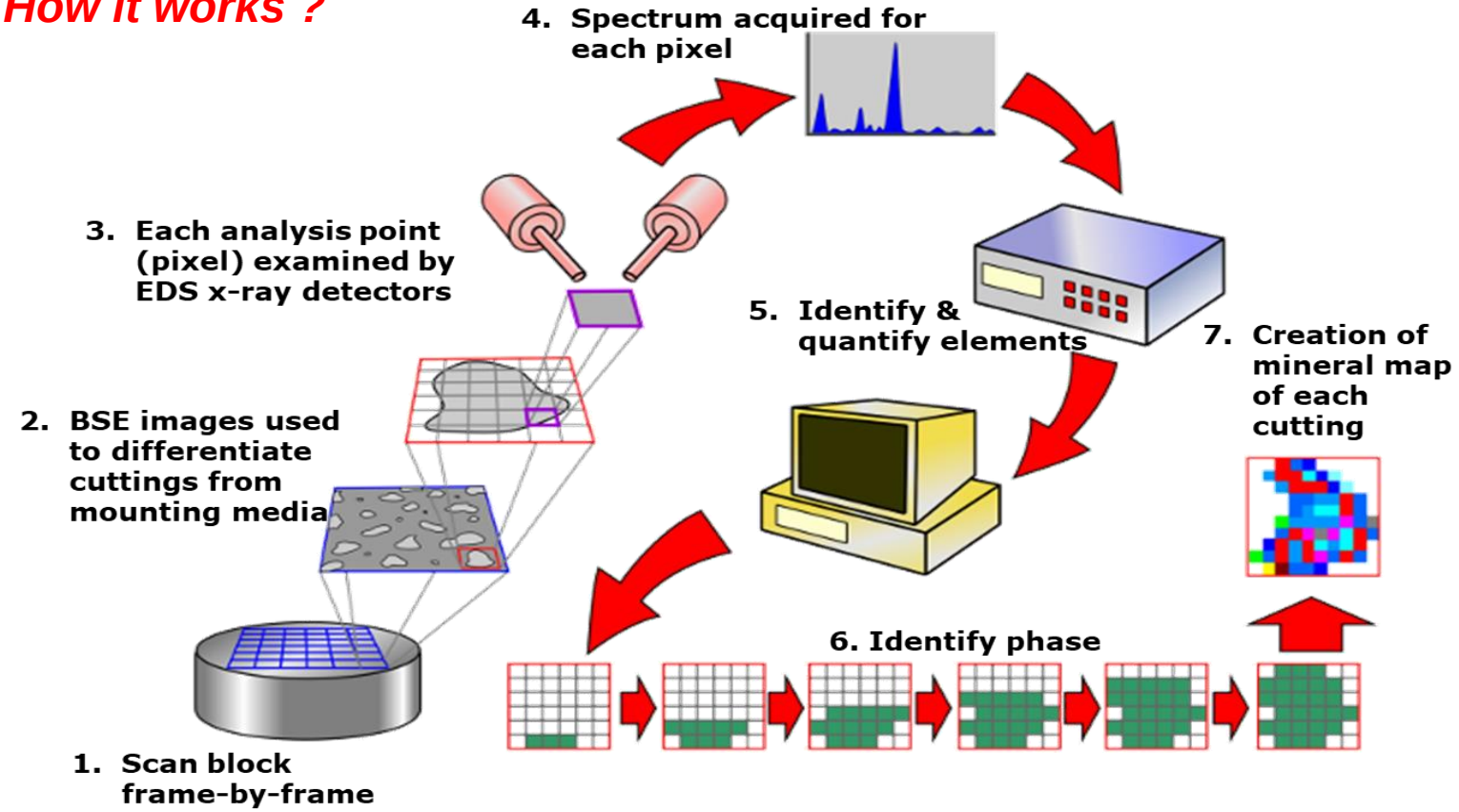
- Automated image analysis system;
- Utilises **BSE** and **EDS** X-ray signals;

The Solution

- Creation of digital images, on-line automatic mineral identification, and off-line data mining, using QEM*SEM® technology and **iExplorer** software.

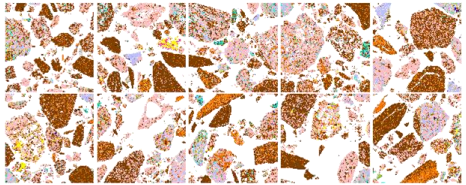
WHAT is QEMSCAN ?

How it works ?



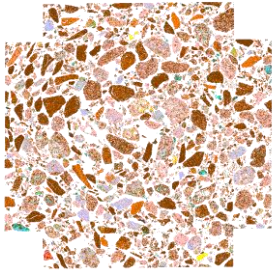
WHAT is QEMSCAN ?

1) Individual Fields



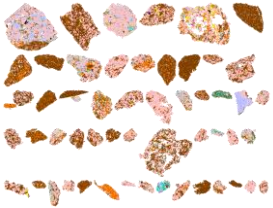
Mineral maps are created of each individual field (3mm x 3mm area), allowing modal analysis on a field-by-field basis.

2) Stitched Fields



Each field is then stitched together to produce a single composite image of the entire measured area, allowing modal analysis of the entire sample.

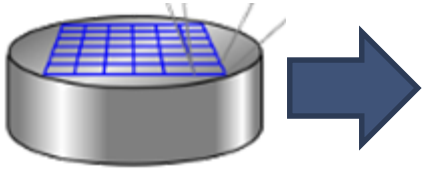
3) Particulated Cuttings

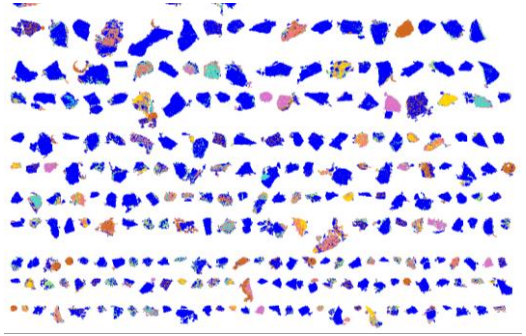


The composite image can then be particulated to enable the classification of each cutting into uniquely defined lithotypes.

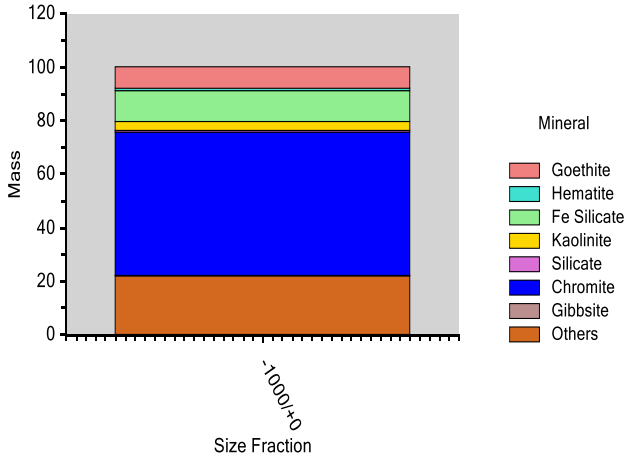
WHAT is QEMSCAN ?

(a) Model Report





- ✓ Elemental Composition
- ✓ Phase Composition
- ✓ Grain properties

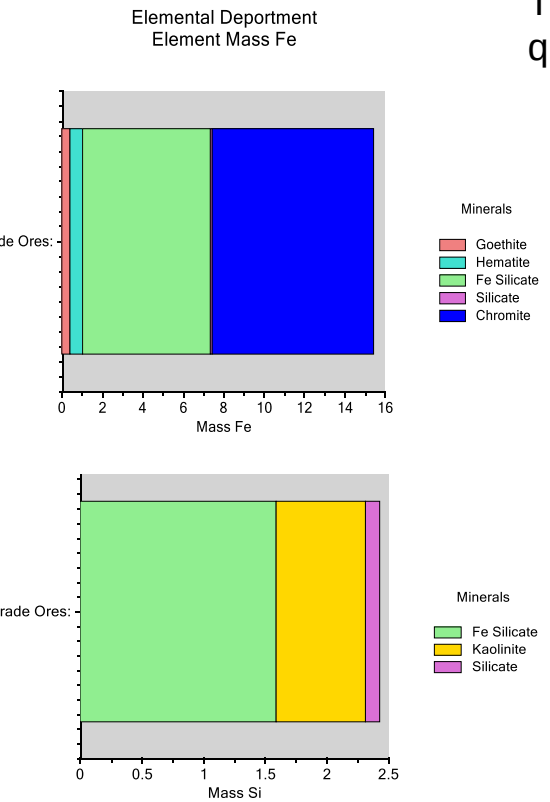


Product		ID	**Low Grade Ores**
		Label	**Low Grade Ores**
		Mass Flow	**100**
Fraction		Id	Low Grade ores
		Name	-1000/+0
	m	Min Size	0.0
	m	Max Size	1,000.0
	m	Calculated ESD Particle Size	97.3
	%	Mass Size Distribution (%)	100.00
		Mass Flow	100.00
Chemical Assay		Element	-1000/+0
		Al	5.31
		Cr	20.59
		Fe	15.42
		H	0.15
		Mg	3.27
		O	26.47
		Si	2.43
Mineral Mass		Mineral	-1000/+0
		Goethite	8.03
		Hematite	0.89
		Fe Silicate	11.53
		Kaolinite	3.33
		Silicate	0.63
		Chromite	53.54
		Gibbsite	0.17
		Others	21.88

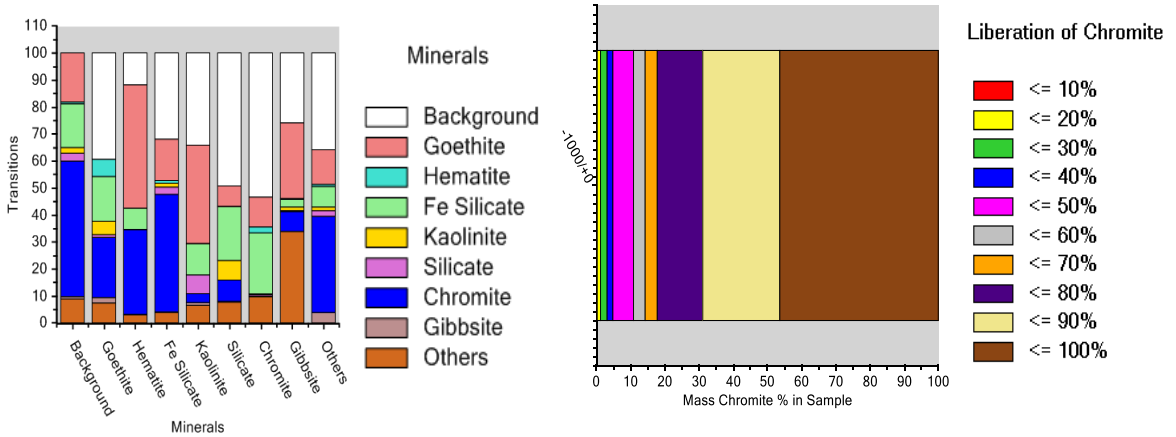
WHAT is QEMSCAN ?

(b) Elemental Deportment

To predict the performance of beneficiation process & quality of concentrate



(c) Liberation and Association



WHAT is QEMSCAN ?

ADVANTAGES:

- Fast analysis of sample particle, can rapidly obtain thousands of high resolution images and then apply rigorous statistical evaluation of the data.
- Ability to cope with a wide variety of ore types by utilizing number of different models.
- Can analysis standard polished, drill core or rock slabs.
- Can provide information regarding bulk mineralogy, grain shape and size, size distribution, liberation and mineral association data.
- Can be used for online process control.
- Less human dependence

LIMITATIONS:

- Standard data files need to be developed for every ore type being analyzed
- Limited detection sensitivity
- Grain < 2 micron can not be identified.
- No crystallographic information

QEMSCAN Analysis of Bauxite

- Bauxite samples from Lohardaga mines & Milled samples from Muri refinery were used for this study.
- Representative aliquots for each sample were prepared into 30 mm diameter epoxy blocks, polished and carbon coated.
- Samples were measured on the QEMSCAN 650FEG platform.

The measurement parameters and statistics

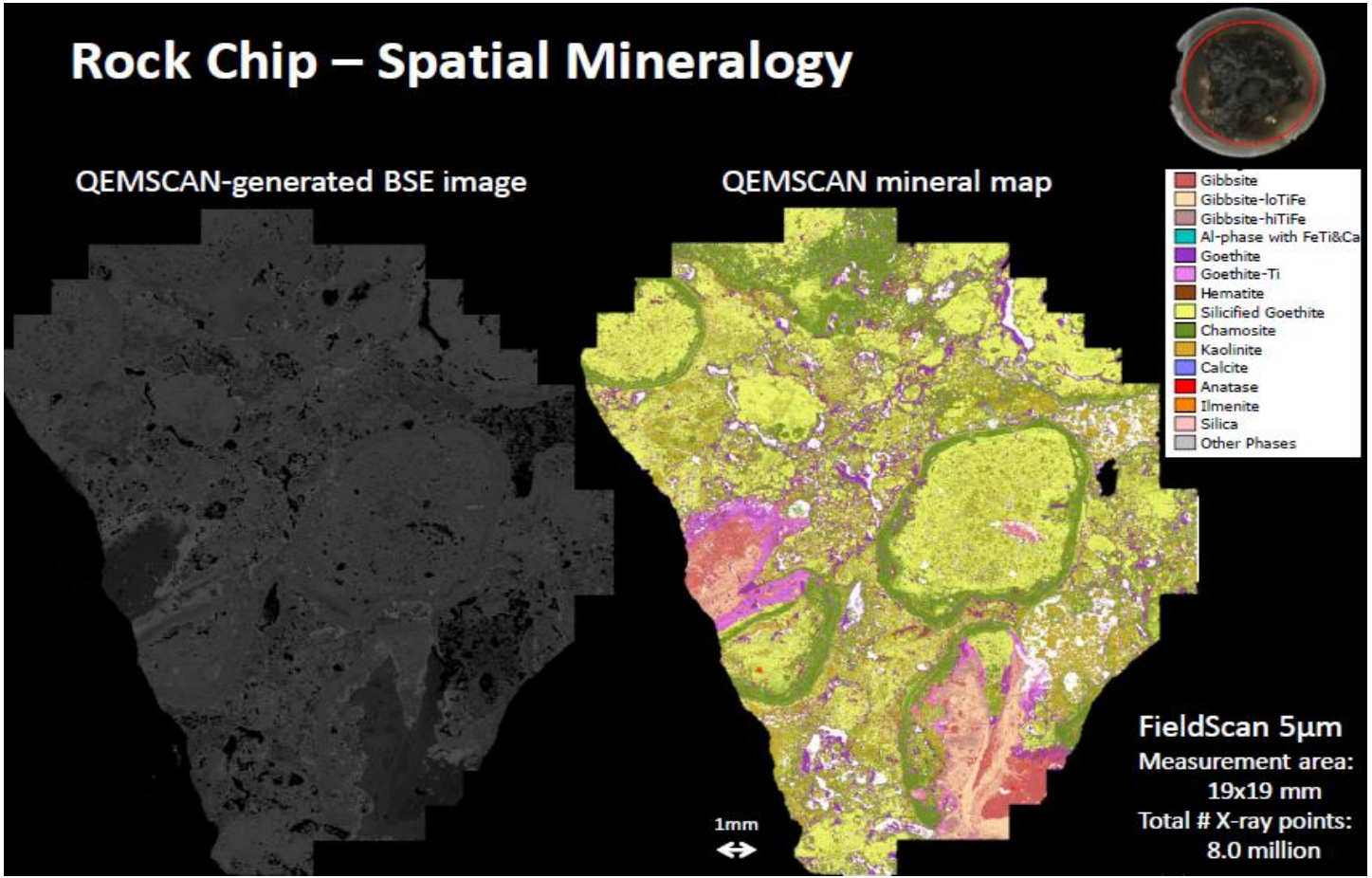
Sample	Rock Chip		Milled Feed	Reactive Grinding
Measurement	FieldScan 5	HiRes	PMA	PMA
Point Spacing (µm)	5.0	2.0	1.8	1.8
X-ray Counts per Point*	2,000	5,000	5,000	5,000
Measurement Time (h:m:s)	15:27:10	04:54:43	01:44:25	01:06:45
Area Measured / # of Particles	Ø 38mm	3x3mm	10,593	10,258
Total # of X-ray Points	8,003,685	1,524,777	467,617	275,224

QEMSCAN Analysis of Bauxite

The table below shows the mineral groups legend that is used to display the QEMSCAN data in this report.

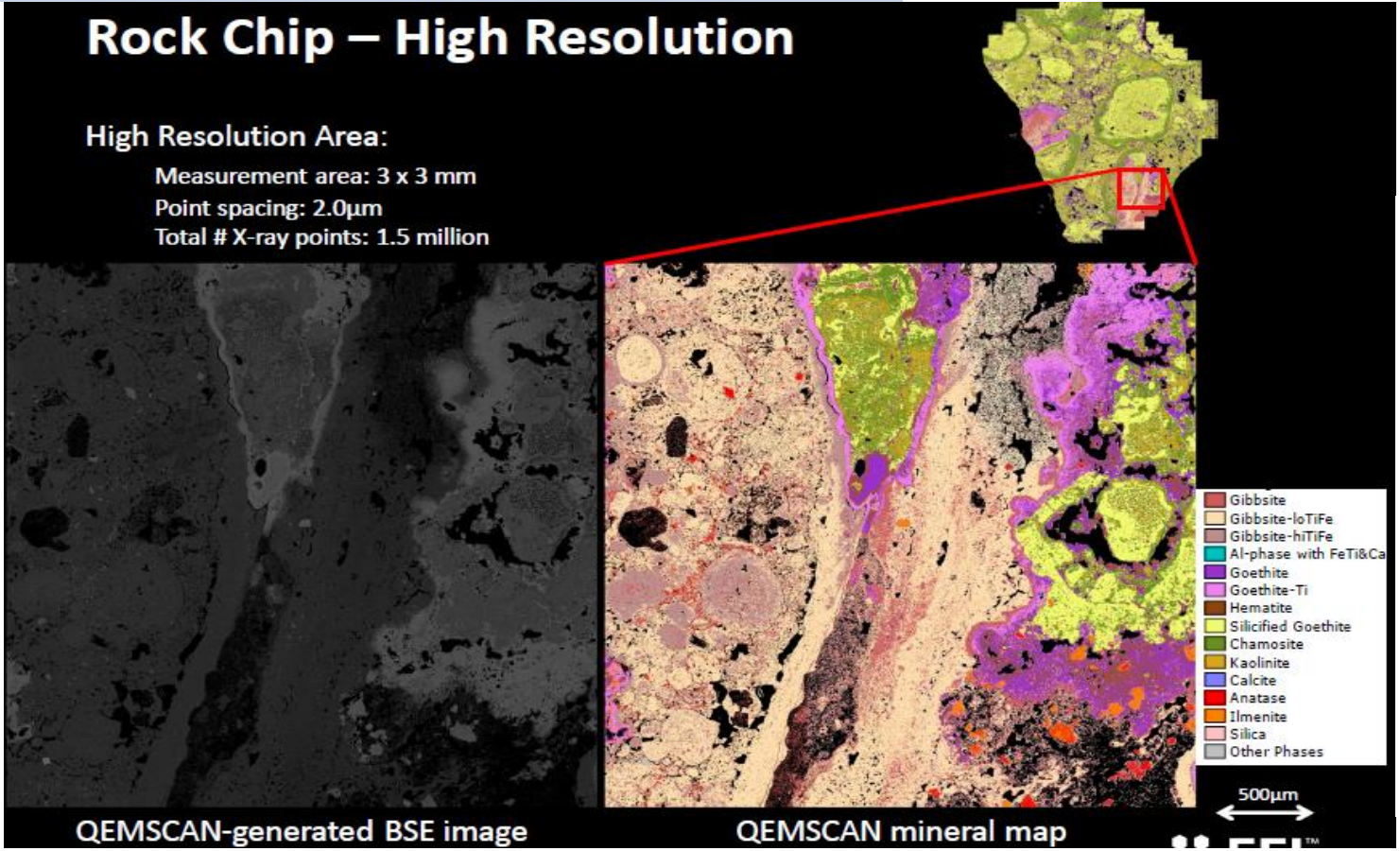
Mineral Group	Description
Gibbsite	Gibbsite and boundary textures with other phases. May include other Al-hydroxide phases.
Gibbsite-loTiFe	Gibbsite with low amount of Ti (up to 10 mass-%)and Fe (up to 5 mass-%) and boundary textures with other phases.
Gibbsite-hiTiFe	Gibbsite with Ti (up to 16 mass-%) and Fe(up to 10 mass-%)and boundary textures with other phases.
Al-phase with FeTi&Ca	Al-rich phase containing varying amounts of Fe, Ti and Ca.
Goethite	Goethite and boundary textures with other phases.
Goethite-Ti	Goethite with ±7 mass-% Ti and boundary textures with other phases.
Hematite	Fe-oxide and boundary textures with other phases. May include other Fe-oxide phases.
Silicified Goethite	Fe-rich phase with Si-and Al-content above acceptable Goethite limits.
Chamosite	Chamosite, minor boundary textures with other phases.
Kaolinite	Kaolinite and boundary textures with other phases.
Calcite	Calcite, minor boundary textures with other phases.
Anatase	Predominantly Ti-oxide and boundary textures with other phases. May include other Ti-oxides.
Ilmenite	Predominantly ilmenite and boundary textures with other phases.
Silica	Silica, minor boundary textures with other phases.
Other Phases	Trace amounts of phases such as apatite, zircon, barite and monazite and minor unclassified measurement points.

QEMSCAN Analysis of Bauxite



Mineral Group
Gibbsite
Gibbsite-loTiFe
Gibbsite-hiTiFe
Al-phase with FeTi&Ca
Goethite
Goethite-Ti
Hematite
Silicified Goethite
Chamosite
Kaolinite
Calcite
Anatase
Ilmenite
Silica
Other Phases

QEMSCAN Analysis of Bauxite



Mineral Group
Gibbsite
Gibbsite-loTiFe
Gibbsite-hiTiFe
Al-phase with FeTi&Ca
Goethite
Goethite-Ti
Hematite
Silicified Goethite
Chamosite
Kaolinite
Calcite
Anatase
Ilmenite
Silica
Other Phases

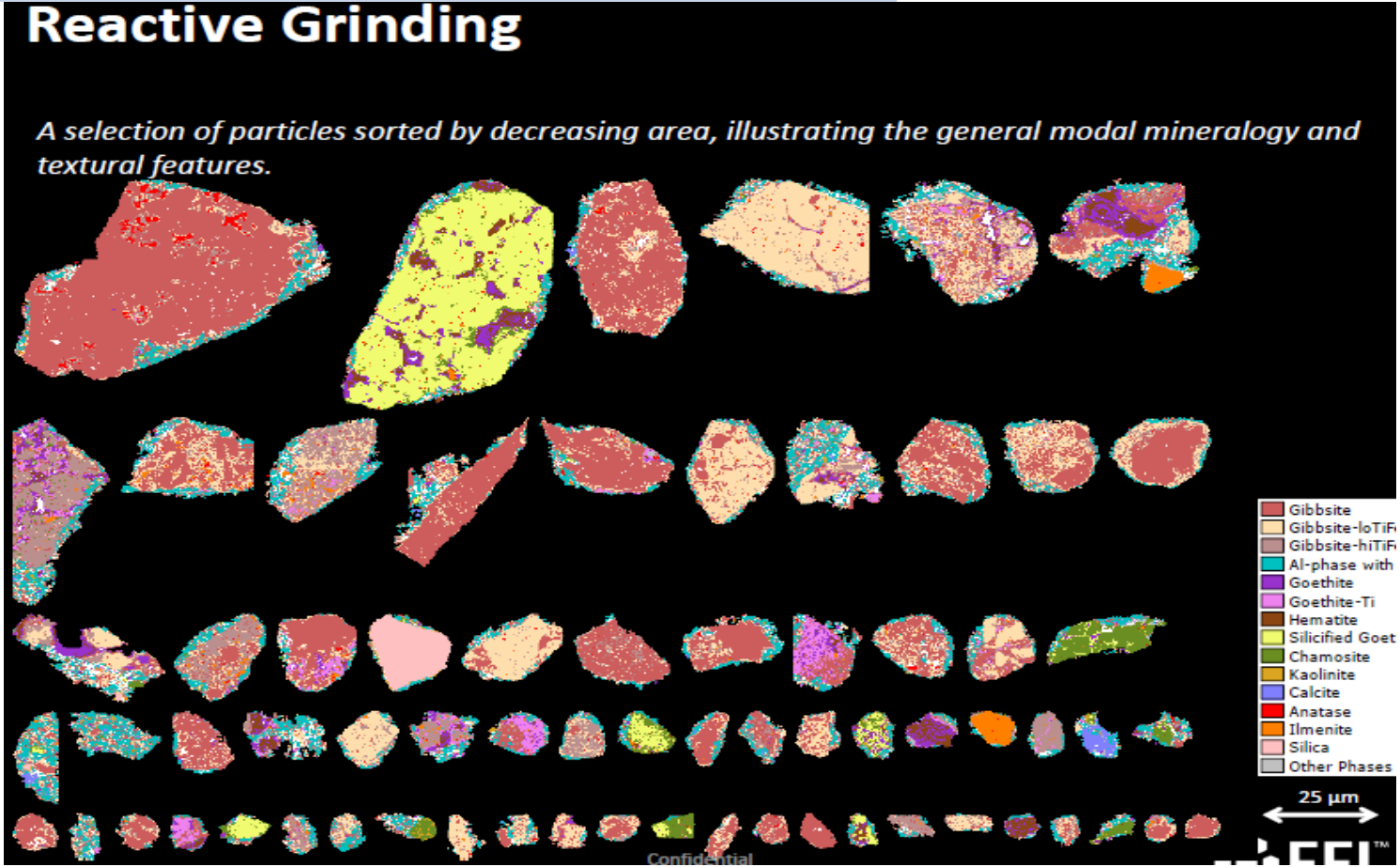
QEMSCAN Analysis of Bauxite

Milled Feed

A selection of particles sorted by decreasing area, illustrating the general modal mineralogy and textural features.

Mineral Group
Gibbsite
Gibbsite-loTiFe
Gibbsite-hiTiFe
Al-phase with FeTi&Ca
Goethite
Goethite-Ti
Hematite
Silicified Goethite
Chamosite
Kaolinite
Calcite
Anatase
Ilmenite
Silica
Other Phases

QEMSCAN Analysis of Bauxite

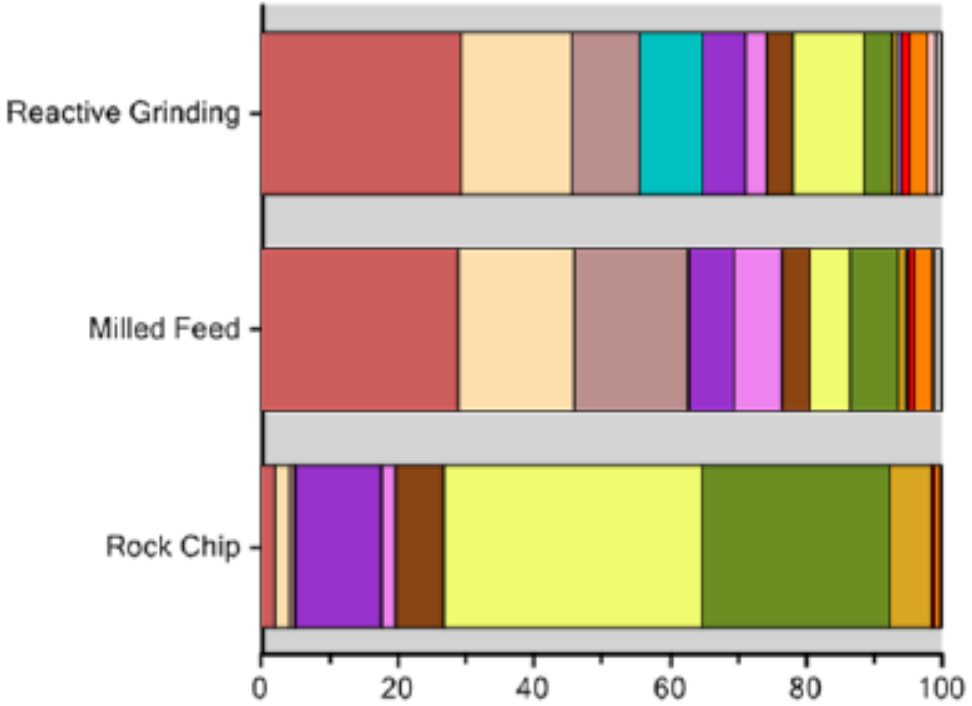


Mineral Group
Gibbsite
Gibbsite-loTiFe
Gibbsite-hiTiFe
Al-phase with FeTi&Ca
Goethite
Goethite-Ti
Hematite
Silicified Goethite
Chamosite
Kaolinite
Calcite
Anatase
Ilmenite
Silica
Other Phases

QEMSCAN Analysis of Bauxite

Mineral Abundance:

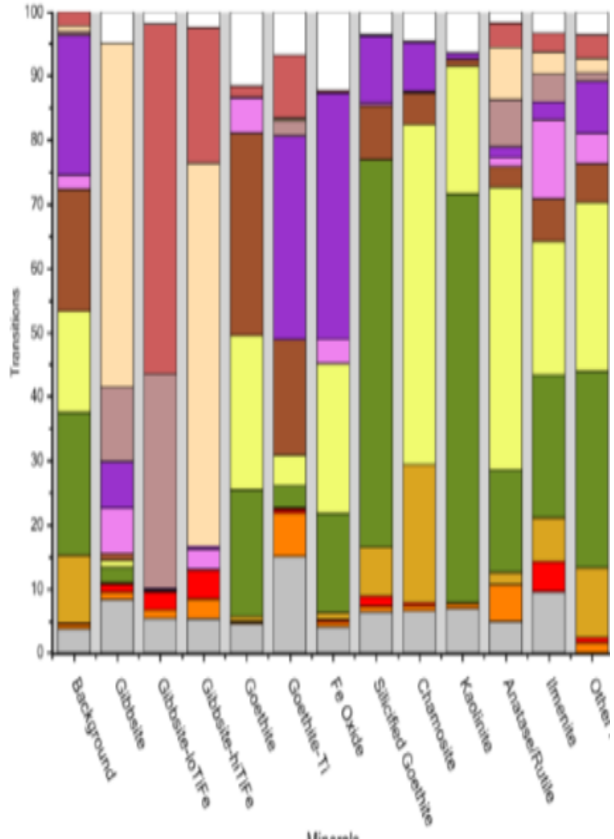
Mineral Abundances (mass-%)	Rock Chip	Milled Feed	Reactive Grinding
Gibbsite	2.1	29.0	29.4
Gibbsite-loTiFe	2.1	17.0	16.2
Gibbsite-hiTiFe	0.8	16.7	10.0
Al-phase with FeTi&Ca	0.0	0.3	9.3
Goethite	12.7	6.5	6.2
Goethite-Ti	2.1	7.0	3.2
Hematite	7.1	4.1	3.8
Silicified Goethite	38.0	5.9	10.5
Chamosite	27.6	7.0	4.1
Kaolinite	6.1	1.2	0.7
Calcite	0.0	0.3	0.6
Anatase	0.5	0.9	1.3
Ilmenite	0.8	2.6	2.6
Silica	0.0	0.2	1.2
Other Phases	0.3	1.2	0.9
Total	*100.0*	*100.0*	*100.0*



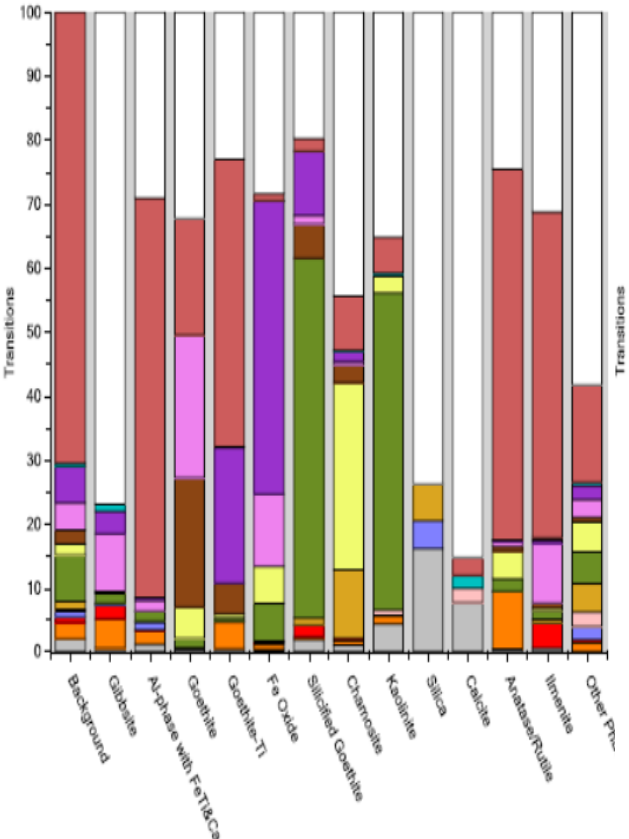
QEMSCAN Analysis of Bauxite

Mineral Association:

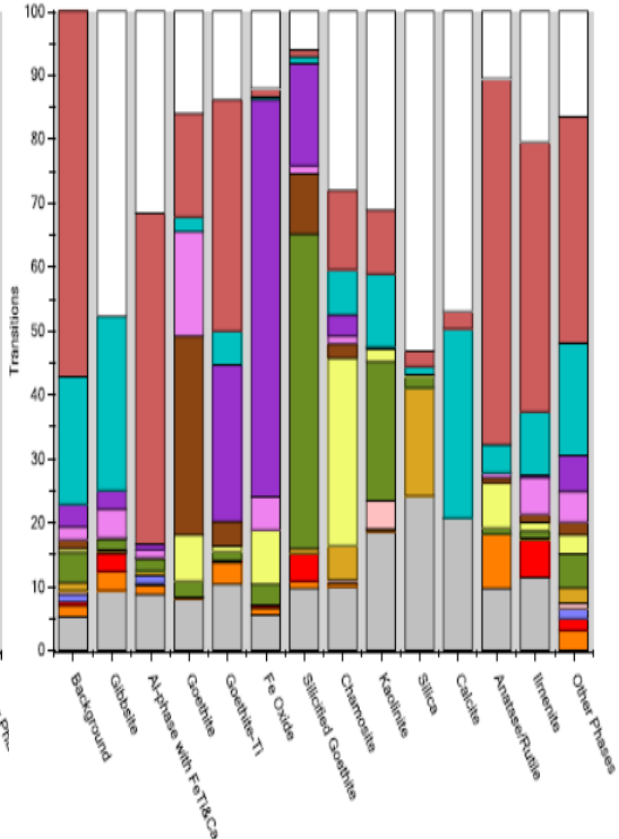
Rock Chips



Mill Feed

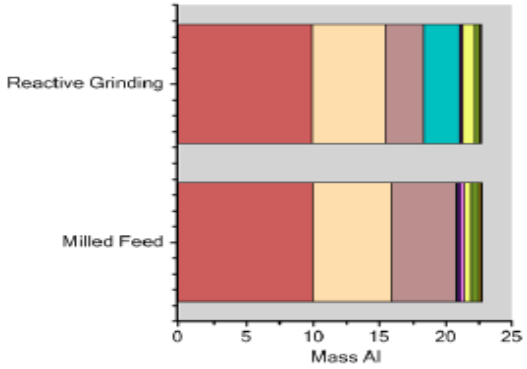


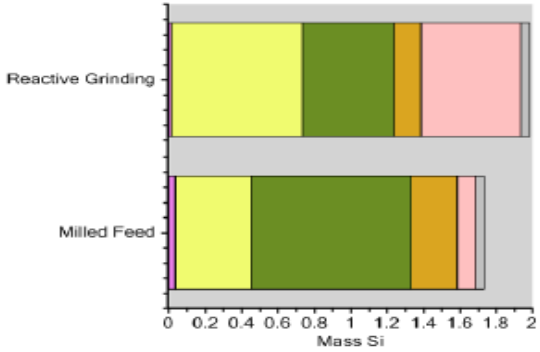
Reactive Grinding

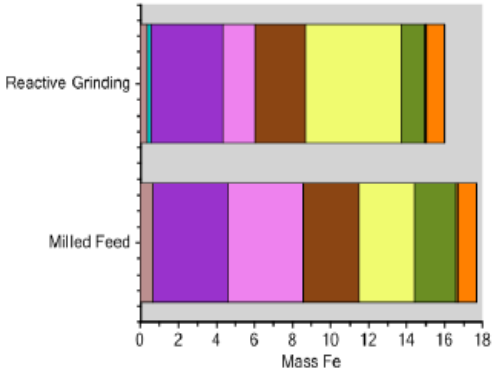


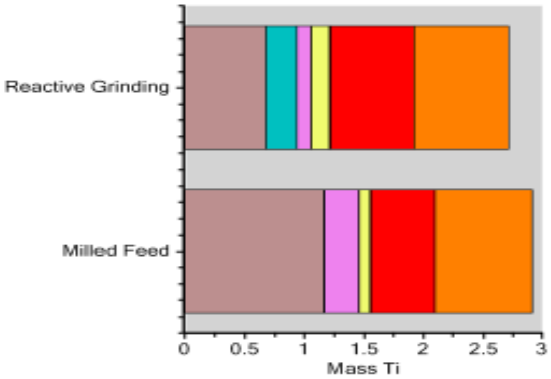
QEMSCAN Analysis of Bauxite

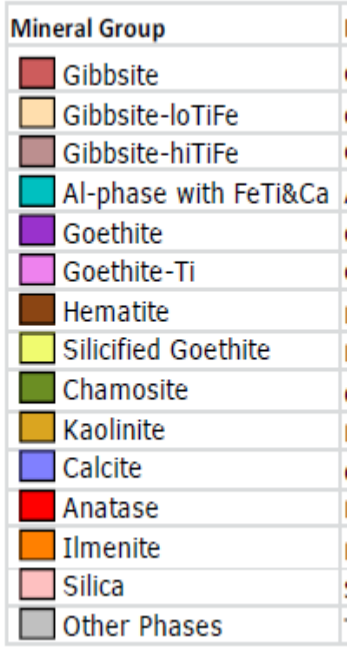
Elemental Deportation :





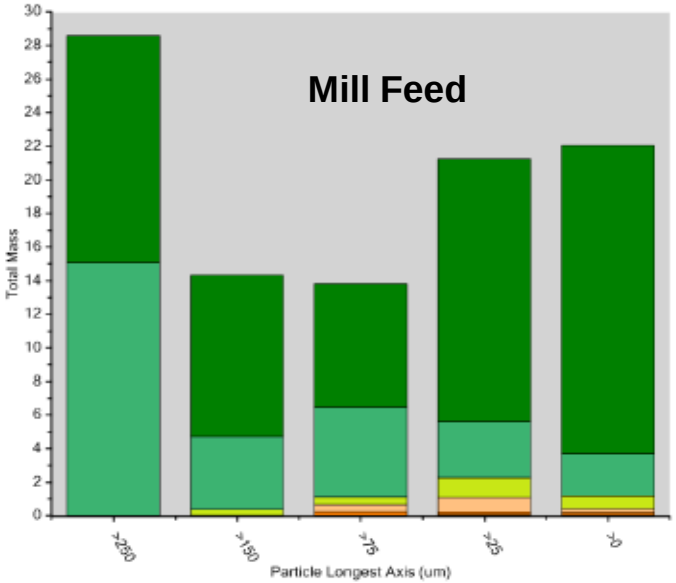


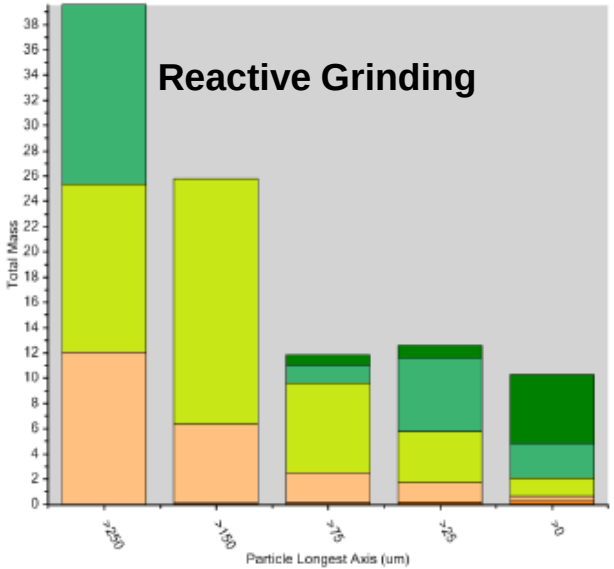




QEMSCAN Analysis of Bauxite

Free Surface of liberated gibbsite:





- The mill feed sample shows significant free surface liberation in all particle section classes
- The Reactive Grinding sample shows a lower degree of gibbsite free surface liberation. This is due to the Al-phase with Ti, Fe & Ca, which occurs as rims around most of the gibbsite particles

Use of QEMSCAN results in Bayer process

Inference:

- QENSCAN can provide mineralogical characterization with detailed texture, association, liberation data at microscopic level.
- The results of Reactive Grinding samples clearly shows formation of complex phases on the surface of impure gibbsite particles which can reduce the free surface area of gibbsite particle and thereby impact the extraction efficiency at digester
- In extreme case only 31.6 mass-% of gibbsite has a free surface liberation of >70%, which is due to the occurrence of rims of the Al-phase with Fe, Ti and Ca.

QEMSCAN is a useful tool in the investigation of bauxite samples to quantify mineral abundance, mineral association and liberation data, as well as to determine the deportment of elements of specific interest.

Conclusion & Way forward

- Detailed mineralogical analysis of bauxite and solids at every unit operations in Bayer process will
  - ✓ Provide better flexibility to use bauxite
  - ✓ Improve the process efficiency & performance
  - ✓ Reduce loss of valuable minerals in bauxite residue
  - ✓ Provide deeper process insight to operations team
- QENSCAN is used as a standard QC tool in many mineral beneficiation plants
- Alumina refineries can jointly develop the Standards and Data bank for effective utilization of QEMSCAN for enhancing performance and sustainability

Acknowledgement

- Special thanks to
  - ✓ Dr Kumaresan (ABSTC), Mrs Chandrakala (ABSTC) & members from Lohardaga mines, Muri Refinery of HINDALCO
  - ✓ FEI Australia for QENSCAN analysis and technical discussions

THANK YOU