2nd Workshop on Revision of Threshold Value of Minerals

Beneficiation Studies on Iron Ores of Eastern India Sector

by

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INTRODUCTION

- According to industry forecasts, the global demand for iron ore is expected to accelerate in the future.
- The global demand for iron ore is expected to grow at the rate of **10%** per annum.
- India also possesses the **7th** largest reserves of iron ore (7000 million tonnes).
- As per the current consumption rank, India has **proven reserves** for **35 - 40 years** for iron ore.
- **Significant mineral potential still untapped in India**
- Unproven 'resources' are more than twice the proven 'reserves'
- Total Resources: **25 Billion Tonnes**

Reserves	Remaining Resources
28%	**72%**

BENCH SCALE BENEFICIATION STUDIES

ON

IRON ORE SAMPLES

FROM

EASTERN SECTOR

CARRIED OUT BY

INDIAN BUREAU OF MINES

BENEFICIATION STUDIES

ON

SAMPLES FROM INDUSTRY

CASE STUDIES

Tantra-Raikela-Bandhal (TRB Mines), Tensa, Dist. Sundargarh, Odisha, from M/s Jindal Steel Power Ltd.

Original Assay %		Results after Beneficiation			Process Adopted
		Conc. Assay %	Fe(T) Recovery	Wt% Yield	
Sample No.1					
Fe(T)	56.18	64.48	39.3%	34.6	Jigging at -10+1mm size
FeO	0.93	-			
SiO_2	4.93	2.50			
Al_2O_3	5.91	2.90			
LOI	8.07	1.97			
Sample No.2					
Fe(T)	52.48	63.45	37%	30.4	Jigging & Tabling
Al_2O_3	8.11	2.68			
SiO_2	8.57	2.47			
LOI	7.03	2.88			

CASE STUDIES

Kasia Iron & Dolomite Mine, Dist. Keonjhar, Orissa, M/s Essel Mining and Industries Ltd.

Original Assay%		Results after Beneficiation			Process Adopted
		Conc. Assay %	Fe(T) Recovery	Wt% Yield	
Fe (T) SiO_2 Al_2O_3 CaO MgO LOI	51.49 11.47 7.83 0.09 0.01 6.30	62.93 4.03 2.72 - - 2.47	35.1%	28.8	Jigging
Jilling Mine, Dist. Keonjhar, Orissa, M/s Essel Mining and Industries Ltd.					
Fe (T) SiO_2 Al_2O_3 TiO_2 LOI	49.73 13.00 7.31 0.26 5.71	63.99 3.67 2.04 -- 1.61	26.5%	26.6	Screening, Scrubbing, Tabling

CASE STUDIES

Oraghat, Keonjhar dist., Odisha for M/s Rungta Sons Pvt. Ltd.

Original Assay%		Results after Beneficiation			Process Adopted
		Conc. Assay %	Fe(T) Recovery	Wt% Yield	
Fe (T) SiO2 Al2O3 Mn LOI	53.50 8.30 7.20 0.05 7.35	62.38 2.85 3.18	38%	32.4	Grinding, Tabling, WHIM
Sanindpur, Keonjhar dist., Odisha, for M/s Rungta Son's Pvt. Ltd.					
Fe(T) SiO_2 Al_2O_3 LOI	57.12 5.81 5.75 5.98	63.53 2.23 2.48 3.82	42.5%	38.2	Screening, Jigging & Tabling

CASE STUDIES

Combined slimes from Kiriburu iron beneficiation plant, M/s SAIL, West Singhbhum dist., Jharkhand (RMDS).

Original Assay%		Results after Beneficiation			Process Adopted
		Conc. Assay %	Fe(T) Recovery	Wt% Yield	
Fe	45.25	60.26			Mozley MGS, Mozley Mineral Separator
Al_2O_3	11.64	4.86	32.10%	24.1	
SiO_2	11.91	3.43			
LOI	9.37	4.52			
TiO_2	0.65	0.26			
P	0.06	0.04			
Mn	0.09	0.08			
Low grade iron ore sample from M/s Sri Ram Mineral Company, Chaibasa, Singhbhum(W), Jharkhand					
Fe(T)	41.85	61.42			Gravity Separation (Jigging, Tabling)
SiO_2	17.10	5.47	33.1	22.6	
Al_2O_3	13.62	4.50			
P	0.02	0.04			
LOI	6.88	6.56			

CASE STUDIES

Iron ore fines sample from Barbil region, Odisha for M/s Jagnathpur Steel Limited, Ranchi, Jharkhand.

Original Assay%		Results after Beneficiation			Process Adopted
		Conc. Assay %	Fe(T) Recovery	Wt% Yield	
Fe(T) SiO_2 Al_2O_3 LOI	58.15 7.05 4.39 4.30	64.22 2.91 2.08 2.78	69.7%	63.5	Gravity & Magnetic separation
Limited Tests, Ore Fines from crusher plant, Barpada, Dist. Keonjahar, M/s Tulip Mines (P) limited,					
Fe(T) Al_2O_3 SiO_2 LOI	58.30 5.14 3.71 6.81	60.14 2.00 1.09 3.71	34.3%	30.6	Gravity separation (Tabling)
	Fe(T) Al_2O_3 SiO_2 LOI	60.11 4.20 2.82 6.51	75.5%	78.3	Magnetic separation WHIMS

BENCH SCALE

BENEFICIATION STUDIES

ON

EXPLORATION SAMPLES

(*G2 Stage*)

EXPLORATION BLOCKS

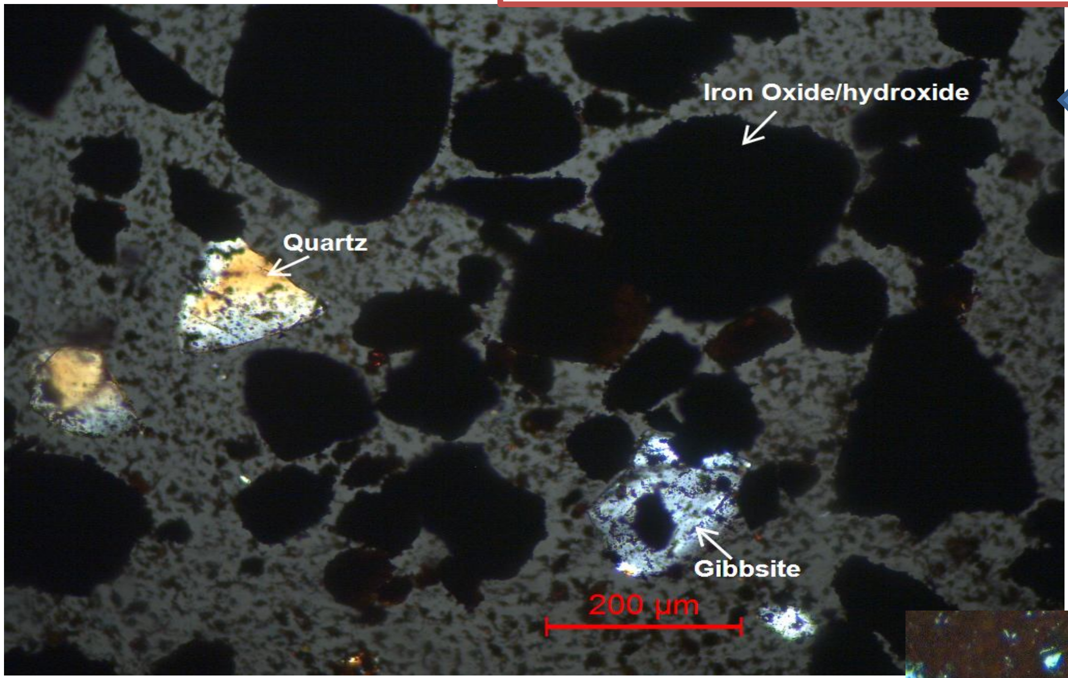
Mendhamaruni Block, Dist. Sundergarh, from GSI, Odisha

<table>
<tr><th colspan="2" rowspan="2">Original Assay%</th><th colspan="3">Results after Beneficiation</th><th rowspan="2">Process Adopted</th></tr>
<tr><th>Conc. Assay%</th><th>Fe(T) Recovery</th><th>Wt% Yield</th></tr>
<tr><td rowspan="2">Fe(T)
SiO₂
Al₂O₃
Mn(T)
LOI</td><td rowspan="4">60.26
5.00
4.23
0.14
3.54</td><td colspan="3">1st Route</td><td rowspan="2">Screening, Classification, Tabling and Multi gravity separation</td></tr>
<tr><td>63.45
3.05
2.75
--
2.56</td><td>60.2</td><td>57.2</td></tr>
<tr><td rowspan="2">Fe(T)
SiO₂
Al₂O₃
LOI</td><td colspan="3">Alternate Route</td><td rowspan="2">Stage grinding, Classification followed by Tabling and MGS</td></tr>
<tr><td>64.62
2.43
2.26
2.43</td><td>53.8</td><td>50.5</td></tr>
</table>

Mineralogical Studies – Modal Distribution & Liberation Characteristics

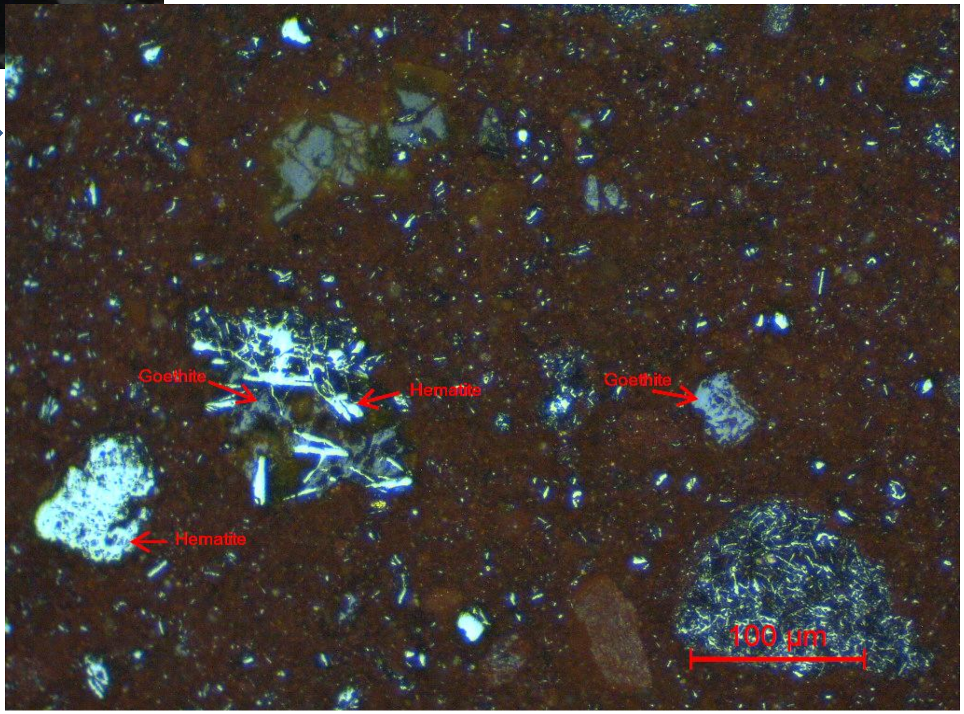
Minerals/ Approx%	Original	Table Conc. (- 50#)	MGS Conc.	Table Tails
Hematite	45 – 50	~70	~75	25 – 30
Goethite+Limonite	35 – 40	~25	15 – 20	55 – 60
Clay (Kaolinite)	5 – 8	1- 2	1 – 2	1- 2
Gibbsite	3 – 5	1 – 2	1 – 2	3 – 4
Quartz	2 – 3	2 – 3	~2	4 – 5
Psilomelane/ Manganomelane	1 – 2	Majority of the hematite and goethite grains are free from interlocking but a number of grains carry fine grained inclusions of silicates	Hematite grains are fine grained in size, some of the grains also carry minute inclusions of silicates	Hematite grains are extremely fine grained and are embedded in limonitic groundmass. Clay is intermixed with iron oxides/hydroxides
Magnetite(Martsd)	1 – 2			
Mica (Muscovite)	Traces			
Garnet	Trcaes			
Tourmaline	Traces			
Amphibole	Traces			

PHOTOMICROGRAPHS



-65# Original Sample:

Quartz and gibbsite grains are free from interlocking but carry minute inclusions of iron oxides (Transmitted light/ Crossed Nicol).

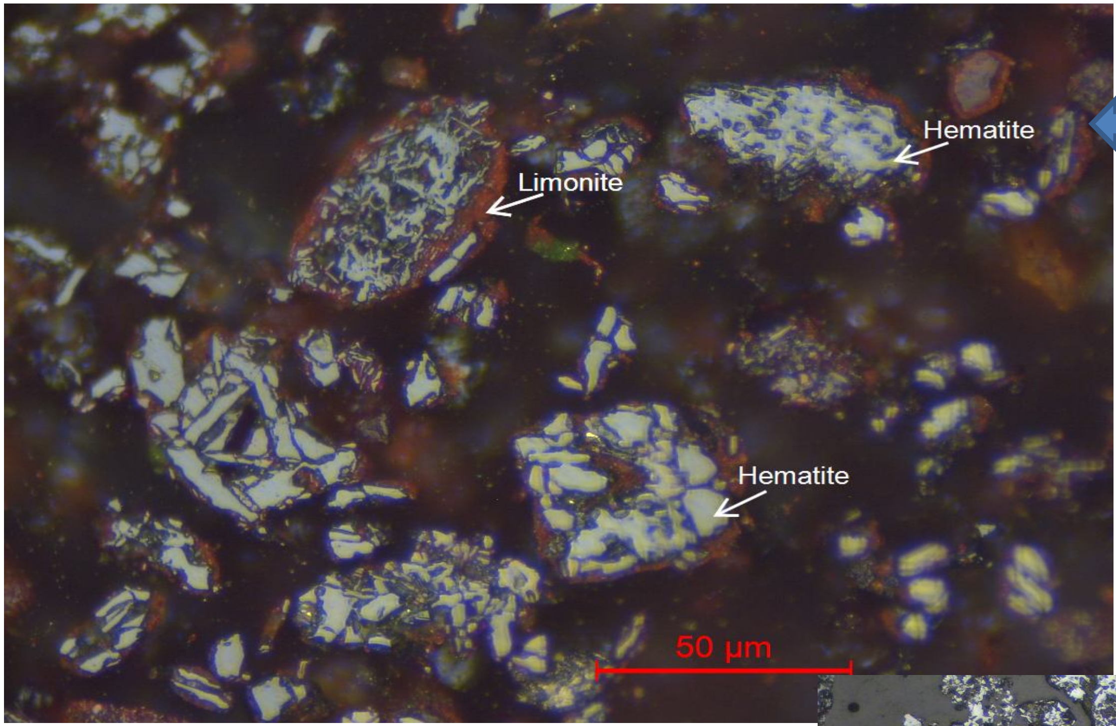


-65# Original :

Distribution of hematite and goethite in limonitic ground mass(matrix).

***Note*: Preponderance of thin needle like grains and fibrous aggregate of hematite.**

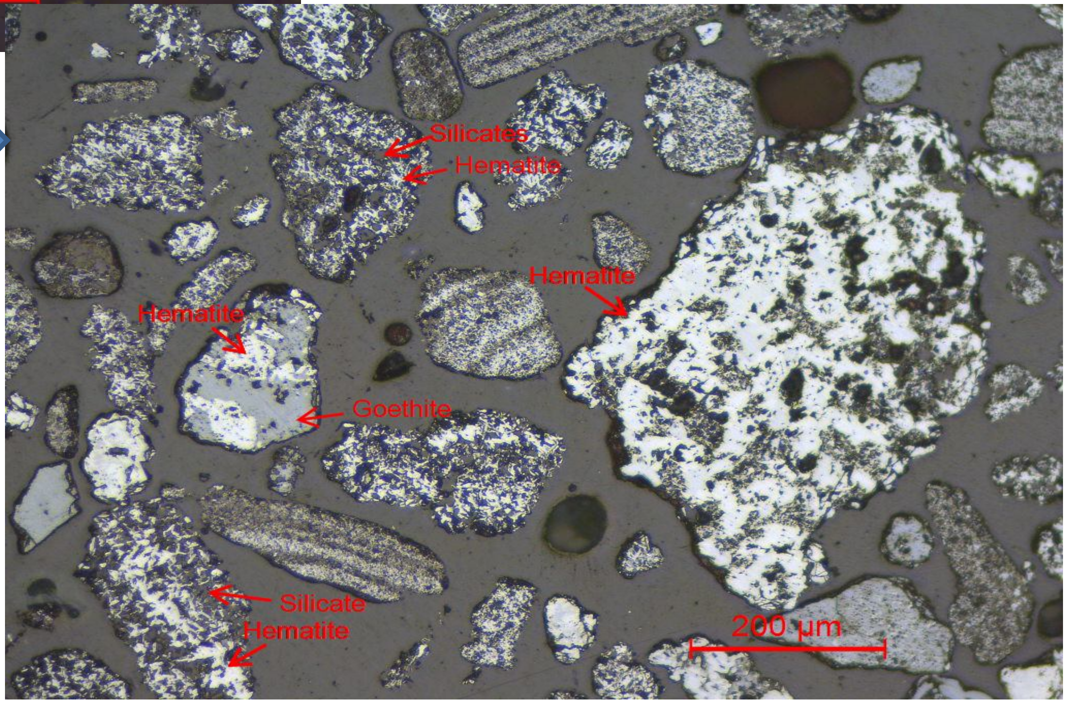
(Reflected Light/Uncrossed/Oil)

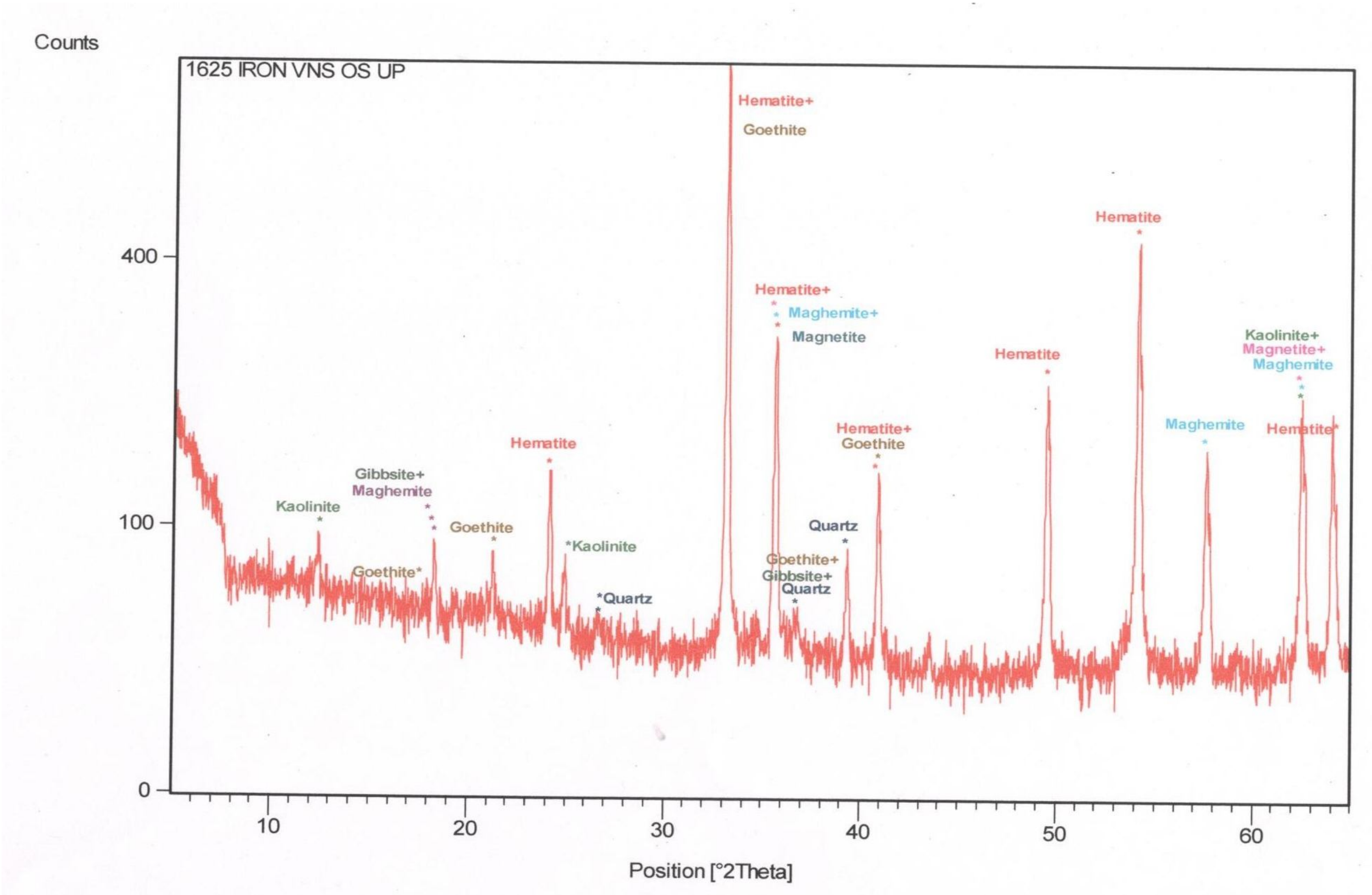


PHOTOMICROGRAPHS

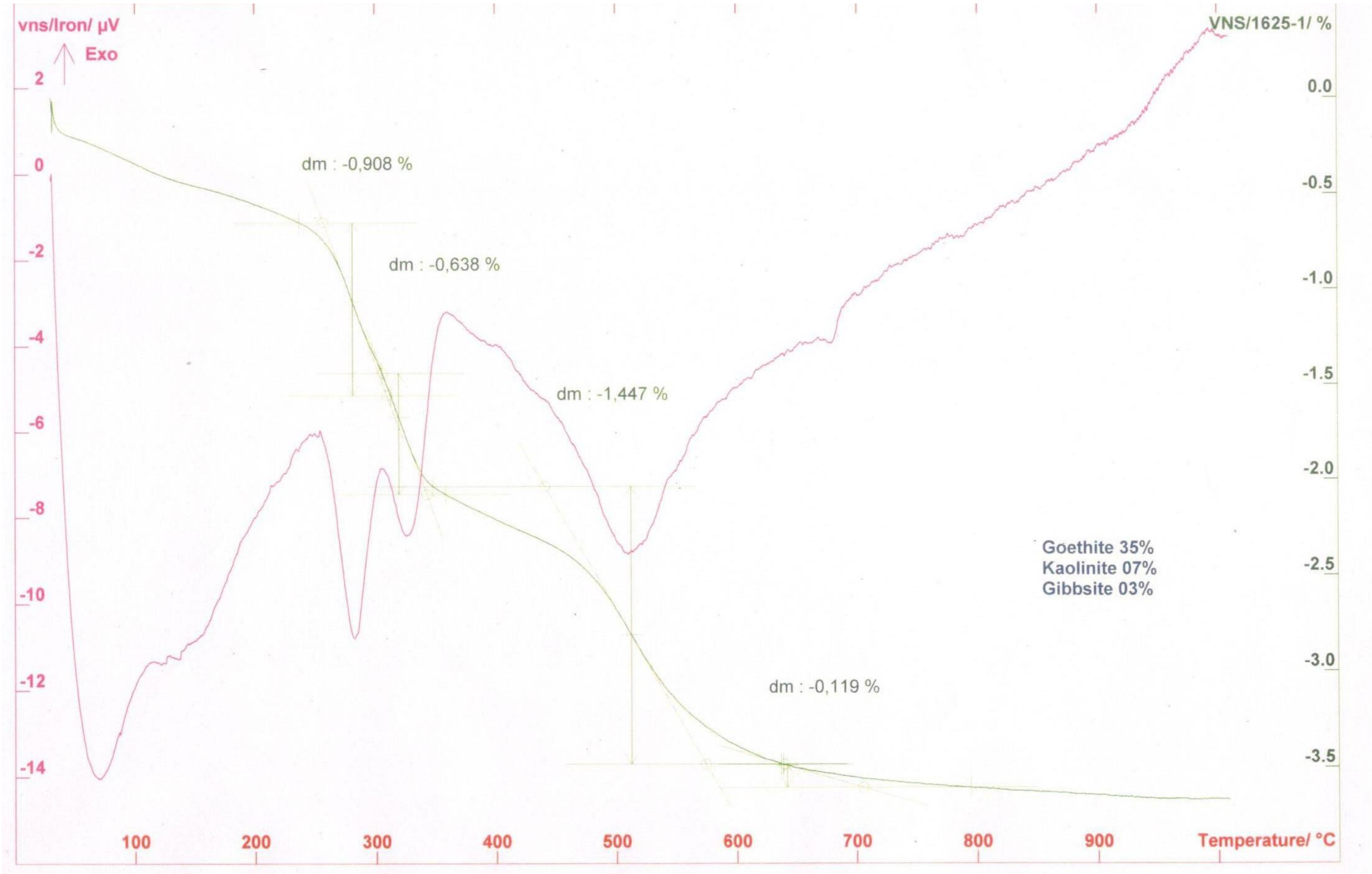
MGS Concentrate:
Granular aggregates of hematite within the ground mass of limonite. Intricate association of hematite with cryptocrystalline goethite and gangue.
(Reflected Light/Uncrossed/Oil)

Table Concentrate:
Presence of fine granular aggregates of hematite intermixed with goethite and silicate gangue. *Note*: Intricate association/ intergrowth of hematite with crystalline goethite
(Reflected Light/Uncrossed/Air)





X-Ray Diffractogram of original Iron Ore sample



TG-DTA graph: Quantitative estimation of goethite, kaolinite and gibbsite in the the iron ore sample

EXPLORATION BLOCKS

Kalamang Block, Dist. Sundergarh, from GSI, Bhubaneswar, Odisha

Original Assay%		Results after Beneficiation			Process Adopted
		Conc. Assay %	Fe(T) Recovery	Wt% Yield	
		-30 mesh size			Classification, Tabling and MGS
Fe(T) SiO_2 Al_2O_3 LOI	61.14 4.25 3.43 3.96	64.12 2.31 2.01 3.13	61%	58.3	
		-70 mesh size			
Fe(T) SiO_2 Al_2O_3 LOI	61.14 4.25 3.43 3.96	64.01 2.30 1.83 3.15	68.7%	65.8	

EXPLORATION BLOCKS

Gandhalpada Block, Dist. Keonjhar (Drill Core samples, CBG) from, GSI, Bhubaneswar, Odisha

Original Assay%		Results after Beneficiation			Process Adopted
		Conc. %	Fe(T) Recovery	Wt% Yield	
		Composite Conc. I			
Fe(T) SiO_2 Al_2O_3 LOI	56.78 5.62 6.71 5.10	64.13 1.99 2.78 2.75	48.7	43.2	Dry screening, Jigging, MGS, Classification, Tabling
		Conc. II			
Fe(T) SiO_2 Al_2O_3 LOI		63.75 2.12 2.99 2.90	55.3	49.3	

EXPLORATION BLOCKS

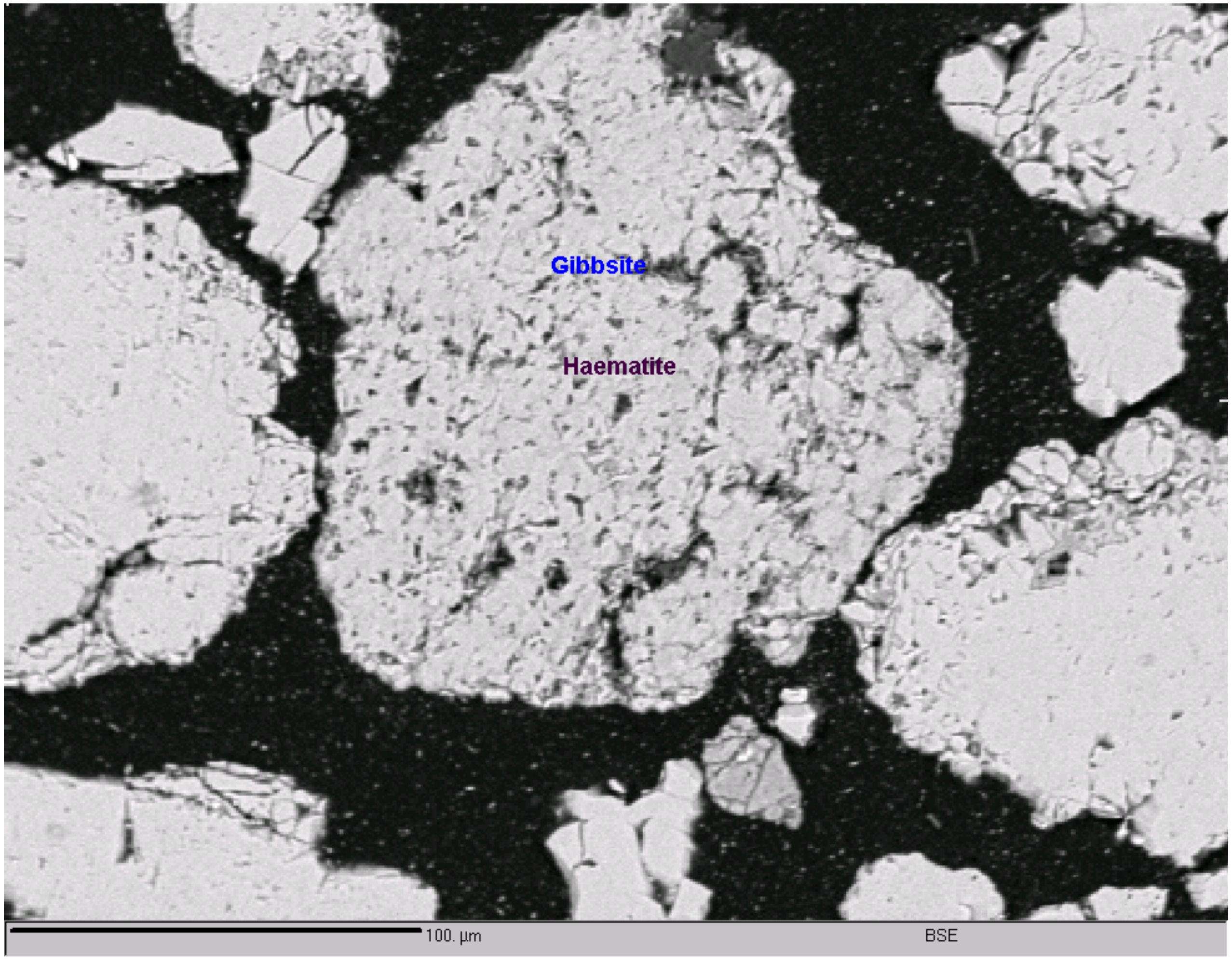
Rengalaberha North-East Block, Dist. Keonjhar (Drill Core sample, CBR) from GSI, Bhubaneswar, Odisha.2143/F/NC

Original Assay%		Results after Beneficiation			Process Adopted
		Conc. Assay%	Fe(T) Recovery	Wt% Yield	
		- 6mm+100mesh product			Crushing, Dry screening, Jigging, WHIMS, MGS, conc.
Fe(T) SiO_2 Al_2O_3 LOI	58.42 6.73 3.70 4.28	64.26 1.81 3.08 3.03	25.7%	23.5	
		-100 mesh screened product			Screened over 100mesh.
Fe(T) SiO_2 Al_2O_3 LOI	58.42 6.73 3.70 4.28	64.00 1.43 2.95 3.40	17.4%	15.90	

ELECTRON PROBE MICRO ANALYSIS (EPMA) STUDY

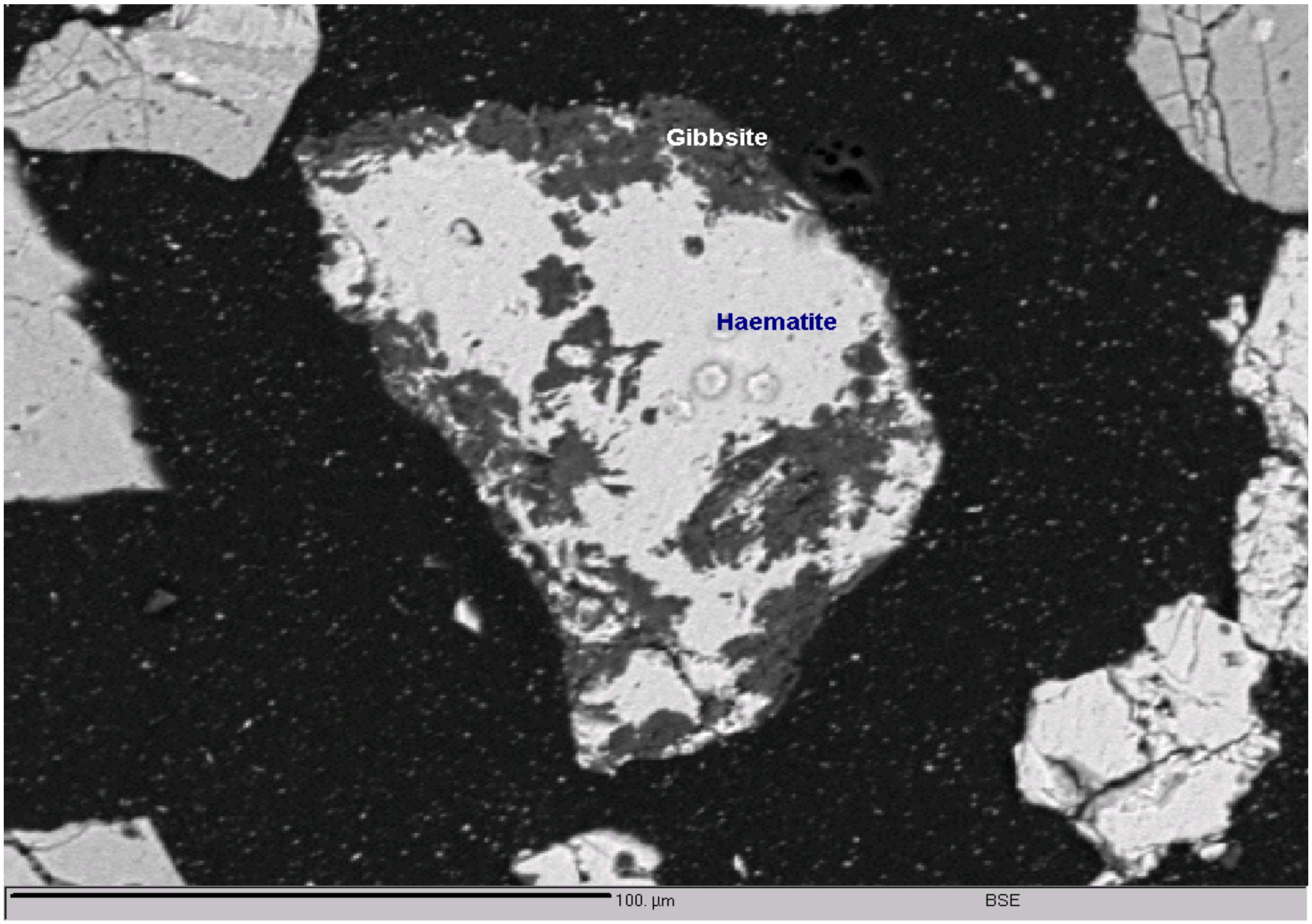
Different case studies are presented wherein association of aluminous minerals with iron oxides/hydroxides directs the beneficiation route to be adopted

I. Case Study: It is impossible to reduce alumina by physical processes of separation



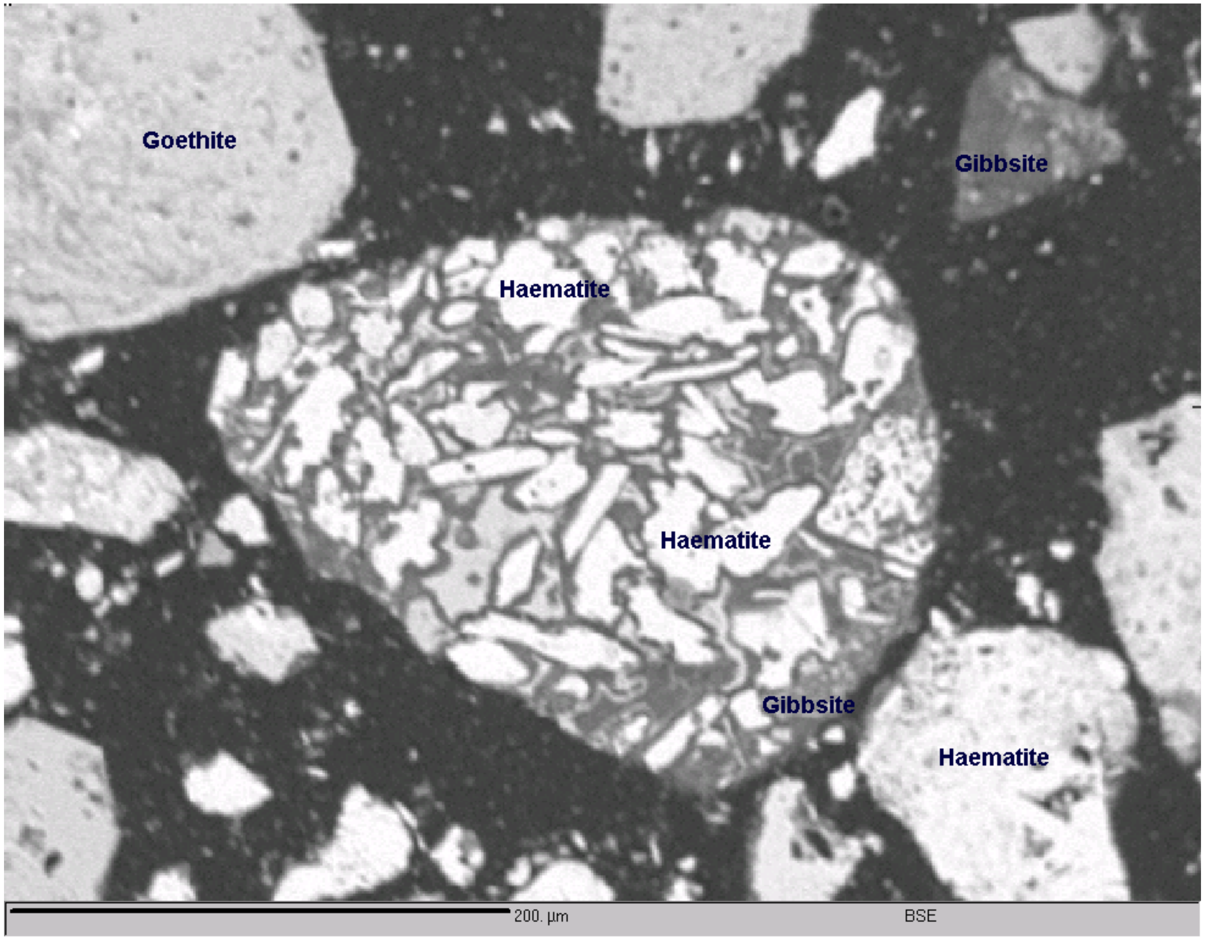
(BSE) image showing very fine inclusions of gibbsite (2 to 20 micron size, dark) within individual hematite grains

II. Case Study: Amenability to reduce alumina by physical processes of separation is less



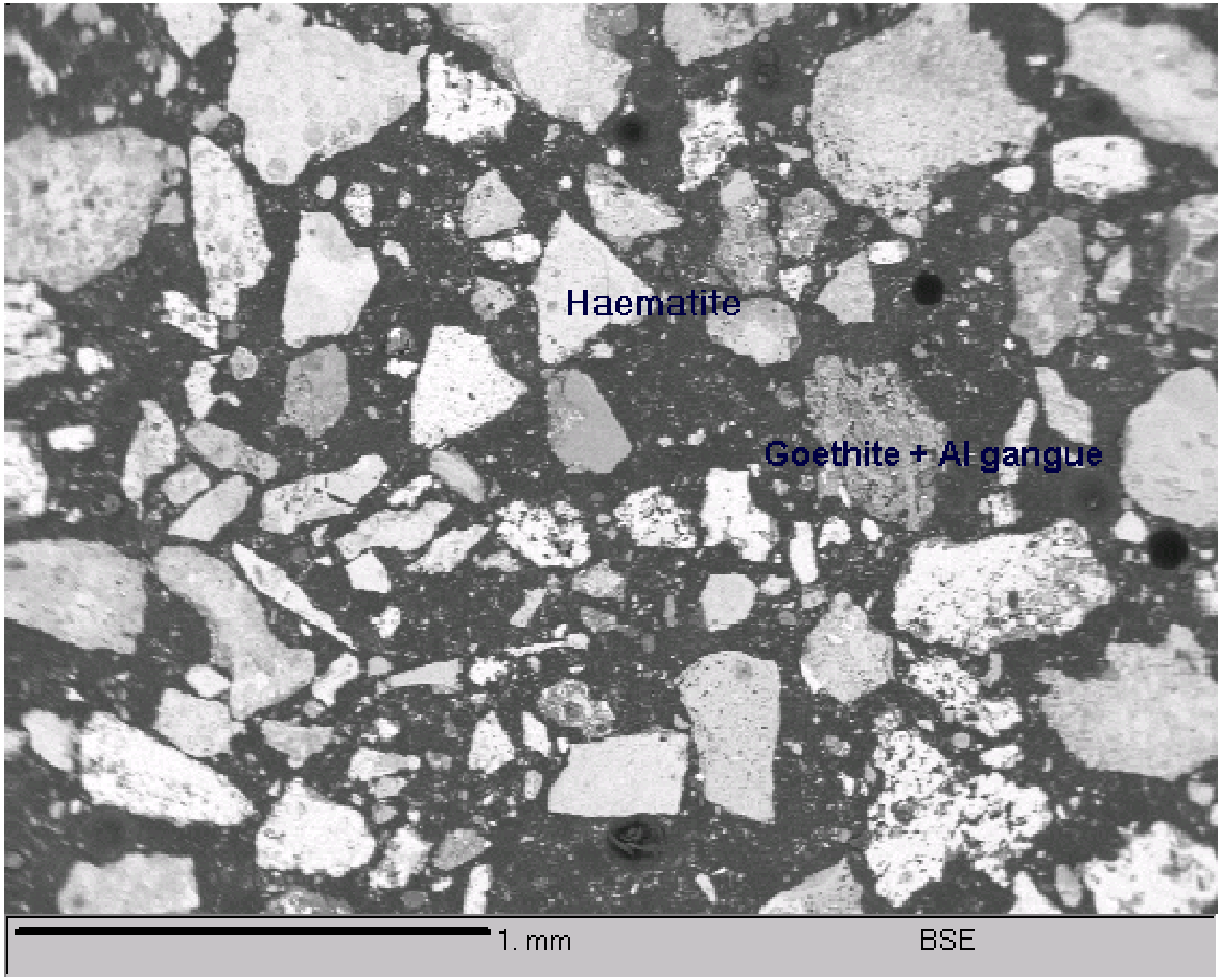
(BSE) image showing intimate association between haematite grains (bright) and gibbsite (dark)

III. Case Study: Amenability to reduce alumina by physical processes of separation is more



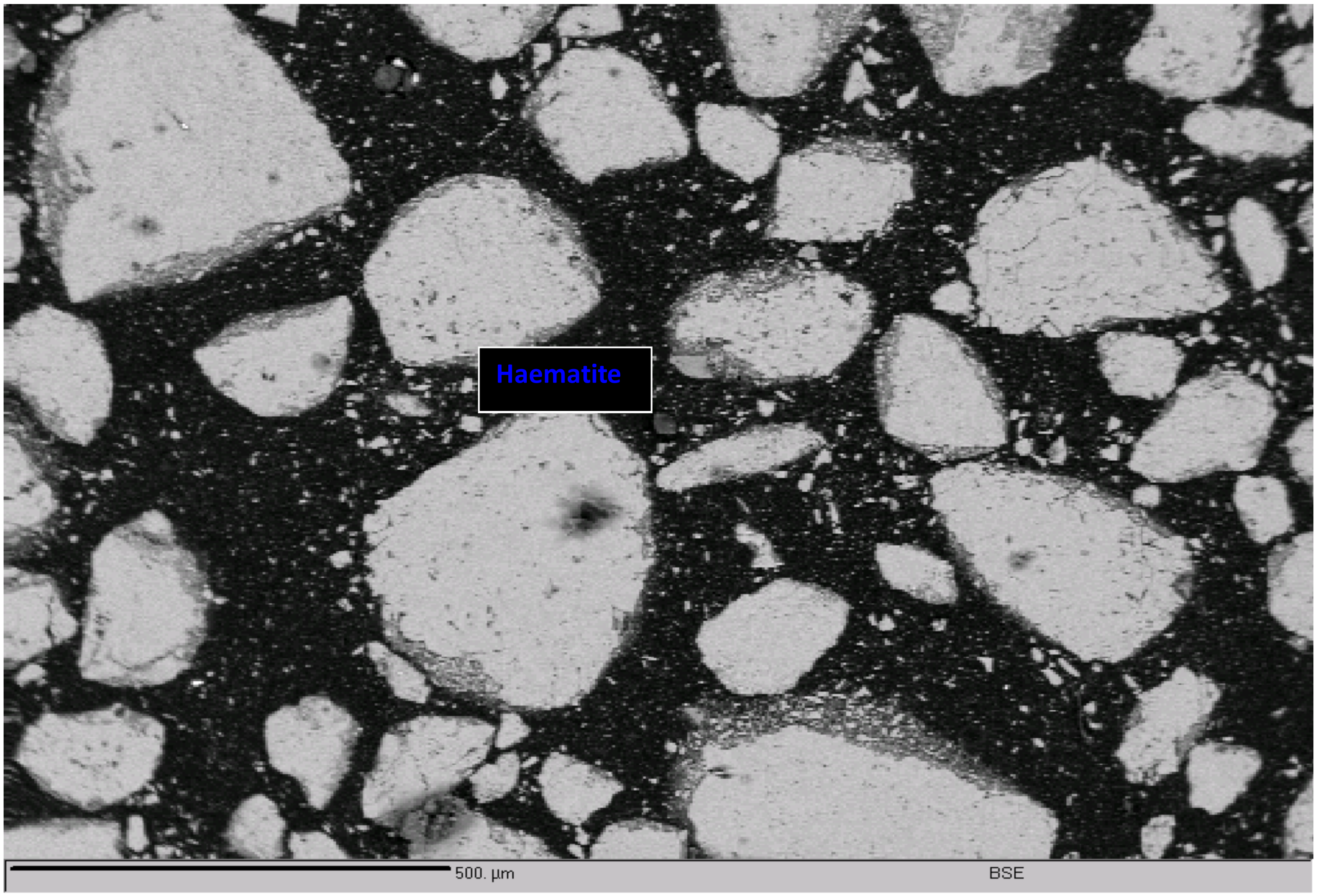
Sandwitching of clear haematite grains with gibbsite. Further grinding clan liberate haematite. Note that they are very clear.

IV. Case Study: Amenability to reduce alumina by physical processes of separation is more



Here aluminous minerals are highly associated with goethite and limonite compared to hematite. Hence, concentration of hematite can reduce the alumina content.

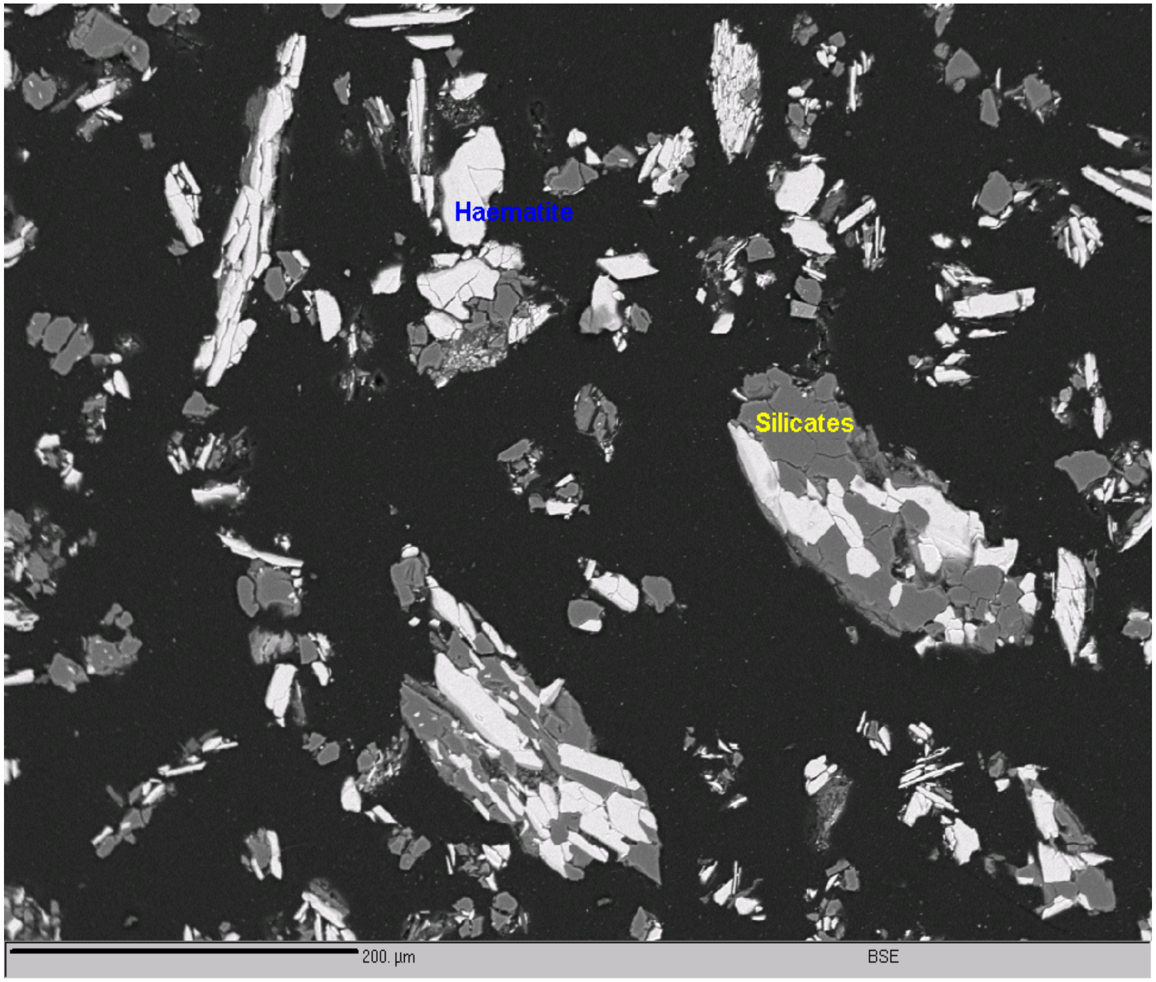
V. Case Study: High grade ore



Hematite is associated with aluminous gangue to a very less extent and can be liberated by further grinding.

VI. Fine Powdery (Blue-Dust) Iron ore

Typical Micaceous Hematite or Specularite

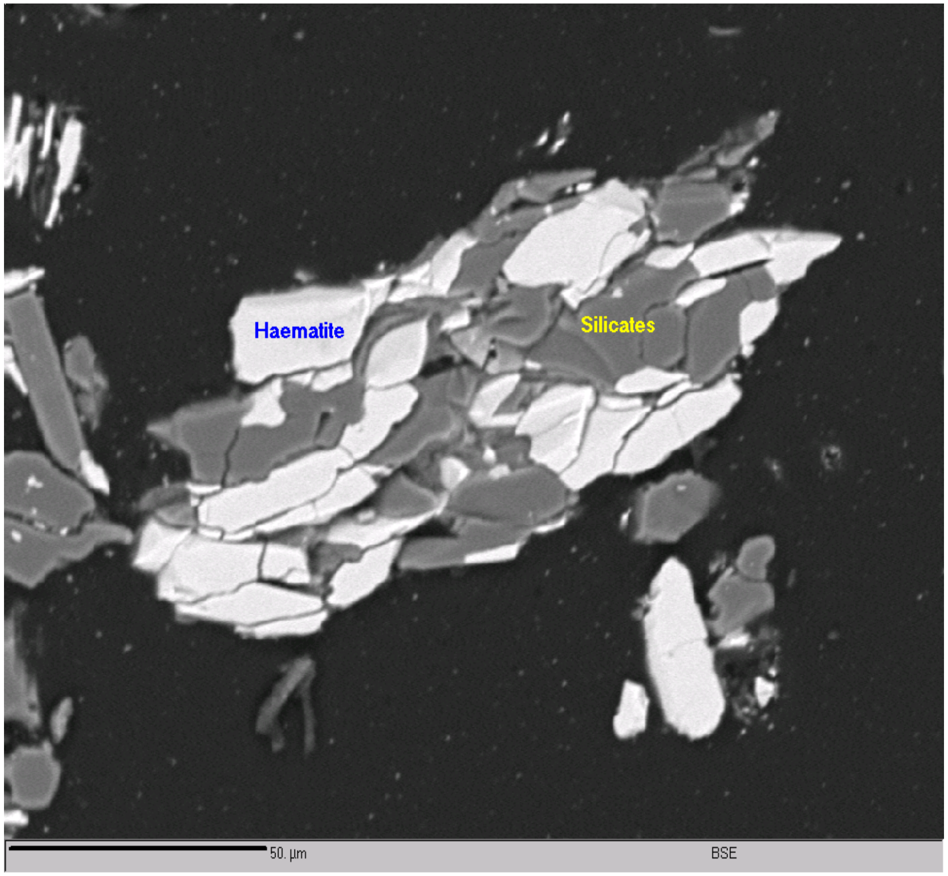


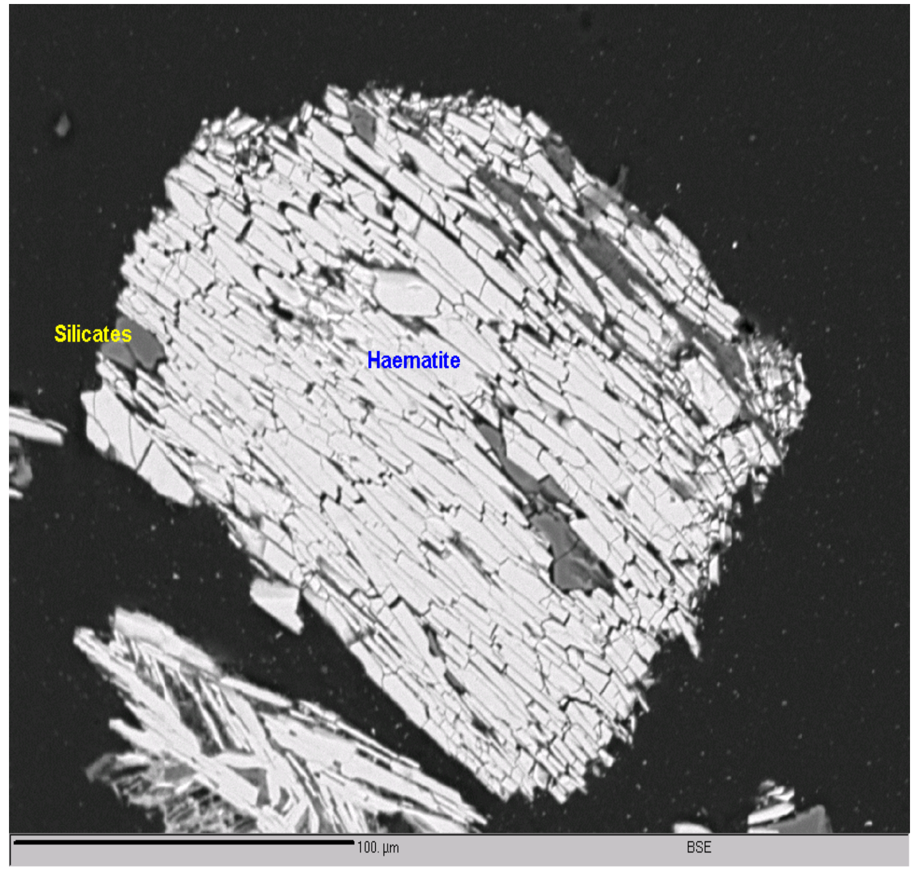
BSE image by EPMA revealing the thorough association between iron minerals (white) and silicate gangue (gray).

Mineral	Approx. %
Haematite	**60-62**
Goethite + Limonite	~1
Magnetite/ martitised magnetite	Traces
Quartz + Feldspar (albite)	**35**
Clay (kaolinite)	1
Mica(muscovite)	<1
Amphibole	<1
Chlorite	<1

Fine Powdery (Blue-Dust) Iron ore

Typical Micaceous Hematite or Specularite





EPMA-BSE image demonstrating the character of the sample wherein iron ore minerals (white) are embedded within silicate host phases (gray) even up to a size of <20 microns. Platy/flaky type hematite is soft & loosely bonded, amenable to beneficiation.

SUMMARY

- Major alumina contributing mineral in eastern Indian iron ores include gibbsite, boehmite, clay (kaolinite, montmorillonite) and to some extent mica (muscovite and biotite).

- Identification of these minerals, their proportion, mode of occurrence and grain size determination dictates Fe : Al in the given sample.

- Mineralogy of the sample comprises predominantly hematite, followed by goethite and limonite interlocked/intermixed with gibbsite and clay.

- EPMA/SEM studies have revealed that alumina contributing minerals such as gibbsite and clay are present in intimate association with the hematite at micron size level and inhibiting the reduction of alumina content to the desired level, in some of the ores.

Way Forward

✓In view of the complex mineralogy of Indian Iron Ores, evaluation of **threshold value for deposit/sector-wise** may be looked up, which can be assessed based on detailed **mineralogical characterization & amenability process test-work**.

✓To maintain alumina / silica ratio within 5% limit for steel making, adequate focus has to be given on **technological up-gradation** for utilizing low grade ores.

✓Sub-grade or marginal grade ores (-60 +45% Fe) staked in **dumps**, together with the **staked fines** (-10 mm) and **slimes** (in tailing ponds) containing significant **tonnages of valuable hematite** are presently locked up, value addition for its utilization is the need of the hour.

✓Beneficiation and Pelletisation and capacity **augmentation of pelletisation and sintering facilities** to utilize low grade fines should become a priority area.

THANKS