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Beneficiation Studies on Lateritic Iron Ores of Sebuku, Indonesia.

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Abstract

Lateritic iron ore deposits of Sebuku island in Indonesia were subjected to characterization and beneficiation studies in order to improve their quality and thereby making them suitable as sinter/pellet grade iron ore concentrates, thus increasing their economic value. Hence, an attempt has been made to conduct Scrubbing tests, Grindability tests, Selective dispersion and flocculation tests and further subjected to Magnetic separation, Flotation and Calcination studies.

Keywords: *Beneficiation, Scrubbing, Grindability, Flocculation, Flotation and Calcination*

1. Introduction

A composite lateritic iron ore sample from Sebuku island, Indonesia was collected by the Author during the field visit and bench scale beneficiation studies were carried out with an aim to evolve a process flow sheet producing sinter or pellet grade iron ore concentrates, to meet the industry requirements for iron and steel making as given in Table 1. The paper constitutes the results of various characterisation and beneficiation studies namely Scrubbing tests, Grindability tests, Selective dispersion and Flocculation tests and the iron ore samples were further subjected to Magnetic separation, Flotation and Calcination studies, which were collected from the Sebuku island in Indonesia

2. Study Area

Sebuku is a low island, covering an area of 275-square-kilometre and administratively part of South Kalimantan, Indonesia, between the longitude 116.390 East and latitude 3.450 South, in the South East Asia, with a tropical climate.

3. Methodology

The iron ore samples were subjected to feed preparation and sampling techniques (Fig. 2) before the Physical, Chemical investigations in the laboratory and to Ore microscopic studies for Mineralogical investigations initially. The Run off mine sample was subjected to wet Scrubbing tests using Sayaji concrete mixer and sized products were subjected to medium intensity magnetic separation (MIMS) tests. A representative sample was stage ground in laboratory Denver rod mill (175 mm dia x 350 mm). Exploratory gravity separation tests were conducted using Mozley mineral separator. Exploratory Tilden selective dispersion, Flocculation and cationic reverse Flotation tests were conducted on ground samples. A representative ROM sample was subjected to dry low intensity magnetic separation. Calcination tests were also conducted on WLIMS concentrates with varying temperatures.

4. Characteristics of the sample

4.1. Physical Characteristics of the sample

The iron ore sample consisted of dark brownish yellow colored hard compact lumps with considerable amount of fines. Some lumps were porous and used to soil the fingers and found to be slightly magnetic in nature.

4.2. Chemical Characteristics of the sample

The sample was subjected to Chemical analysis and the results are tabulated in Table 2.

4.3. Mineralogical Characteristics of the sample

The Ore microscopic studies revealed that, the sample mainly consists of goethite and altered

chlorite (Chamosite). Gibbsite, magnetite, hematite, quartz, chromite, garnet, wad, muscovite mica and clay are found in minor to trace amounts.
Goethite is amorphous to fine grained and forms the ground mass to other minerals. Silicates (Chlorites mostly altered chamosite/clay) are fine to medium grained (25 to 180 microns) and occurs as granular aggregates, as pockets and thick veins within the goethite. Silicates are also present in the inter-granular spaces of magnetite. It shows fine inclusions of goethite (refer plate 3 – 5).
Magnetite is fine to medium grained (25 to 240 microns) and normally present as inclusions within the goethite. At places coarse (more than 2 mm) magnetite grains also noticed within goethite. Magnetite is altering to Hematite. (refer plate 1).
Hematite is fine to medium (6 to 180 microns) grained and occurs as discrete grains, granular aggregates, as bands and pockets within the goethite. Hematite is altering to goethite.
Chromite is fine to medium grained (18 to 180 microns) and present as discrete grains within the goethite. (refer plate 2). Gibbsite is fine grained (25 microns) and occurs as discrete grains, granular aggregates and veins in goethite. The approximate percentage of different mineral constituents is given in Table 3.

4.4 Diagnostic characterization

The chemical analysis indicated that Al2O3, LOI were the major dilutents. The mineralogy indicated that altered chlorite (chamosite), clay, gibbsite and quartz were the gangue minerals and altered magnetite, hematite and goethite were the ore minerals of oxides.
The sample when subjected to de-sliming, magnetic separation of sand fraction at -72mesh size, yielded a concentrate assaying close to 60% Fe total, 2.03% SiO2, 4.35% Al2O3 and 7.11% loss on ignition (LOI). The above test indicated that pellet grade concentrates may not be produced by simple physical beneficiation methods, warranting pyro-processing to remove water of hydration in the lattice. Presence of Ni, Cr2O3, H2O besides close association of chamosite may dilute the grade.

5. Experimental Work

5.1 Feed Preparation and sampling

The iron ore sample was subjected to feed preparation and sampling techniques. The feed preparation scheme is shown in Fig. 1.

5.2 Dry size analysis of ROM sample

The representative portion of ROM sample was subjected to dry size analysis from 75000 to 100 microns. The results are shown in Fig 2. The results indicated that the ROM sample contained 63% lumps, assaying 57.59% Fe (T) and 7.96% LOI.

5.3 Scrubbing and wet sieve analysis of ROM sample

A representative portion of ROM sample was subjected to wet scrubbing and wet sieve analysis from 75000 to 35 microns. The test conditions and results are given in Table 4 and shown in Fig.3. The results indicated that : (i) Fe values marginally taper at sizes finer than 100 mesh. (ii) A lumpy concentrate (+10 mm) assaying 57.65% Fe (T), 2.13% SiO2, 4.95% Al2O3 with 57.7 Fe recovery at 56.9% yield could be produced

5.4 Magnetic separation of scrubbed, sized product of ROM sample

A representative portion of ROM sample was scrubbed and sized. The sized products were subjected to medium intensity magnetic separation (MIMS). The test conditions are results are given in Table 5. The test produced (a) A lumpy concentrate assaying 59.10 Fe (T), 0.55% FeO, 1.96% SiO2, 3.77% Al2O3, with 46.5% Fe (T) recovery at wt% yield of 44.7. (b) A sandy concentrate (-10mm +72 mesh) assaying 59.25% Fe (T), 1.52% FeO, 1.85% SiO2, 4.20% Al2O3, with 17.4% Fe (T) recovery at wt% yield of 16.65. (c) A slimy concentrate (- 72 +400 mesh) assaying 56.79% Fe (T), 1.68% SiO2, 7.53% Al2O3, with 1.85% Fe (T) recovery at wt% yield of 1.85. (d) The composite magnetic concentrate assaying 59.07% Fe (T), 1.21% FeO, 1.79% SiO2, 3.96% Al2O3, 2.35% Cr2O3, 0.46% Mn, 0.48% Ni, 0.07% CaO, 0.06% P, traces of TiO2, traces of alkalies, 7.11% LOI with 65.7% Fe (T) recovery at wt% yield of 63.2 could be produced.

5.5 Sieve analysis of -10 mesh original sample

A representative portion of -10 mesh original sample was subjected to wet sieve analysis from 10 to 500 mesh. The sieve fractions were subjected to chemical and mineralogical analysis. The results are given in Table 6 and shown in Fig. 4. The results indicated a marginal enrichment of Fe values in sand size range (+72 mesh size) assaying 57.41% Fe (T), 1.59% SiO2, 5.77% Al2O3 and 8.18% LOI.

5.6 Stage grind rod mill grindability tests

A representative portion of 500 gms -10mesh original sample was stage ground in laboratory Denver rod mill (175 mm dia X 350 mm) with 6.5 kg rod charge at 67% solids pulp density to -72/-100/-150/-200 mesh size in stages for intervals of 5’ each. The results are given in Table 7 and shown in Fig. 4.

5.7 Selective dispersion and flocculation tests

The mineralogy indicated that altered chlorite (chamosite), clay, quartz and gibbsite were associated with ore minerals at finer sizes (200 microns). Hence, experiments were conducted to selectively disperse altered chlorite, clay and gibbsite using dispersant sodium silicate and flocculating ferruginous slimes on representative samples stage gound to -100 / -150 / -200 mesh. The test conditions and results are given in Table 8. The results indicate that selective dispersion and flocculation was ineffective and marginally increased Fe content of sand.

5.8 Split dry magnetic separation tests on -10 mesh original sample

A representative portion of -10 mesh sample was wet screened over 72 and 500 mesh, and the dried fraction were subjected to dry medium intensity magnetic separation (DMIMS) using a Bo Mag Rapid disc magnetic separator. The test conditions and results are given in Table 9.

The results indicated that dry low intensity magnetic separation of sized fractions of - 10 mesh sample yielded : (i) A sandy concentrate (_10 +72 mesh) assaying 59.83% Fe (T), 1.32% FeO, 2.23% SiO2, 4.92% Al2O3 and 6.80% LOI with 50.4% Fe (T) recovery (wt% yield of 48.2). (ii) A slimy concentrate (-72 +500 mesh) assaying 59.32% Fe (T), 1.1% FeO, 1.77% SiO2, 5.30% Al2O3and 7.50% LOI wi

th 16.3% Fe (T) recovery (wt% yield of 15.7%). (iii) A composite concentrate assaying 59.71% Fe (T), 1.26% FeO, 2.12% SiO2, 5.01% Al2O3 and 7.04% LOI with 66.7% Fe (T) recovery (wt% yield of 63.9).

The results indicated that sinter/pellet grade concentrates could not be produced by physical means only, warranting chemical processing, confirming diagnostic characterization.

5.9 Exploratory WLIMS tests

Exploratory wet low intensity magnetic separation tests were conducted on samples stage ground to -72 / -100 / = 150 / -200 mesh size employing Eriez Davis Tube. The test conditions and results are given in Table 10 and shown in Fig 5.

The results indicated that (i) The concentrate grade marginally increased with decrease in size. (ii) The best results were obtained at -150 mesh size, yielding a concentrate assaying 61.71% Fe (T), 2.22% FeO, 1.62% SiO2, 2.77% Al2O3, 1.79% Cr2O3. 0.44% Mn, 0.57% Ni, 0.07% CaO, 0.15% MgO, 0.09% P and 4.45% LOI with 49.6% Fe (T) recovery (wt% yield of 45.3).

5.10 Exploratory Mozley gravity mineral separation tests

Exploratory gravity separation tests were conducted using Mozley mineral separator varying MOZ -72 / -100 / -150 / -200 mesh. The test conditions and results are given in Table 11 and shown in Fig. 6. The best results were obtained at – 72 mesh grind producing concentrates assaying 58.73% Fe (T), 2.27% FeO, 1.80% SiO2, 5.15% Al2O3 with 59.3 Fe (T) recovery at wt% yield of 57.0, thus indicating that the sample is not amenable to gravity concentrate.

5.11 Flotation test

Exploratory Tilden selective dispersion, flocculation and cationic reverse flotation tests were conducted on samples stage ground to -100 / - 150 / -200 mesh size. The test conditions and results are given in Table 12 and shown in Fig. 7. The results indicated that the sample was not amenable to flotation.

5.12 Dry LIMS of crushed sized lumps of ROM

A representative portion of ROM was screened over 10 mesh and + 10 mesh fraction was crushed to -10 mesh. The crushed lumps were subjected to dry low intensity magnetic separation. The test conditions and results are given in Table 13. The test yielded a sandy concentrate analyzing 60.2 Fe (T), 1.71% FeO, 3.21% Al2O3, 1.69% SiO2, traces of TiO2, 2.4o% Cr2O3, 0.27% Ni, 0.26% Mn, 0.11% MgO, 0.07% CaO, 0.10% P, traces of S and 6.49% LOI with 58.9% Fe (T) recovery at wt% yield of 55.5%.

5.13 Calcination tests

Calcination tests were conducted on exploratory WLIMS concentrates varying temperature 300o C / 800o C / 1000o C. The test conditions and results are given in Table 14, and shown in Fig. 8. The results indicated that (i) Calcination tests at 300o C failed to improve the grade, as 380o C is decomposition temperature for goethite. (ii) Calcination improved the grade by 2% only. (iii) Calcination of WLIMS concentrate and DLIMS sandy concentrate at 1000o C, for 6 hours improved the grade to 64.22% Fe (T), 1.72% SiO2, 3.95% Al2O3 and 61.98% Fe (T), 2.17% SiO2, 4.09% Al2O3 respectively.

6 Summary and Conclusions

6.1 The composite laterite iron ore sample from Sebuku island, Indonesia was tested for bench scale beneficiation studies to evolve a process for producing sinter grade iron ore concentrate (Fe>62%, -10 mm, % -100 mesh <5%) or a pellet grade iron ore concentrate (Fe>66%, -100 mesh, 90% -270mesh).

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6.2 The iron ore sample consists of dark brownish yellow colored hard compact lumps with considerable amount of fines and slightly magnetic in nature.

6.3 The sample assayed 56.27% Fe (T), 0.78% FeO, 5.98% Al2O3, 3.68% SiO2, traces of TiO2, 2.59% Cr2O3, 0.39% Ni, 0.40% Mn, 0.10% MgO,0.07% CaO,0.005% Na2O,0.005% K2O, 0.09% P, traces of S and 8.46% LOI.

6.4 Iron ore sample consisted of goethite, chamosite (altered chlorite), gibbsite, magnetite, hematite, quartz, chromite, garnet, wad and mica were found in minor to trace amounts.

6.5 The sample when subjected to diagnostic tests comprising of de-sliming, magnetic separation of sand fraction at -72 mesh size, yielded a concentrate assaying -60% Fe (T), 2.03% SiO2, 4.35% Al2O3, 7.11% LOI. The above test indicated pellet grade concentrates may not be produced by simple physical beneficiation methods, warranting pyro-processing to remove water of hydration in the lattice. Presence of Ni, Cr2O3, H2O, besides close association of chamosite, may dilute the grade.

6.6 Dry sizing of ROM yielded lumps, assaying 57.59% Fe (T), 7.96% LOI with 63.0% yield.

6.7 Scrubbing and wet screening of ROM yielded a lumpy concentrate (+ 10mm) assaying 57.65% Fe (T), 2.13% SiO2, 4.95% Al2O3, with 57.7 Fe recovery at 56.9% yield. As Fe values marginally taper at sizes finer than 100 mesh, the removal of fines by sizing improves the grade marginally.

6.8 Dry medium intensity magnetic separation of above scrubbed sized + 10 mm lumps, a -10mm + 72 mesh sand and -72 + 400 mesh slimes yielded a (a) a lumpy concentrate assaying 59.10% Fe (T), 1.96% SiO2, 3.77% Al2O3 with 46.5% Fe (T) recovery at wt% yield of 44.7. (b) A sandy concentrate (-10 mm + 72 mesh) assaying 59.25% Fe (T), 1.85% SiO2, 4.20% Al2O3 with 17.4% Fe (T) recovery at wt% yield of 16.65. (c) A slimy concentrate (-72 + 400 mesh) assaying 56.79% Fe (T), 1.68% SiO2, 7,53% Al2O3 with 1.85% Fe (T) recovery at wt% yield of 1.85. (d)The composite magnetic concentrate assaying 59.07% Fe (T), 1.79% SiO2, 3.96% Al2O3, 2.35% Cr2O3, 0.46% Mn, 0.48% Ni, 0.07% CaO, 0.06% P, traces of TiO2, traces of alkalies and 7.11% LOI with 65.7% Fe (T) recovery at wt% yield of 63.2 could be produced.

6.9 Split dry low intensity magnetic separation (72 mesh) of ROM crushed to-10 mesh yielded (a) A sandy concentrate (-10 + 72 mesh) assaying 59.83% Fe (T), 2.23% SiO2, 4.92% Al2O3 and 6.89% LOI with 50.4% Fe (T) recovery (wt% yield of 48.2). (b) A slimy concentrate (-72 + 500 mesh) assaying 59.32% Fe (T), 1.77% SiO2, 5.30% Al2O3 and 7.50% LOI with 16.3% Fe (T) recovery (wt% yield of 15.7) (c) A composite concentrate assaying 59.71% Fe (T), 2.12% SiO2, 5.01% Al2O3 and 7.04% LOI with 66.7% Fe (T) recovery (wt% yield of 63.9) could be produced.

6.10 Exploratory selective dispersion of gangue, flocculation of iron values and cationic reverse flotation of iron mineral varying -100, -150 and -200 mesh could not produce the desired grade concentrates. Similarly exploratory Mozley gravity separation tests varying -72, -100, -150, -200 mesh could not produce the desired concentrates.

6.11 Exploratory wet low intensity magnetic separation tests varying -72 / - 100 / - 150 / - 200 mesh indicated that concentrate grade increased with fineness. The best results were obtained at – 150 mesh size, yielding a concentrate assaying 61.71% Fe (T), 1.62% SiO2, 2.77% Al2O3, 1.79% Cr2O3, 0.44% Mn, 0.57% Ni, 0.07% CaO, 0.15% MgO, 0.09% P and 4.45% LOI with 49.6% Fe (T) recovery (wt% yield of 45.3).

6.12 Calcination of WLIMS concentrate and sandy – 10 mesh DLIMS concentrate at 1000o C for 6 hours improve the grade to 64.22% Fe (T), 1.72% SiO2, 3.95% Al2O3 and 61.98% Fe (T), 2.17% SiO2, 4.09% Al2O3 respectively.

6.13 A test comprising of ROM over 10 mesh and dry LIMS of dumps crushed to – 10 mesh produced a sandy concentrate analyzing 60.2% Fe (T). 1.71% FeO, 3.21% Al2O3, 1.69% SiO2, traces of TiO2, 2.40% Cr2O3, 0.27% Ni, 0.26% Mn, 0.11% MgO, 0.07% CaO, 0.10% P, traces of S and 6.49% LOI with 58.9% Fe (T) recovery at wt% yield of 55.5%. This concentrate can be used as sinter feed after calcination . Pellet grade concentrates could not be produced due to associated Chamosite, Cr2O3, Ni values and combined H2O in lattice.

Table-1: Specifications of iron ore concentrates for sintering and pelletising industry

Constituent	Sinter feed	Pellet feed
Fe (T)	>62%	>66%
SiO2	<4%	<2%
Al2O3	<4%	<2%
P	<0.15%	<0.06%
Size	-10 mm	- 270 mesh
-100 mesh %	< 5%	>99%

Table-2: Chemical analysis of as received sample

Radical	Assay %
Fe (T)	56.27
FeO	0.78
Al2O3	5.98
SiO2	3.68
TiO2	Traces
Mn	0.4
Cr2O3	2.59
MgO	0.1
CaO	0.07
K2O	0.005

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Na2O	0.005
Ni	0.39
P	0.39
S (T)	Traces
LOI	8.46

Table 3 : Mineralogy of as received sample

Mineral	Approximate %
Magnetite	4 – 5
Hematite	04-May
Goethite	65 – 70
Chamosite (Alt. Chlorite)	10 – 15
Gibbsite	4 – 5
Chromite	3 – 4
Quartz	1 – 2
Wad	Traces
Mica	Traces
Clay	Traces

Table 4 : Scrubbing and wet sieve analysis of ROM sample

7 Kg ROM soaked in 7 ltrs water for 5' and scrubbed in 610 mm dia Sayaji Concrete mixer, at 28 rpm, 52% CS at 33% solids pulp density for 5 minutes.

Product	Wt %	Assay % Fe (T)	% Dist. Fe (T)
-75 + 50 mm	4.6	55.43	4.5
-50 + 30 mm	2.5	57.37	2.5
-30 + 25 mm	4.9	59.03	5.1
-25 + 20 mm	13.2	56.59	13.1
-20 + 10 mm	31.7	58.24	32.5
-10 + 6.25 mm	14.8	56.55	14.7
-6.25mm+10 #	8.8	55.72	8.6
-10 + 16 mesh	2.0	59.06	2.1
-16 + 25 mesh	0.5	59	0.5
-25 + 36 mesh	0.3	60.03	0.3
-36 + 52 mesh	0.1	57.51	0.1
-52 + 72 mesh	0.2	56.86	0.2
-72 + 100 mesh	0.1	55.44	0.1
-100+ 150 mesh	0.3	55.35	0.3
-150+ 200 mesh	0.9	54.6	0.9
-200+ 300 mesh	1.6	54.34	1.5
-300+ 400 mesh	0.8	55.26	0.8
-400 mesh	12.7	54.41	12.2
Head (Calc.)	**100**	**56.84**	**100**
Lumps(+10mm)	56.9	57.65	100
SinterSand(-10 mm + 72 mesh)	26.7	56.55	26.5
Fines(-10mm)	43.1	55.77	42.3

Table 5 : Magnetic separation of sized scrubbed fractions of ROM

7 Kg ROM soaked and scrubbed for 5' each at 33% solids in 610 mm dia Sayaji concrete mixer and screened over 20 mm,10 # and 400#. 20mm O/S was crushed to -20mm.

Product	Wt%	Assay % Fe (T)	% Dist. Fe (T)
Cr. Lumps HF Mag (+10 mm)	44.7	59.1	46.5
Cr. Lumps HF Nonmag (+10 mm)	12.2	52.33	11.2
Cr. Sand HF Mag (-10 mm +10 #)	14.8	59.12	15.4
Cr. Sand HF Non-mag (-10mm+10 #)	8.8	51.4	7.9
- 10 + 72 mesh Mag	1.85	60.28	2
-10+ 72 Mesh NonMag	1.25	56.98	1.2
- 72 + 400 mesh Mag	1.85	56.79	1.85
-72 + 400 # NonMag	1.85	52.63	1.75
- 400 mesh slimes	12.7	54.41	12.2
Head (Calc.)	100	56.6	100
Comp. Mag (Calc.)	63.2	59.07	65.7
Comp. Mag Lumps (+ 10 mm)	44.7	59.1	46.5
Com. Mag sand (- 10 mm + 72 mesh)	16.65	59.25	17.4

Table 6 : Size analysis of – 10 mesh sample

Mesh size Product	Wt %	Assay % Fe (T)	Assay % LOI	% Dist. Fe (T)
6	12	57.24	7.85	12.1
9	17.7	56.86	7.79	17.8
- 25 + 36	16.7	56.68	8	16.7
16	10	56.21	8.23	9.9
20	9.3	58.88	8.11	9.7
- 72 + 100	5.3	57.42	8.38	5.4
50	6	56.48	8.6	6
50	5	54.98	8.8	4.9
100	5	56.74	9.15	5
100	2	53.65	9	1.9
100	1.3	55.08	8.79	1.3
-500	9.7	54.45	9.42	9.3
Head (Calc.)	**100**	**56.83**	**8.3**	**100**

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Table 7 : Grindability data

Mesh Size Product	Microns	-72 mesh	-100 mesh	-150 mesh	-200 mesh
28	212	12	--	--	--
50	150	17	3	--	--
50	106	15	18	6	--
100	74	14	21	26	20
100	45	7	10	13	15
100	35	6	7	9	15
-500	25	29	41	46	50
Total		100	100	100	100
d80 microns		**128**	**74**	**60**	**45**

Table 8 : Selective dispersion and flocculation tests

Grind : Variable -100 / - 150 / - 200 mesh rod mill stage product.

MOG	Product	Wt %	Assay % Fe (T)	% Dist. Fe (T)
-100 mesh	Sand (+ 5 microns)	98.2	56.5	98.4
-100 mesh	Slimes (- 5 microns)	1.8	50.04	1.6
-100 mesh	Head (Calc.)	100	56.21	100
- 150 mesh	Sand (+ 5 microns)	98	56.91	98.4
-150 mesh	Slimes (- 5 microns)	2	48.1	1.6
-150 mesh	Head (Calc.)	100	56.74	100
-200 mesh	Sand (+ 5 microns)	97.8	56.95	98.1
-200 mesh	Slimes (- 5 microns)	2.2	49.8	1.9
-200 mesh	Head (Calc.)	100	56.8	100

Table 9 : Split dry magnetic separation of -10 mesh sample

-10 mesh sample screened over 72 and 500 mesh; -10 +72 mesh and -72 + 500 mesh fractions subjected to DMIMS.

DMIMS: Box Mag Rapid UK disc separator 200 mm disc dia, 100 mm wide belt, disc rpm – 60, 3 mts/min belt speed.

Mag-1 : 6 mm air gap, 1.0 A, 2000 Gauss

Mag-2 : 2 mm air gap, 3.0 A, 12000 Gauss

Product	Wt %	Assay % Fe (T)	Assay % LOI	% Dist. Fe (T)
-10+72 mesh Mag1	48.2	59.83	6.89	50.4
-10 +72 mesh Mag 2	16.1	53.06	11.27	15
-10+72mesh Nonmag	1.4	52.22	10.42	1.3
-72+500mesh Mag1	15.7	59.32	7.5	16.3
-72+500mesh Mag2	7.4	51.19	11.31	6.6
-72+500meshNonmag	1.5	45.75	12.29	1.2
-500	9.7	54.45	9.42	9.2
Head (Calc.)	100	57.18	8.4	100
Comp. Mag 1 (Calc.)	63.9	59.71	7.04	66.7

Table 10 : Amenability to WLIMS by Davis tube

Grind : Variable -72 / -100/ -150/- 200 mesh

Davis tube : 20 rpm, 90^0C turn, 10% Solids pulp density 0.5 LPM pulp, 0.5 LPM wash water per batch

Stage	V	Amps	Gauss
Rougher	75	1.80	2000
I Cleaner	50	0.8	800

MOG	Product	Wt %	Assay % Fe (T)	% Dist. Fe (T)
-72 #	1Cleaner Mag	43	60.32	46.3
-72 #	1 Cleaner Non-Mag	5	55.42	4.9
-72 #	Rougher Non-Mag	52	52.7	48.8
-72 #	Head (Calc.)	100	56.11	100
-72 #	R. Mag (Calc.)	48	59.81	51.2
-100 #	1 Cleaner Mag	43	61.98	47.1
”	1 Cleaner Non_Mag	5	54.83	4.9
”	Rougher Non-Mag	52	52.25	48
”	Head (Calc.)	100	56.56	100
”	R. Mag (Calc.)	48	61.24	52
-150 #	1 Cleaner Mag	45.3	61.71	49.6
”	1 Cleaner Non_Mag	4.7	54.84	4.6
”	Rougher Non-Mag	50	51.52	45.8
”	Head (Calc.)	100	56.29	100
”	R. Mag (Calc.)	50	61.06	54.2
-200 #	1 Cleaner Mag	30	63.79	33.9

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”	1 Cleaner Non_Mag	17	57.18	17.2
”	Rougher NonMag	53	52.15	48.9
”	Head (Calc.)	100	56.48	100
”	R. Mag (Calc.)	47	61.36	51.1

Table 11 : Exploratory Mozley gravity mineral separation tests

Grind : Rod mill stage ground product (-72/-100/-150/-200 mesh product)
V Profile deck, Orbital throw of 7 mm, 60 mm strokes/ min frequency, tilt 1 cm/ 1 m length along axis. Feed water – 0.5 LPM wash water 0.7 LPM. 25 gms material at 33% Solids pulp density per batch.

MOG	Product	Wt %	Assay% Fe (T)	% Dist. Fe (T)
-72 #	Mozley Heavies	57.0	58.73	59.3
”	Mozley tails	43.0	53.50	40.7
”	Head (Calc.)	100.0	56.48	100.0
-100#	Mozley Heavies	53.0	57.80	54.1
”	Mozley tails	47.0	55.40	45.9
”	Head (Calc.)	100.0	56.67	100.0
-150#	Mozley Heavies	42.0	58.0	43.0
”	Mozley tails	58.0	55.80	57.0
”	Head (Calc.)	100.0	56.72	100.0
-200#	Mozley Heavies	34.0	58.70	35.2
”	Mozley tails	66.0	55.80	64.8
”	Head (Calc.)	100.0	56.78	100.0

Table 12 : Exploratory reverse flotation tests

Grind : Rod mill stage ground product (-100/-150/-200 mesh).
Pretreatment : Desliming of 5 microns after adding 1kg/t Na2SiO3, 0.4 Kg/t NaOH , pH 10.5, 0.2 kg/t soluble starch, 5%Solid pulp density.
Flotation : Cell 500 g, 1200 rpm, 19% S, pH 9.2, starch 0.8 kg/t, 5’C T, Coco amine acetate 0.4 kg/t in 2 stages 1’ CT each, FT- 3’ each

MOG	Product	Wt %	Assay % Fe (T)	% Dist. Fe (T)
-100 mesh	Slimes	1.8	50.04	1.6
”	Gangue Float	33.4	55.12	32.7
”	Concentrate	64.8	57.2	65.7
”	Head (Calc.)	100	56.21	100
-150 mesh	Slimes	2	48.1	1.6
”	Gangue Float	34.8	54.67	33.6
	Concentrate	63.2	58.15	64.8
”	Head (Calc.)	100	56.74	100
-200 mesh	Slimes	2.2	49.8	1.9
”	Gangue Float	29.6	55	28.7
	Concentrate	68.2	57.8	69.4
”	Head (Calc.)	100	56.8	100

Table 13 : Dry screening, dry magseparation (LIMS) of crushed lumps (+10 mesh)

ROM dry screened over 10 mesh and lumps (+10 mesh) stage crushed to -10 mesh. Dry LIMS of crushed lumps : Box Mag Rapid disc separator -200 mm dia disc, rpm 60, 100 mm wide belt, belt speed 3 mts/mm, Air gap 6 mm, Amps 1.0 A, Intensity 2000 Gauss.

Product	Wt %	Assay % Fe (T)	Dist % Fe (T)
Crushed lumps Mag	55.5	60.20	58.9
Crushed lumps Non-Mag	25.0	50.74	22.3
Fines (-10 mm)	19.5	54.77	18.8
Head (Calc.)	**100.0**	**56.78**	**100.0**

Table 14 : Calcination tests on WLIMS Conc. / DLIMS Conc.

WLIMS (Davis tube) I Cleaner Concentrate of -150 mesh grind /-10+72 mesh DLIMS concentrate, calcined in ceramic boat Temp: 300^0C, 800^0C, 1000^0C. Duration 6 Hours

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Data	Product	Wt %	Assay % Fe (T)	% Dist. (Feed) Fe(T)
300^{0}C : -150#Conc.	Calcine	100.0	61.98	49.6
,,	Wt. loss	--	--	--
,,	Feed (Calc.)	100.0	61.98	49.6
,,	Feed (Act)	100.0	61.71	49.6
800^{0}C : -150#Conc.	Calcine	95.0	62.52	48.2
,,	Wt. loss	4.0	--	--
,,	Feed (Calc.)	100.0	60.0	48.2
,,	Feed (Act)	100.0	61.71	49.6
1000^{0}C -150#Conc.	Calcine	94.4	64.22	48.7
,,	Wt. loss	5.6	--	--
,,	Feed (Calc.)	100.0	60.62	48.7
,,	Feed (Act)	100.0	61.71	49.6
1000^{0}C -10+72# DLIMS Mag1Conc.	Calcine	95.2	61.98	49.7
,,	Wt. loss	4.8	--	--
,,	Feed (Calc.)	100.0	59.00	49.7
,,	Feed (Act)	100.0	59.83	50.4

Fig-1

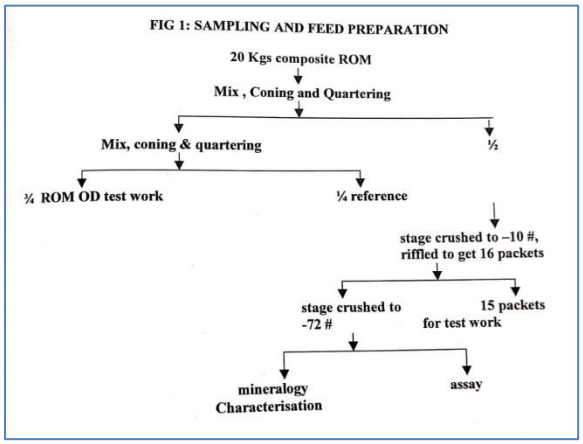

Fig-2

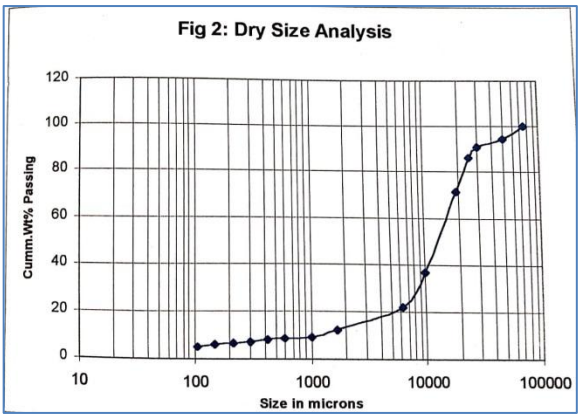

Fig-3

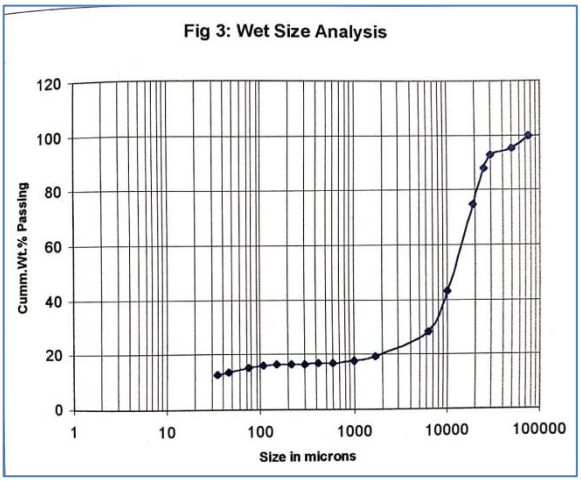

Fig -4

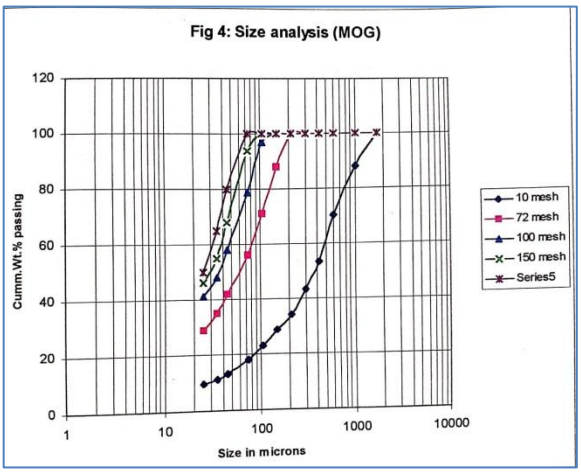

Fig-5

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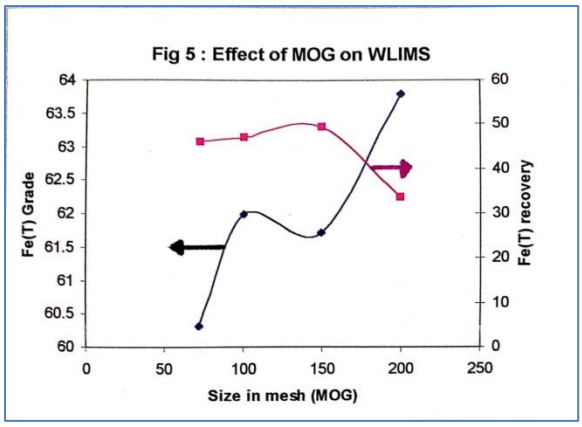


Fig -6

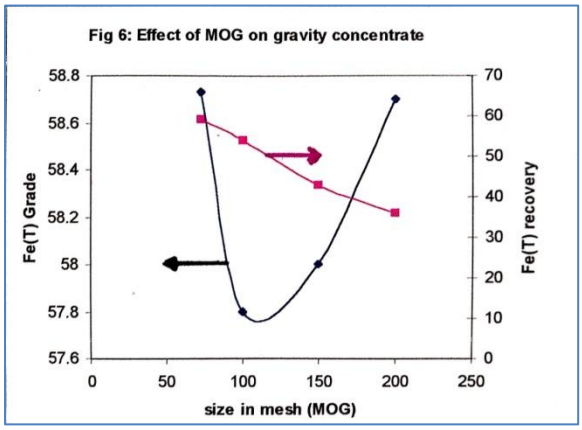


Fig-7

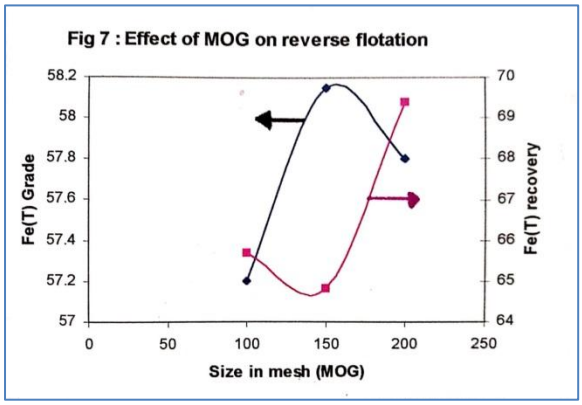


Fig-8

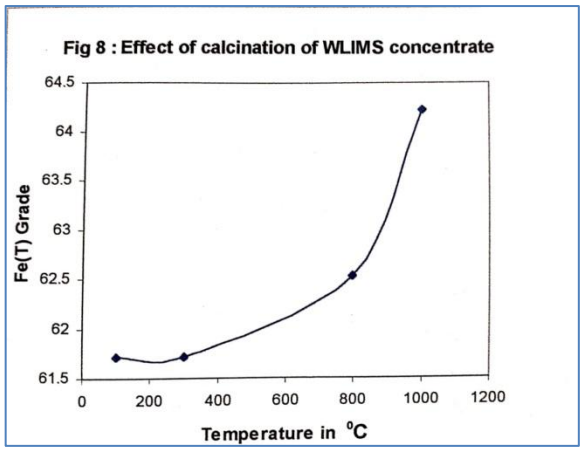


Plate 1 : Magnetite is altering to Hematite (He) [RI P P 20x]

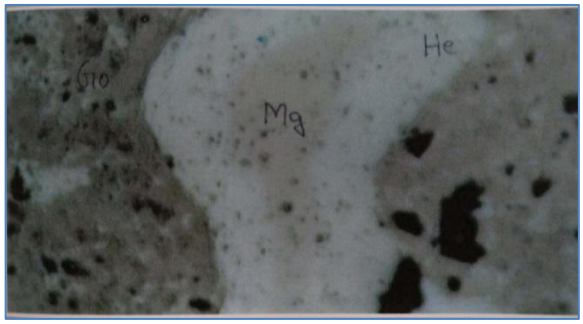


Plate 2 : Chromite (Cr) in Goethite (Go) ground mass [R1 P P 10x]

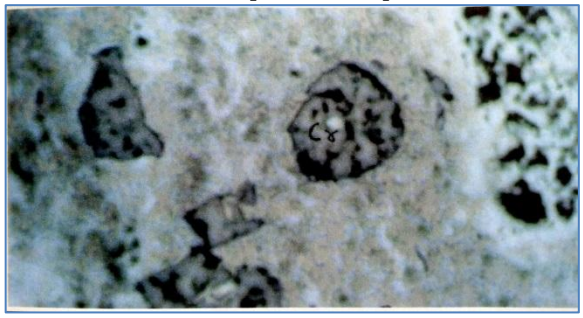


Plate 3 : Clay (Cl) shows fine inclusions of Goethite (Go) [RI P P 20x]

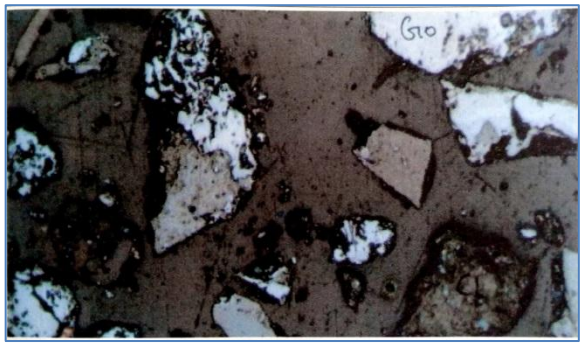
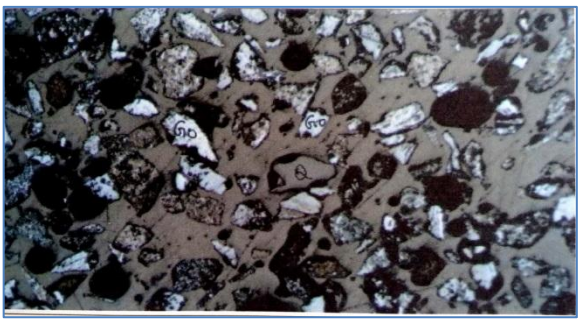


Plate 4 : Clay (Cl) interlocked with Goethite (Go) [RI P P 20x]

Plate 5 : Goethite (Go) inclusions with in the clay (Cl), free quartz (Q), free hematite (Ha) are also seen. [RI P P 20x]



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