

**Research Report of  
Beneficiation Tests for an Iron  
Ore (Sample S), in Australia**

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## **1 Introduction**

An iron ore (sample S) in Australia has been studied since June 18, 2014. Multi-element analysis results show that Fe is main valuable element in the ore sample with a content of 30.79%. Phase analysis results indicate that 93.05% of the iron exists in the form of magnetic iron. Process mineralogy research results show that Fe mainly occurs in the magnetite and a small part of Fe occurs in serpentine and other gangue containing iron.

Beneficiation tests research results show that when beneficiation fineness is 0.074 mm 85%, beneficiation technical indicators assaying 64.42%Fe with a concentrate yield of 44.00% at the recovery of 92.41% can be obtained by flow-sheet “one-time roughing, one-time scavenging and one-time cleaning” whole low intense magnetic separation.

Although under laboratory conditions, low intense magnetic roughing separation can be done namely that magnetite can be basically recovered and scavenging needn't be conducted, but considering many influencing factors of production, in order to ensure stable production indexes, finally “one-time roughing, one-time cleaning and one-time scavenging” whole low intense magnetic separation process is recommended.

## **2 Source and preparation of ore sample**

Four kinds of ore samples are received from client in June 17, 2014,

of which include two samples S, weighing about 30 kg.

Samples are core samples and large size. In order to meet the requirements of test, sample preparation is conducted, the preparation process as shown in Figure 2.1:

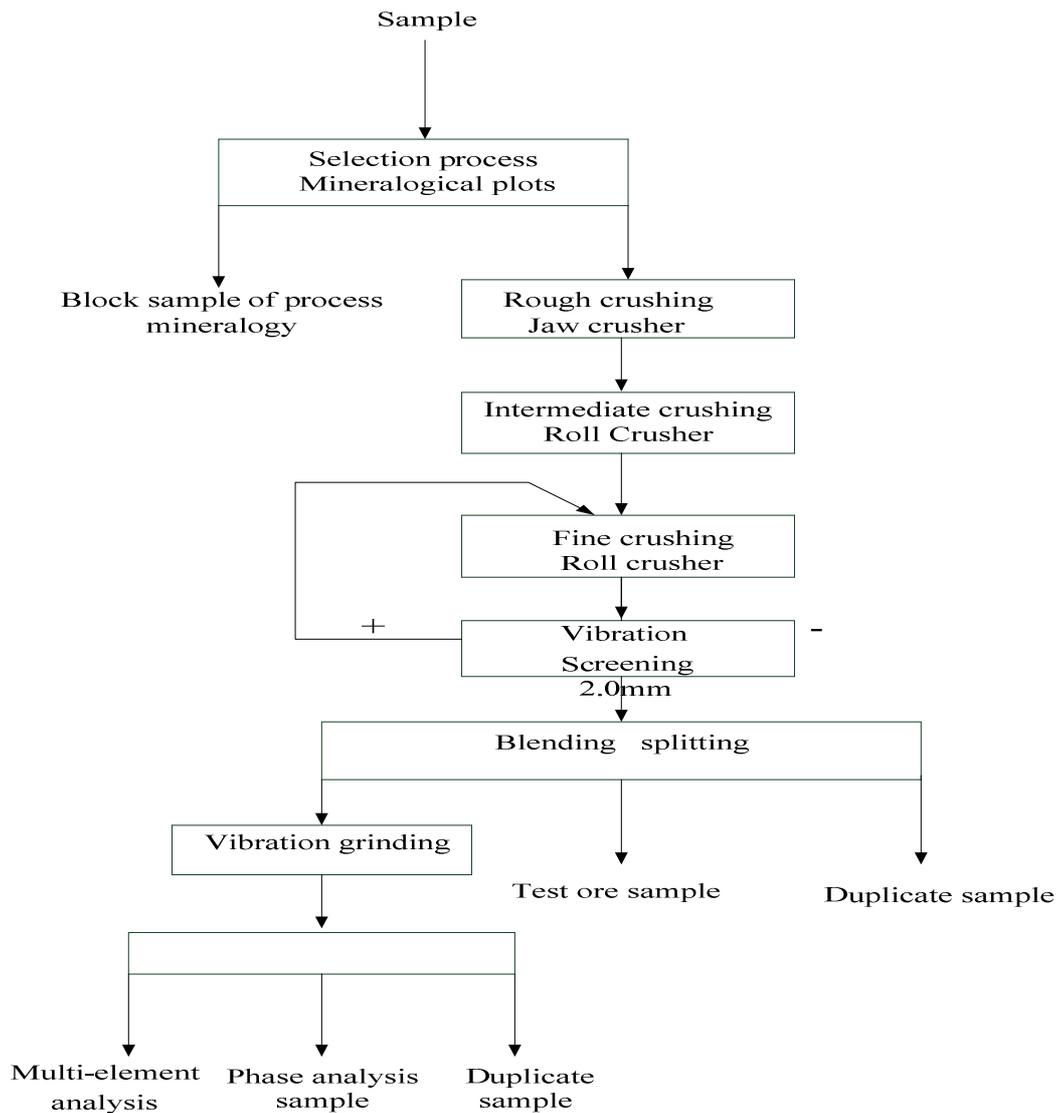


Figure 2.1 Flow chart of test ore sample preparation

### 3 Process mineralogy study

#### 3.1 Mineral composition Of raw ore

Spectrum analysis and multi-element analysis results of ore sample

are shown in Tables 3.1 and 3.2, respectively:

**Table 3.1 Spectrum analysis results of ore sample**

Content /%	Element
>10	Mg, Si, Fe, O
1~10	/
0.1~1	Ca, Al, Mn
0.01~0.1	P, S, Cl, As, W, As, K
<0.01	Ti, Zn, Y, Zr

Spectral analysis results indicate that the elements for content greater than 10% in the ore sample are magnesium, silicon, iron, and oxygen. Main marketable element is Fe.

**Table 3.2 Multi-element analysis results of ore sample**

Element	Fe	Cu	Pb	Zn	Mn	WO <sub>3</sub>	Co	As
Content /%	30.79	<0.005	<0.005	<0.005	0.35	0.0021	<0.005	0.027
Element	S	Sb	Bi	SiO <sub>2</sub>	CaO	MgO	Al <sub>2</sub> O <sub>3</sub>	
Content /%	0.061	<0.005	0.0306	26.14	0.19	25.19	0.31	

Multi-element analysis results indicate that the main marketable element is Fe (30.79%) and other metallic element contents are lower.

### 3.2 Iron phase analysis

Phase analysis results of iron sample are shown in Table 3.3:

**Table 3.3 Phase analysis results of iron sample**

Iron phase	Magnetite	Ferrosilite	Total iron
Content /%	28.65	2.14	30.79
Occupancy /%	<b>93.05</b>	6.95	100.00

### 3.3 Particle size composition of raw ore

Particle size composition results of raw ore crushing to -2.0mm are shown in Table 3.4.

**Table 3.4 Particle size composition results of raw ore crushing to -2.0mm**

Size fraction/mm	Yield /%	Fe grade/%	Fe occupancy /%
-2.0+1.0	43.38	<b>31.64</b>	43.78
-1.0+0.5	19.23	<b>31.30</b>	19.20
-0.5+0.25	13.34	<b>30.22</b>	12.86
-0.25+0.074	15.12	<b>33.88</b>	16.34
-0.074+0.043	2.90	<b>35.27</b>	3.26
-0.043	6.03	<b>23.69</b>	4.56
Raw ore	100.00	31.35	100.00

Results show that after raw ore crushing to 2 mm, Fe distribution exists in every size fraction, and Fe grade of every size fraction are less than 40%. This indicates that there is magnetite and gangue minerals in every size fraction, and magnetite and gangue separation cannot be effectively realized by using classification. Relatively iron grade in fine fraction is slightly low indicating that too crushing of magnetite is less during crushing process.

### 3.4 Mineral composition and content of raw ore

Mineral composition and content of raw ore is measured using MLA, the results as shown in Table 3.5. The results show that iron minerals in the ore are mainly magnetite, trace of limonite and siderite; Other metal sulfide minerals are mainly trace of pyrite, sphalerite, galena, chalcopyrite

and arsenopyrite, etc; gangue minerals are mainly large number of serpentine, followed by a small amount of chlorite and calcite, dolomite, etc.

**Table 3.5 Mineral composition and content of raw ore**

Mineral	Content %	Mineral	Content %	Mineral	Content %
Magnetite	43.060	Sericite	0.008	Nephelite	0.003
Limonite	0.059	Phlogopite	0.034	Fluorite	0.007
Siderite	0.007	Biotite	0.010	Calcite	0.146
Pyrite	0.015	Sahlite	0.060	Dolomite	0.089
Chalcopyrite	0.001	Iron salite	0.005	Magnesite	0.092
Sphalerite	0.003	Amphibole	0.016	Rhodochrosite	0.017
Galena	0.002	Actynolin	0.037	Apatite	0.021
Cobaltite	0.001	Epidote	0.012	Pyrophanite	0.003
Arsenopyrite	0.001	Tourmaline	0.005	Sphene	0.003
Native bismuth	0.001	Serpentine	55.299	Other	0.102
Quartz	0.032	Talcum	0.052	Total	100.000
Feldspar	0.034	Chlorite	0.763		

### 3.5. Measurement results of disseminated particle size of magnetite

Dissemination size of magnetite in raw ore lumps is measured under the microscope, the result as shown in Table 3.6. The results show that the magnetite particle size is coarse, uneven distribution and main size range of 0.01 ~ 1.28 mm.

**Table 3.6 Measurement results of disseminated particle size of magnetite**

Size fraction /mm	Disseminated particle size distribution of magnetite/%
-2.56+1.28	2.11
-1.28+0.64	13.70
-0.64+0.32	19.76
-0.32+0.16	22.52

-0.16+0.08	18.84
-0.08+0.04	9.02
-0.04+0.02	5.58
-0.02+0.01	6.28
-0.01	2.19
Total	100.00

### 3.6 Disseminated state and physicochemistry properties of main minerals

#### 3.6.1 Magnetite $\text{Fe}^{3+}(\text{Fe}^{2+}, \text{Fe}^{3+})_2\text{O}_4$

Magnetite is iron black, fracture half shells, mohs hardness 5.5 ~ 6 and density of 4.9 ~ 6.2 g/cm<sup>3</sup>. It is a typical ferromagnetic mineral. Energy spectrum analysis results of chemical composition of magnetite in the sample are shown in Table 3.7, the results indicating that the magnetite contains a small amount of magnesium, manganese, silicon, aluminum and other impurities, containing 70.82% Fe on average.

**Table 3.7 Energy spectrum analysis results of chemical composition of magnetite**

Measure point	Chemical composition and content/%					
	Fe	Mn	Mg	Al	Si	O
1	70.71	0.09	0.72	0.16	0.31	28.01
2	68.11	0.38	2.05	0.20	0.75	28.51
3	71.05	0.16	0.61	0.09	0.20	27.89
4	71.28	0.15	0.52	0.04	0.17	27.84
5	70.85	0.12	0.76	0.09	0.23	27.95
6	69.70	0.16	1.19	0.16	0.56	28.23
7	71.00	0.13	0.69	0.00	0.26	27.92
8	70.92	0.28	0.72	0.02	0.19	27.87
9	71.00	0.11	0.74	0.04	0.20	27.91
10	71.43	0.06	0.48	0.06	0.14	27.83

11	71.20	0.08	0.57	0.10	0.17	27.88
12	70.92	0.10	0.73	0.09	0.23	27.93
13	71.42	0.06	0.41	0.08	0.18	27.85
14	71.23	0.27	0.45	0.03	0.19	27.83
15	71.28	0.13	0.57	0.00	0.18	27.84
16	70.79	0.20	0.69	0.09	0.28	27.95
17	70.59	0.24	0.77	0.10	0.31	27.99
18	70.94	0.13	0.65	0.13	0.22	27.93
19	71.10	0.09	0.57	0.10	0.23	27.91
20	70.83	0.21	0.74	0.03	0.26	27.93
Average	70.82	0.16	0.73	0.08	0.26	27.95

Magnetite in the ore is mainly euhedral~subhedral granular aggregates, of which embeds in serpentine (Photos 1 and 2); Part of micro-granular magnetite present star point or beaded, embedding in the serpentine (Photos 3 and 4); A small amount of magnetite contains fine chalcopyrite, pyrite, cobaltite, native bismuth and apatite (Photos 5, 6, 7 and 8).

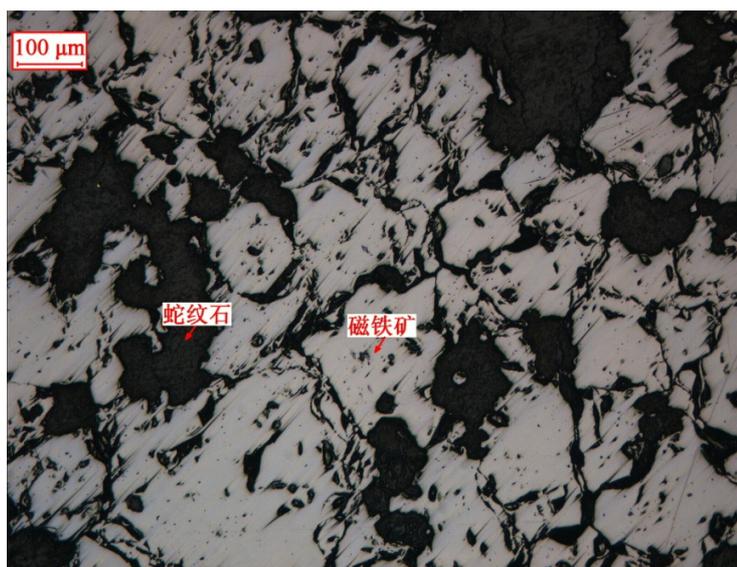


Photo 1 microscope, reflection Magnetite is euhedral~subhedral granular aggregates, embedding in serpentine.



Photo 2 microscope, reflection  
Magnetite is euhedral~subhedral  
granular aggregates, embedding  
in serpentine.

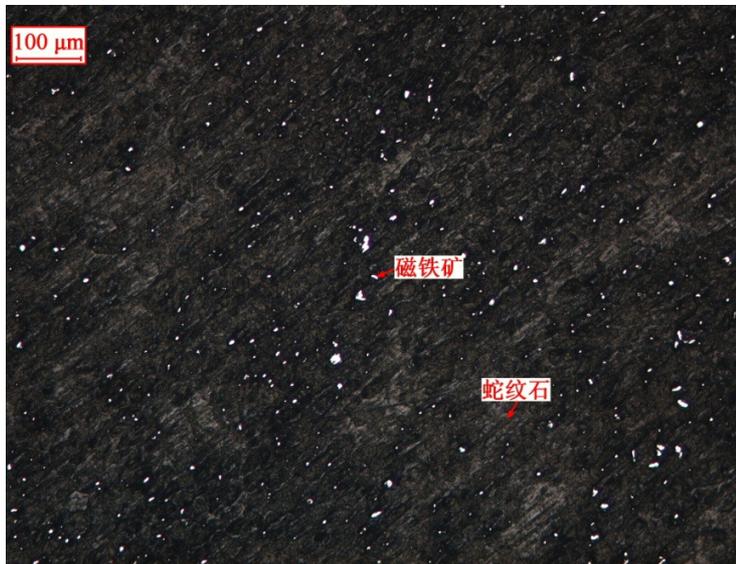


Photo 3 microscope, reflection  
Micro-granular magnetite presents  
star point, distributing in the  
serpentine.

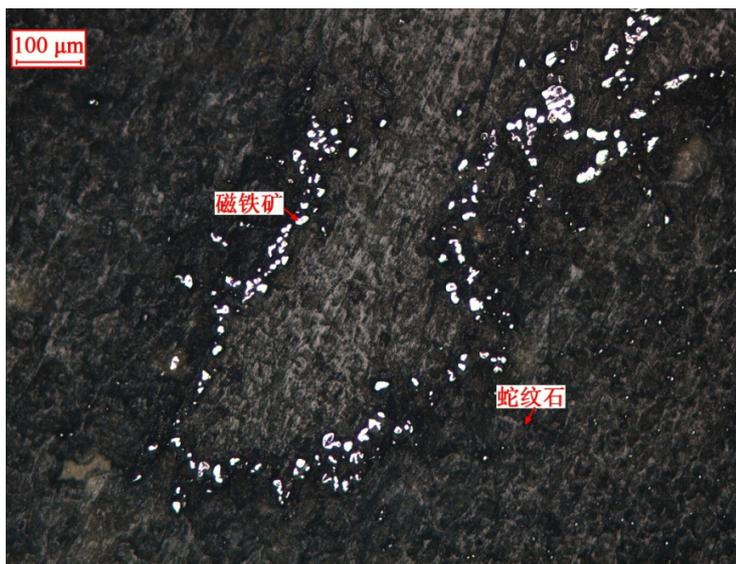


Photo 4 microscope, reflection  
Micro-granular magnetite  
presents beaded, distributing  
in the serpentine.

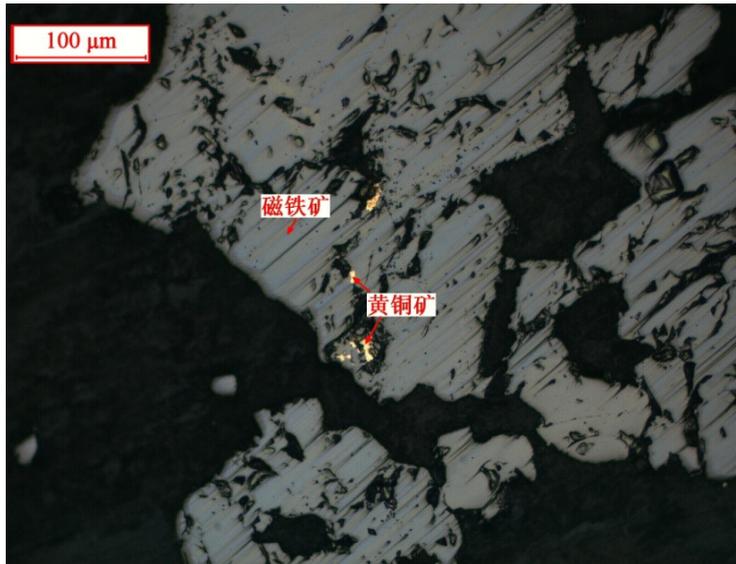


Photo 4 microscope, reflection  
Magnetite contains fine  
chalcopyrite particle.

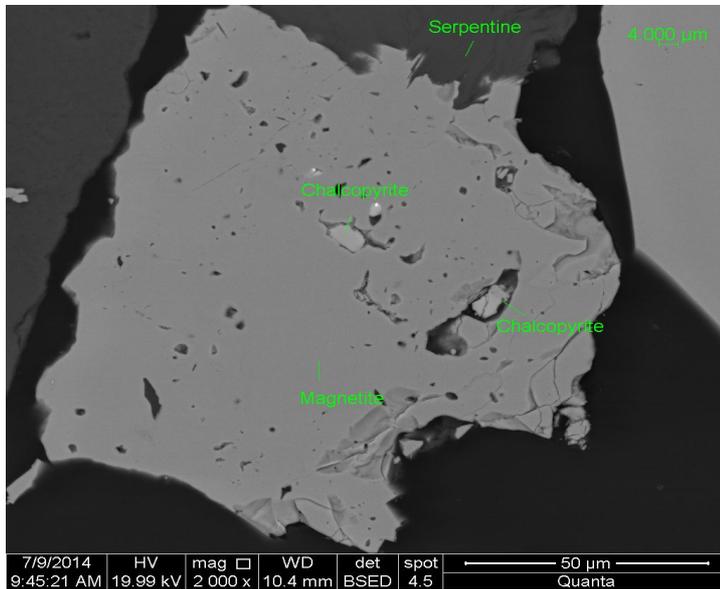


Photo 6 SEM, BSE image  
Magnetite contains fine  
chalcopyrite particle.

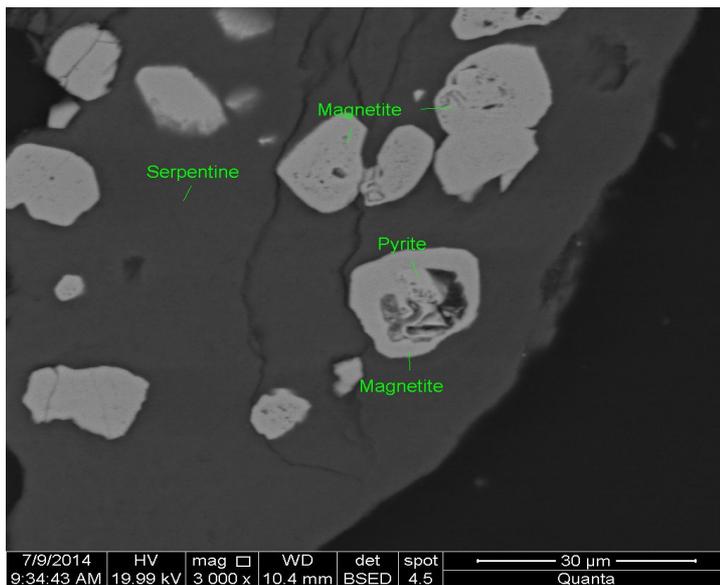


Photo 7 SEM, BSE image  
Magnetite is contact  
metasomatic pyrite,  
magnetite containing  
residual pyrite.

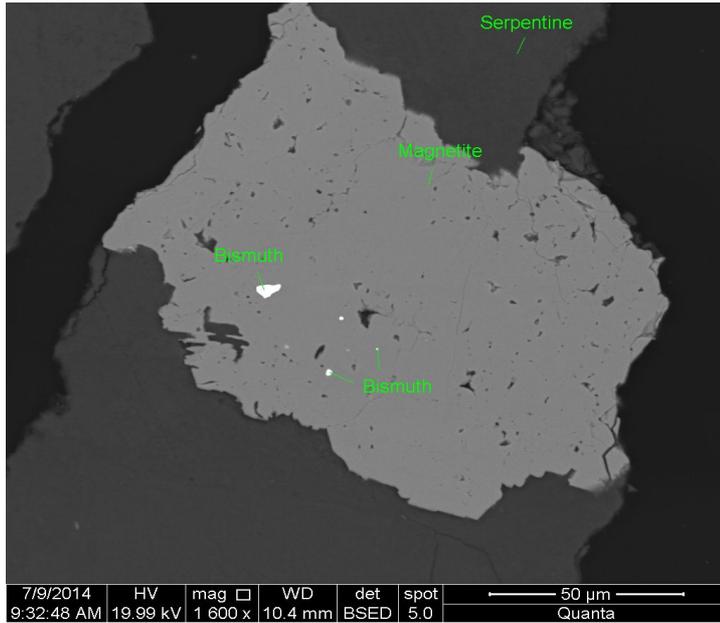


Photo 8 SEM, BSE image  
Magnetite contains fine  
native bismuth particle.

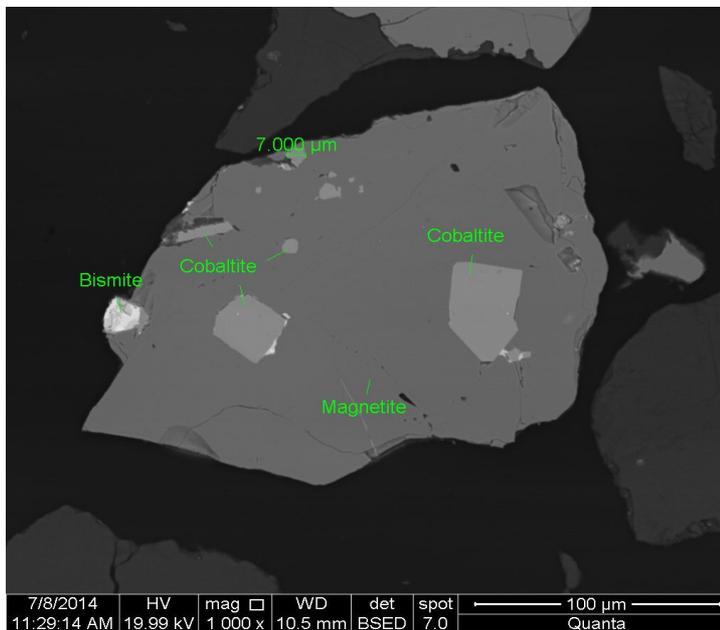


Photo 9 SEM, BSE image  
Magnetite contains  
cobaltite euhedral  
crystal.

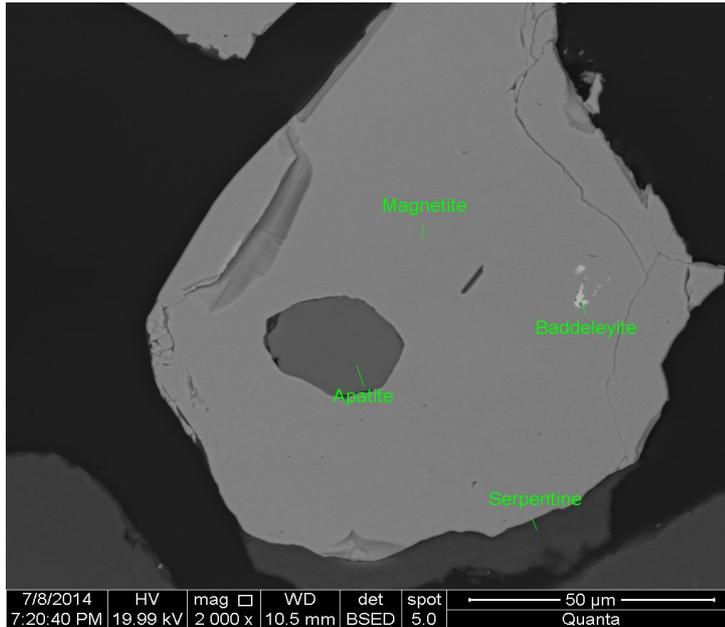


Photo 10 SEM, BSE image  
Magnetite contains  
apatite particle.

### 3.6.2 Serpentine $Mg_6[Si_4O_{10}](OH)_8$

Serpentine is main gangue mineral in the ore, ideal composition formula is:  $Mg_6[Si_4O_{10}](OH)_8$ , and main mixed with elements are iron, manganese, aluminum, nickel and fluoride, etc. It often possesses a variety of colors. Energy spectrum detection results of chemical composition of the serpentine in the ore as shown in Table 3.8, serpentine contains iron, and contains a small amount of manganese, aluminum and calcium, containing FeO4.38% (Fe3.40%) on average.

**Table 3.8 Energy spectrum detection results of chemical composition of the serpentine**

Measure point	Chemical composition and content/%					
	MgO	SiO <sub>2</sub>	MnO	FeO	Al <sub>2</sub> O <sub>3</sub>	CaO
1	48.45	46.96	0.28	4.31	0.00	0.00
2	46.02	45.24	0.34	8.07	0.33	0.00
3	45.64	44.46	0.72	8.68	0.39	0.11
4	46.09	46.58	0.36	6.97	0.00	0.00

5	48.51	46.73	0.32	4.44	0.00	0.00
6	48.47	46.27	0.40	4.86	0.00	0.00
7	48.02	46.50	0.44	4.34	0.34	0.36
8	49.92	47.20	0.22	2.66	0.00	0.00
9	49.10	46.96	0.30	3.09	0.55	0.00
10	48.74	47.71	0.43	3.12	0.00	0.00
11	51.25	45.96	0.19	2.60	0.00	0.00
12	49.30	47.35	0.43	2.59	0.33	0.00
13	48.16	48.42	0.39	2.59	0.44	0.00
14	46.27	50.35	0.24	3.14	0.00	0.00
15	47.77	49.01	0.29	2.44	0.49	0.00
16	48.33	48.45	0.29	2.38	0.55	0.00
17	50.46	47.06	0.21	2.27	0.00	0.00
18	48.77	48.32	0.21	2.29	0.41	0.00
19	48.91	47.52	0.46	2.50	0.61	0.00
20	49.95	47.65	0.28	2.12	0.00	0.00
21	48.15	48.82	0.31	2.72	0.00	0.00
22	49.80	46.79	0.29	2.60	0.52	0.00
23	46.65	50.13	0.38	2.84	0.00	0.00
24	47.96	48.33	0.31	2.74	0.66	0.00
25	45.68	43.44	0.29	4.93	5.66	0.00
26	45.72	48.02	0.49	5.32	0.45	0.00
27	49.27	45.95	0.27	4.15	0.36	0.00
28	50.13	45.92	0.27	3.24	0.44	0.00
29	45.00	44.69	0.46	9.49	0.36	0.00
30	41.57	38.58	0.64	19.21	0.00	0.00
31	49.35	47.40	0.22	3.03	0.00	0.00
Average	47.98	46.86	0.35	4.38	0.42	0.02

### 3.7 Brief summary

1 ) Valuable element in the ore is iron. MLA test results indicate that iron minerals in the ore are mainly magnetite, traces of limonite and siderite; the gangue minerals are mainly large number of serpentine,

followed by a small amount of chlorite, calcite and dolomite, etc.

2 ) Measurement results of disseminated particle size of magnetite show that magnetite particle size in the ore is coarser, maldistribution and main particle size range of 0.01 ~ 1.28mm.

3 ) Magnetite in the ore is mainly euhedral~subhedral granular aggregates, of which embeds in serpentine; A small account of micro-granular magnetite present star point or beaded, embedding in the serpentine. This part of magnetite is difficult to dissociate with serpentine. If entering into concentrate, they will have a certain impact on the grade of iron concentrate.

#### **4 Beneficiation test**

Process mineralogy research results indicate that the deposit is a typical of iron ore mainly containing magnetite, which is the most valuable mineral in the ore. Magnetite is strong magnetic mineral, existing obvious magnetic differences with other minerals in the ore, and the enrichment and recovery of magnetite are realized by using low intense magnetic separation.

Therefore, conducting magnetic separation test about the ore, magnetic analysis test, fineness test, one-time roughing - one-time cleaning - one-time scavenging whole process of magnetic separation test and rough concentrate regrinding test are carried out, respectively.

## 4.1 Magnetic analysis test

In order to master the magnetic differences between different minerals in the ore and provide magnetic separation basis of various minerals, magnetic analysis test is first studied, test process and results as shown in Figure 4.1 and Table 4.1, respectively:

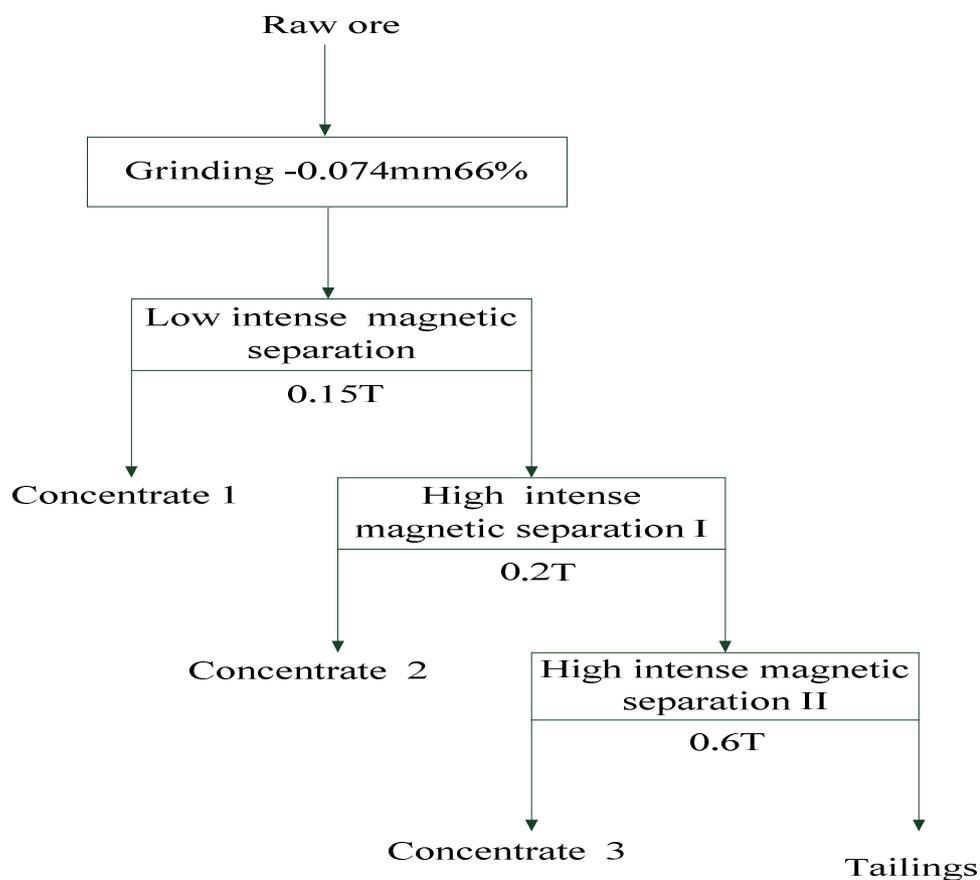


Figure 4.1 Flow chart of magnetic analysis test

**Table 4.1 Results of magnetic analysis test**

Product name	Yield/ %	Fe grade/%	Fe recovery/%
Concentrate 1 ( iron concentrate )	50.09	<b>57.83</b>	<b>95.72</b>

Concentrate 2	24.67	3.29	2.68
Concentrate 3	10.52	2.02	0.70
Tailing	14.72	1.84	0.90
Raw ore	100.00	30.26	100.00

Results show that various mineral in the ore present obvious magnetic differences, iron concentrate can be obtained with a grade of 57.83% at the recovery of 95.72% using low intense magnetic separation at 0.15 T. Further adopting high intense magnetic separation, Fe content of magnetic product is lower than 3.5%, indicating that high intense magnetic separation mainly obtains gangue minerals which contain low Fe, and there is no need for high intense magnetic separation.

#### **4.2 Fineness test**

Beneficiation fineness is one of the key factors influencing the effect of magnetic separation. Because of fineness too coarse, magnetite is not fully dissociated, and high grade iron concentrate is difficult to be obtained. Meanwhile due to magnetite associating with gangue results in the magnetic force of the ore particles decline and also affects the recovery of magnetite. And owing to fineness too fine, not only results in a significant increase in grinding costs, but also because recovery effect of micro-fine particles of iron is not ideal, also leads to the decrease of the iron recovery. Therefore, the choice of appropriate grinding fineness is critical to obtain good magnetic separation indexes, so fineness test research is carried out. Test process and test results are shown in Figure

4.2 and Table 4.2, respectively:

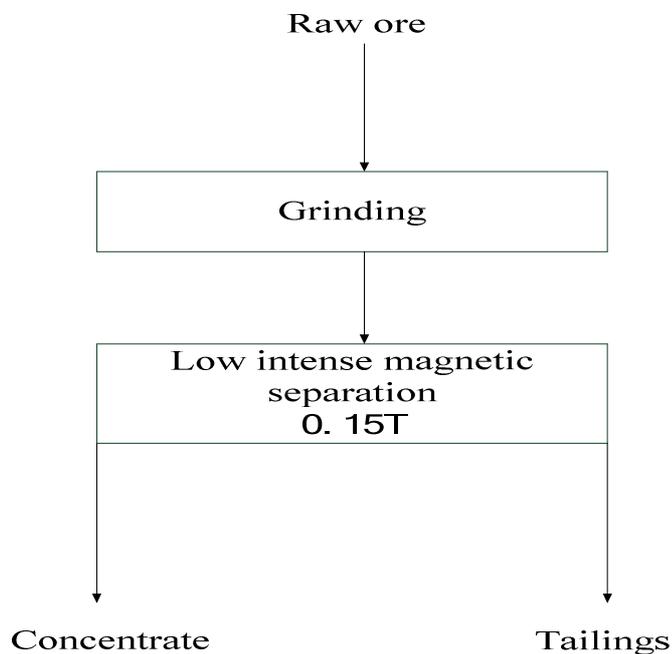


Figure 4.2 Flow chart of magnetic separation fineness test

**Table 4.2 Fineness test results**

-0.074mmcontent/%	Product name	Yield /%	Fe grade/%	Fe recovery/%
35	Concentrate	57.09	<b>50.80</b>	<b>95.20</b>
	Tailings	42.91	3.41	4.80
	Raw ore	100.00	30.46	100.00
44	Concentrate	53.67	<b>54.52</b>	<b>95.84</b>
	Tailings	46.33	2.74	4.16
	Raw ore	100.00	30.53	100.00
55	Concentrate	51.79	<b>56.21</b>	<b>95.37</b>
	Tailings	48.21	2.93	4.63
	Raw ore	100.00	30.52	100.00
66	Concentrate	50.22	<b>57.83</b>	<b>95.09</b>
	Tailings	49.78	3.01	4.91
	Raw ore	100.00	30.54	100.00
75	Concentrate	49.05	<b>59.13</b>	<b>94.69</b>
	Tailings	50.95	3.19	5.31
	Raw ore	100.00	30.63	100.00
85	Concentrate	46.44	<b>62.57</b>	<b>94.88</b>

	Tailings	53.56	2.93	5.12
	Raw ore	100.00	30.62	100.00
94 ( -0.043mm 81% )	Concentrate	45.21	<b>63.96</b>	<b>94.60</b>
	Tailings	54.79	3.01	5.40
	Raw ore	100.00	30.57	100.00
-0.043mm 87%	Concentrate	44.22	<b>65.24</b>	<b>94.19</b>
	Tailings	55.78	3.19	5.81
	Raw ore	100.00	30.63	100.00

Test results indicate that with the increase of grinding fineness, because of the increase of magnetite dissociation degree, magnetite concentrate grade continues to increase, while the recovery is not basically affected. Overall, the fineness of more than - 0.074 mm (85%), increase amplitude of grade decreases. Considering the grinding cost factors, - 0.074 mm accounting for 85% or so is recommended.

#### **4.3 Magnetite rough concentrate regrinding and re-election tests**

Regrinding and re-election test researches for magnetite rough concentrate are carried out, and examines improving grade effect by regrinding and re-election tests. Test process and results are shown in Figure 4.3 and Table 4.3, respectively:

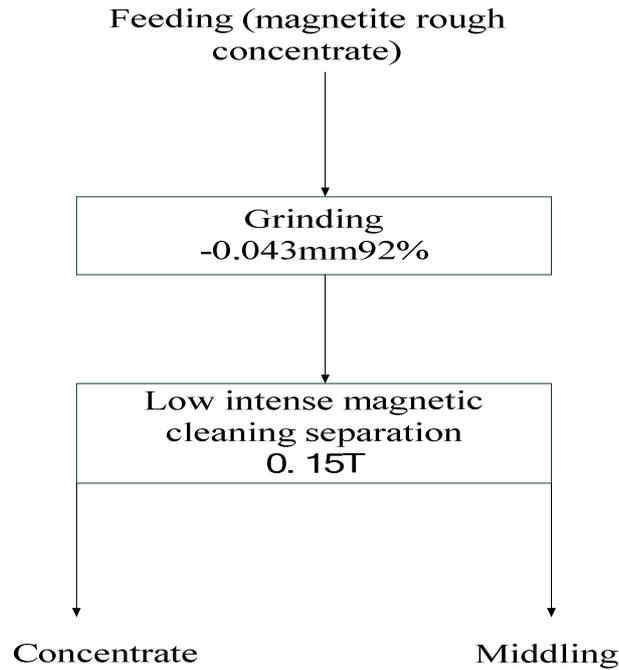


Figure 4.3 Flow chart of regrinding and re-election tests of magnetite rough concentrate

**Table 4.3** Regrinding and re-election tests of magnetite rough concentrate

-0.043mm content/%	Product name	Yield /%		Fe grade /%	Fe recovery/%	
		For operation	For raw ore		For operation	For raw ore
73	Concentrate	94.34	72.61	<b>65.46</b>	<b>99.39</b>	94.30
	Middling	5.66	4.36	6.69	0.61	0.58
	Feeding	100.00	76.97	62.13	100.00	94.88
81	Concentrate	93.17	71.71	<b>66.19</b>	<b>99.17</b>	94.09
	Middling	6.83	5.26	7.56	0.83	0.79
	Feeding	100.00	76.97	62.19	100.00	94.88
90	Concentrate	93.19	43.28	<b>66.65</b>	<b>99.26</b>	94.18
	Middling	6.81	3.16	6.79	0.74	0.70
	Feeding	100.00	46.44	62.57	100.00	94.88

The result indicates that due to the further increase of monomer dissociation degree of magnetite, magnetite concentrate with a high grade is obtained by magnetite rough concentrate regrinding. But considering regrinding and cleaning process is relatively complex and costly.

Therefore, regrinding and cleaning process is not recommended.

#### 4.4 “one-time roughing, one-time scavenging and one-time cleaning ” whole process test

In order to examine scavenging effect on increasing Fe recovery and cleaning effect on improving Fe grade, “one-time roughing, one-time scavenging, one-time cleaning” whole process test is carried out. Test process and results are shown in Figure 4.4 and Table 4.4, respectively:

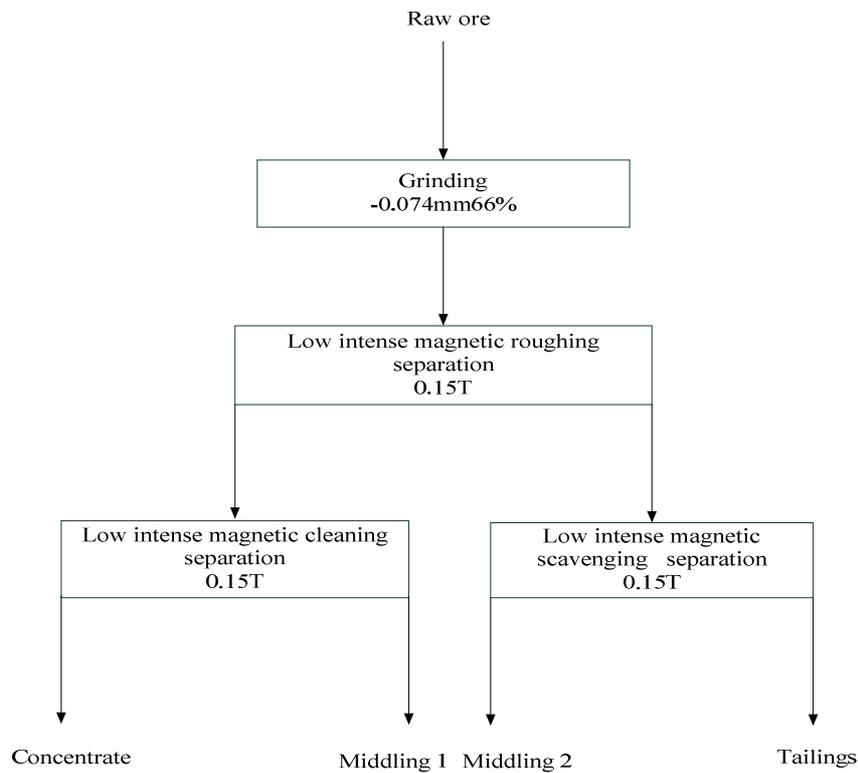


Figure 4.4 Flow chart of “one-time roughing, one-time scavenging and one-time cleaning” whole process test

**Table 4.4 “one-time roughing, one-time scavenging and one-time cleaning” whole process test results**

Product name	Yield /%		Fe grade/%		Fe recovery/%	
	Individual	Accumulation	Individual	Average	Individual	Accumulation
Concentrate	44.00	46.30	<b>64.42</b>	62.03	<b>92.41</b>	93.64
Middling 1	2.30		16.33		1.22	
Middling 2	0.74		35.39		0.86	
Tailings	52.95		3.19		5.51	
Raw ore	100.00		30.67		100.00	

Results show that it is of great significance that iron concentrate grade increase by 2.39% (from 62.03% to 64.42%). Under the experimental conditions, due to basic and effective recovering of magnetite in roughing, so scavenging yield less than 1% and Fe recovery of less than 1%, scavenging significance is not big.

## 5 Multi-element analysis of iron concentrate

Multi-element analysis results of iron concentrate is shown in

Table 5.

**Table 5 Multi-element analysis results of iron concentrate**

Element	Fe	Cu	Pb	Zn	P	Co	As
Content /%	64.42	<0.005	<0.005	<0.005	<0.005	<0.005	0.012
Element	S	Sb	SiO <sub>2</sub>	CaO	MgO	Al <sub>2</sub> O <sub>3</sub>	
Content /%	0.016	<0.005		0.041	4.85	0.096	

Multi-element analysis results show that sulfur, phosphorus, arsenic and other impurities in the iron concentrate are below the requirements of

magnetite concentrate and iron concentrate can reach C63 standards.

## 6 Recommend beneficiation flowsheet for the iron

The beneficiation flowsheet for the iron is recommend as shown in

Table 6 :

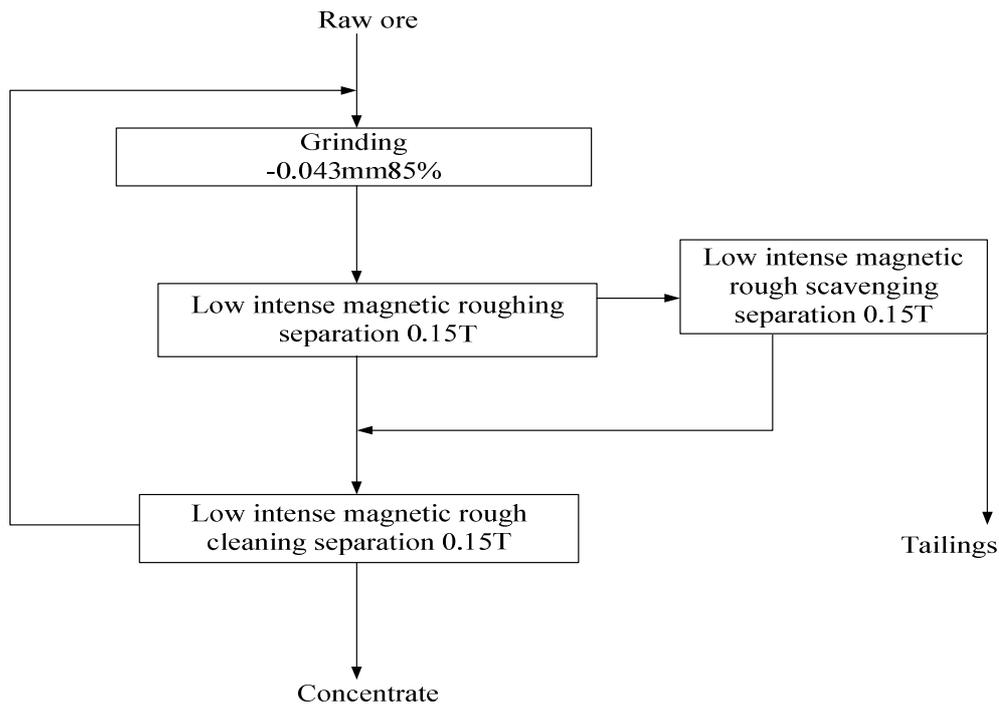


Figure 6 The beneficiation flowsheet for the iron

## 7 Conclusions

Through the research on the ore, conclude the following points:

- ( 1 ) The main valuable element in the ore is Fe with a content of 30.79%. Fe mainly exists in the form of magnetite.
- ( 2 ) “ one-time roughing, one-time cleaning and one-time scavenging ”whole low intense magnetic separation test is carried out under experimental conditions using 0.15 T, beneficiation

technical indicators assaying 64.42%Fe with a concentrate yield of 44.00% at the recovery of 92.41% are obtained.

( 3 ) While under the condition of laboratory, effective recovery of magnetite can be done by low intense magnetic roughing separation and scavenging operations need not be conducted. But considering many influencing factors of actual production, in order to ensure stable production indexes, eventually “one-time roughing, one-time cleaning and one-time scavenging ”whole low intense magnetic separation process is recommended(see Figure 6).