

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

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Non-Ferrous Metals**

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## **1 Introduction**

An iron ore (Sample C) in Australia has been studied since June 18, 2014. Multi-element analysis results show that Fe (51.37%) is main valuable element. Phase analysis results indicate that 94.57% of the iron exists in the form of magnetic iron. Process mineralogy research results show that Fe mainly occurs in the magnetite and small amount of Fe occurs in serpentine, chlorite, talcum and other silicate gangue minerals containing Fe.

Beneficiation tests research results show that when beneficiation fineness is -0.074 mm 61%, using 0.15T low intensity magnetic roughing separation (LIMS), Fe concentrate assaying 65.25% Fe with 76.97% yield at 96.73% recovery can be obtained. The test results show that the separability of the iron ore is good, the magnetite concentrate grade and recovery obtained are higher.

Although under laboratory conditions, test indexes of grade and recovery of higher iron concentrate can be obtained adopting low magnetic roughing separation, considering many influencing factors of actual production, in order to ensure stable production indexes, finally the flowsheet “one-time roughing, one-time cleaning and one-time scavenging” whole low intensity magnetic separation is recommended.

Process mineralogy research results also show that the ore contains 0.031% cobalt, reaching the requirements of industrial grade of 0.03%;

cobalt mainly exists in the form of allosite and sulfur antimony cobalt and has the comprehensive recovery value; at the same time, the ore contains 0.30% bismuth, bismuth mainly exists in the form of native bismuth, sulfide bismuth minerals, oxide bismuth mineral, bismuth carbonate mineral and bismuth silicate minerals, and has the comprehensive recovery value. In addition, the ore contains gold 0.68 g/t, and has recovery value. The recovery of cobalt, bismuth and gold remains to be further studied.

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

Four kinds of ore samples are received from client in June 17, 2014, of which include two C samples, 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:

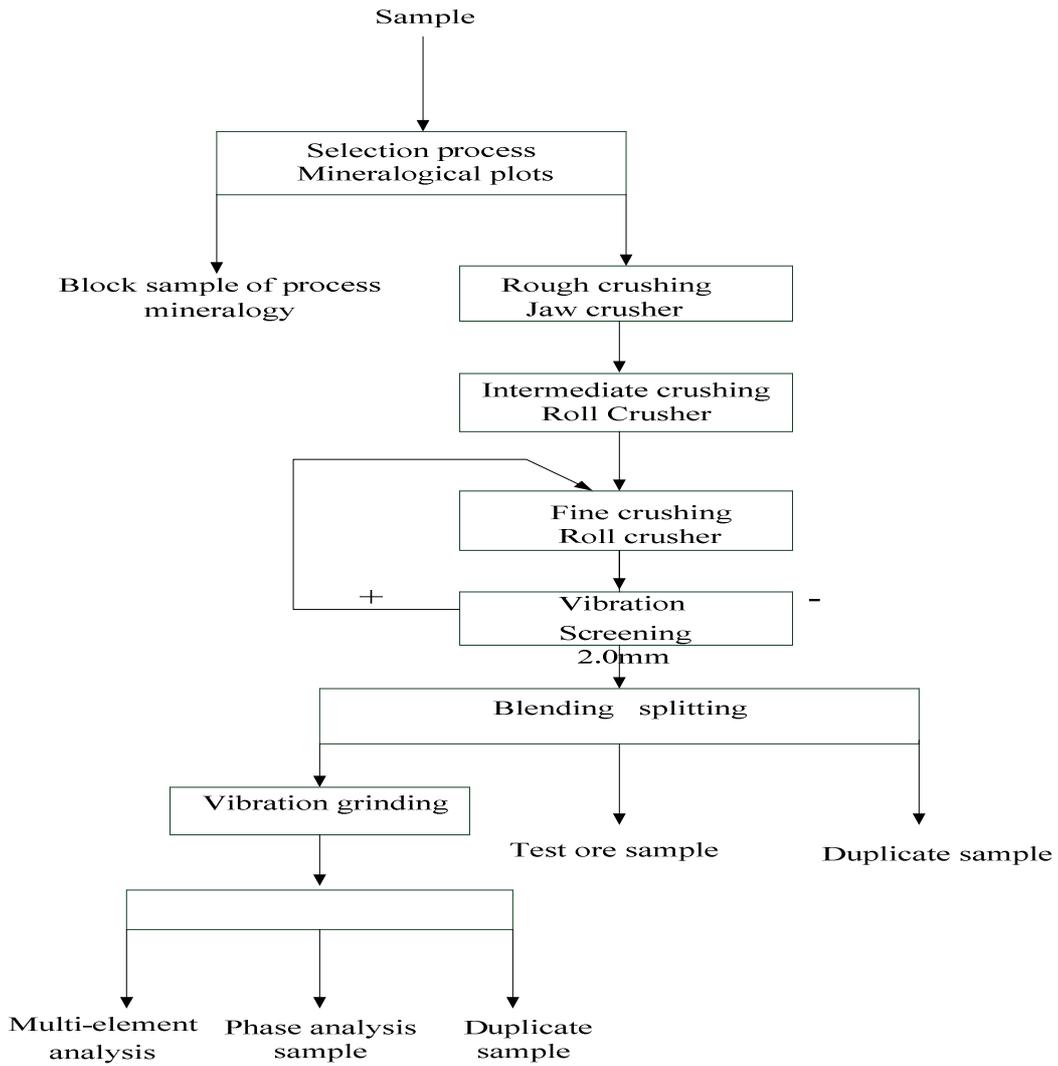


Figure 2.1 Flow chart of test ore sample preparation

### 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	Ca
0.1~1	F, Al, Mn

0.01~0.1	P, S, Cl, As, Sn, Zn, Na
<0.01	Sr, Ge, I, Cr

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 /%	51.37	<0.005	0.0221	0.0505	0.18	0.0031	0.031	0.042
Element	S	Sb	Bi	SiO <sub>2</sub>	CaO	MgO	Al <sub>2</sub> O <sub>3</sub>	
Content /%	0.056	<0.005	0.30	6.54	3.33	9.29	0.35	

Multi-element analysis results indicate that the main marketable element is Fe (51.37%). At the same time, the sample is associated with 0.031% Co, 0.30% Bi and 0.68g/t Au.

### 3.2 Iron phase analysis

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

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

Iron phase	Magnetite	Ferrosilite	Total iron
Content /%	48.58	2.79	51.37
Occupancy /%	94.57	5.43	100.00

Iron phase analysis results show that 94.57%Fe in the ore exists in the form of magnetic.

### 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	34.79	<b>53.45</b>	35.90
-1.0+0.5	16.82	<b>52.18</b>	16.95
-0.5+0.25	12.96	<b>47.83</b>	11.97
-0.25+0.074	23.27	<b>53.78</b>	24.16
-0.074+0.043	4.57	<b>52.54</b>	4.63
-0.043	7.59	<b>43.65</b>	6.40
Raw ore	100.00	51.80	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 60%. 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; cobalt minerals are mainly cobaltite and trace of sulfur antimony cobalt; the species of bismuth mineral are more and mainly bismite, bismuthinite, native bismuth, native bismuth, ferrosilicon bismuth ore and kettnerite; Other metal sulfide minerals are mainly trace of sphalerite, pyrrhotite,

pyrite, arsenopyrite and galena, etc; other metal oxide minerals include a small amount to trace cassiterite, scheelite, rutile, etc.; Gangue are mainly dolomite, magnesite, serpentine, greenalite, talc, chlorite, etc.

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

Mineral	Content %	Mineral	Content %	Mineral	Content %
Magnetite	71.618	Cassiterite	0.036	Chlorite	1.615
Siderite	0.247	Hydroxyl tin Brucite	0.020	Glauconite	0.017
Limonite	0.249	Quartz	0.066	Calcitum	0.713
Arsenopyrite	0.137	Feldspar	0.050	Dolomite	8.793
Sulfur antimony cobalt	0.003	Nepheline	0.014	Magnesite	5.838
Native bismuth	0.055	Lepidolite	0.035	Brucite	0.328
Bismuthinite	0.066	Sahlite	0.063	Fluorite	0.010
Bismite	0.111	Bronzite	0.246	Sellaite	0.002
Kettnerite	0.060	Hypersthene	0.247	Fluoborite	0.161
Ferrosilicon bismuth	0.065	Ferrohyperst hene	0.171	Apatite	0.016
Arsenopyrite	0.012	Tremolite	0.035	Rutile	0.001
Pyrite	0.015	Andradite	0.015	Diaspora	0.011
Pyrrhotite	0.036	Epidote	0.021	Psilomela ne	0.006
Chalcopyrite	0.001	Tourmaline	0.012	Other	0.191
Sphalerite	0.055	Serpentine	3.507	Total	100.000
Galena	0.007	Greenalite	2.731		
Scheelite	0.003	Talcum	2.289		

### 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 ~ 2.56 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	2.97
-1.28+0.64	4.45
-0.64+0.32	6.68
-0.32+0.16	15.02
-0.16+0.08	36.82
-0.08+0.04	22.98
-0.04+0.02	8.49
-0.02+0.01	2.45
-0.01	0.15
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, silicon, aluminum and other impurities, containing 70.56% Fe on average.

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

Measure point	Chemical composition and content/%				
	Fe	Mg	Al	Si	O
1	71.85	0.19	0.03	0.20	27.73
2	69.82	1.08	0.12	0.21	28.77
3	71.21	1.99	0.07	0.24	26.49
4	71.19	0.85	0.07	0.17	27.72
5	71.86	0.77	0.06	0.21	27.10
6	70.64	1.11	0.09	0.17	27.99
7	70.01	1.00	0.00	0.19	28.80
8	69.82	2.75	0.00	0.08	27.35
9	71.41	1.34	0.00	0.09	27.16
10	68.82	2.80	0.00	0.00	28.38
11	69.52	2.07	0.00	0.00	28.41
Average	70.56	1.45	0.04	0.14	27.81

Magnetite in the ore is mainly euhedral~subhedral granular aggregates, embedding in serpentine and other gangue minerals (Photos 1 and 2); part of magnetite is contact metasomatic pyrite, magnetite containing residual pyrite (Photo 3); also a small amount of magnetite is contact metasomatic pyrite (Photo 4); a small amount of micro-granular magnetite present wormlike and star point, distributing in the dolomite, serpentine and other gangue minerals (Photos 5 and 6); A small amount of

magnetite contains fine dolomite, chlorite, kettnerite and other minerals(Photos 7and 8).

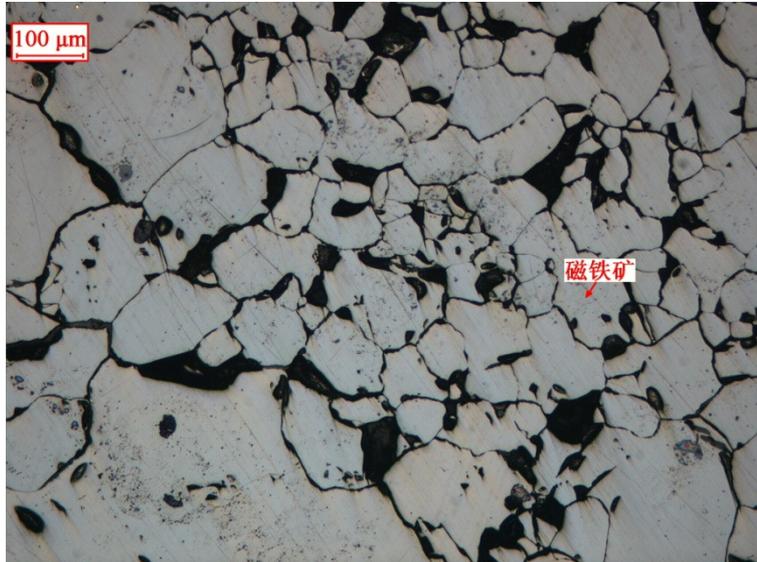


Photo 1 microscope, reflection  
Magnetite is euhedral~subhedral granular aggregates, embedding in gangue。

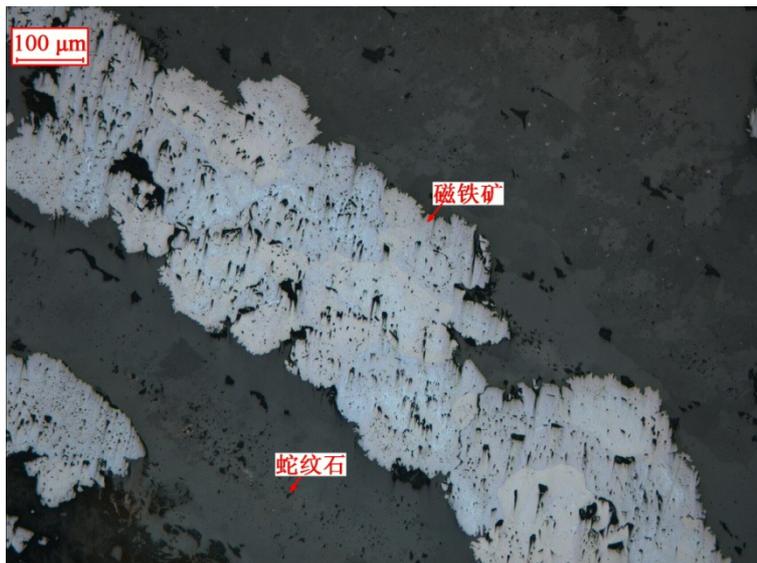


Photo 2 microscope, reflection  
Fine magnetite aggregates present lode, embedding in serpentine.

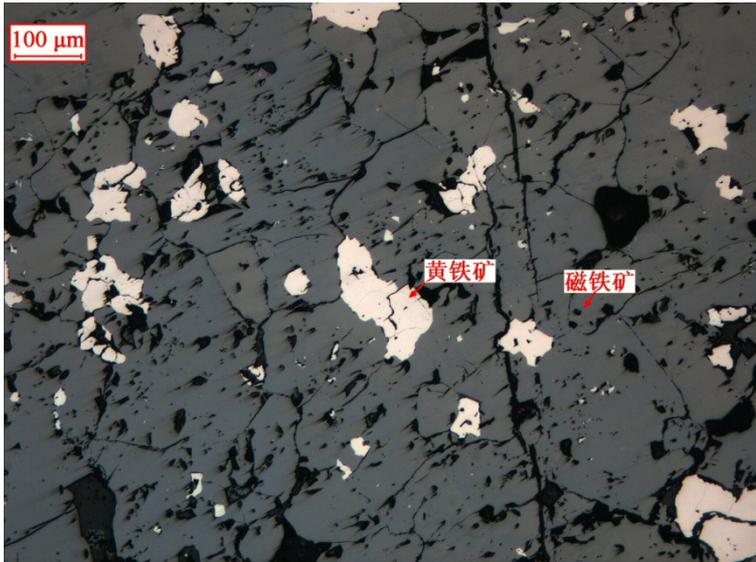


Photo 3 microscope, reflection  
Magnetite is contact  
metasomatic pyrite, magnetite  
containing metasomatic residual  
pyrite.

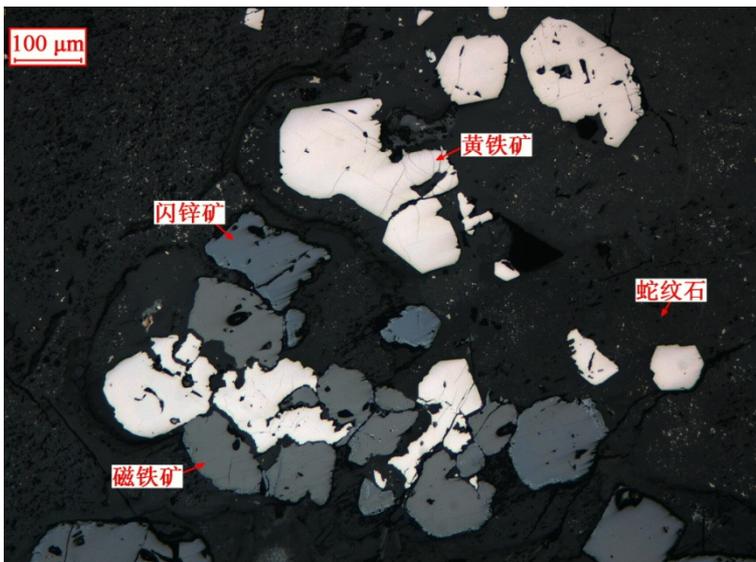


Photo 4 microscope, reflection  
Pyrite fills metasomatic along  
the magnetite particles gap.

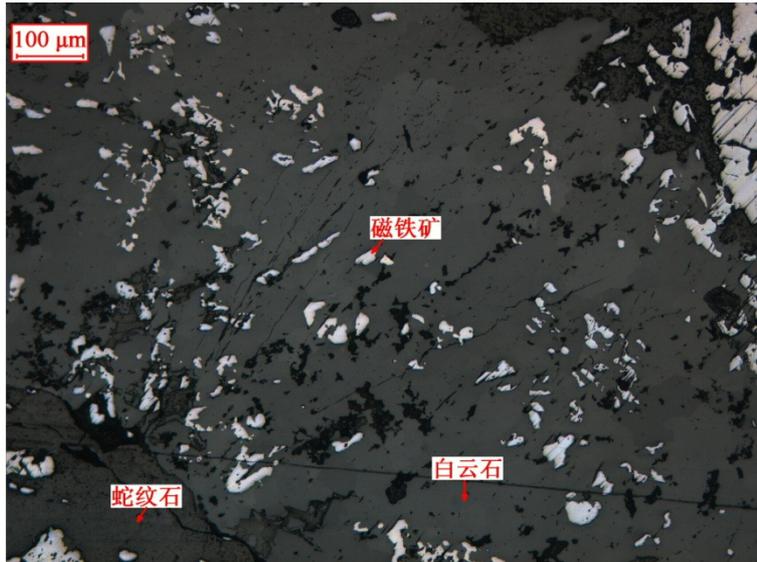


Photo 5 microscope, reflection  
Magnetite presents worm-like,  
distributing in dolomite and  
fine-grained.

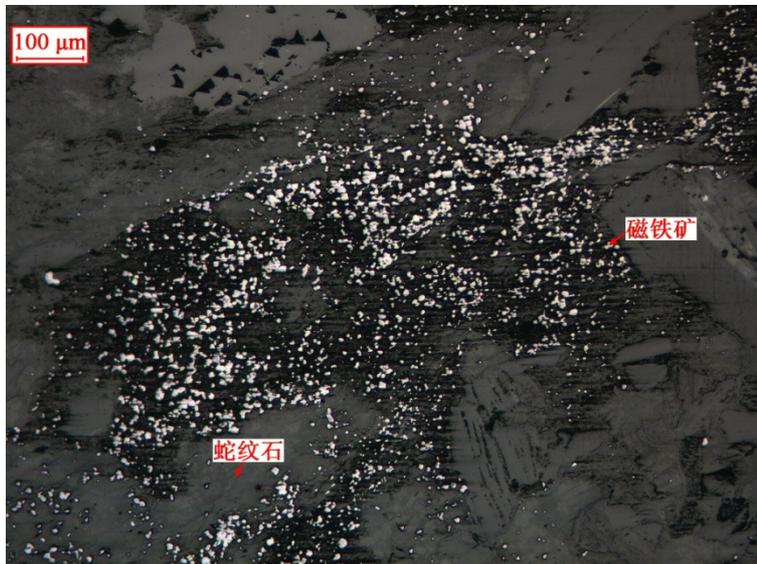


Photo 6 microscope, reflection  
Fine magnetite presents star point,  
densely distributing in the serpentine.

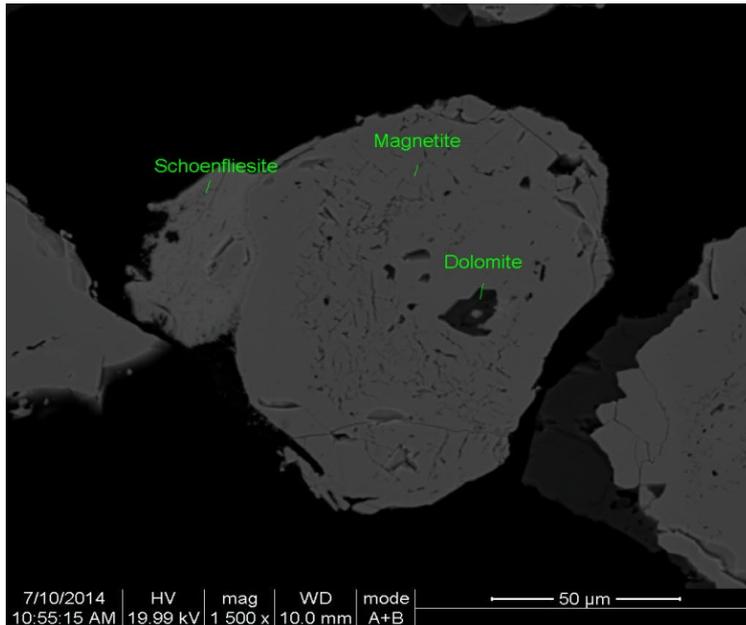


Photo 7 SEM, BSE image  
Magnetite is associated with hydroxyl tin magnesium and contains fine dolomite.

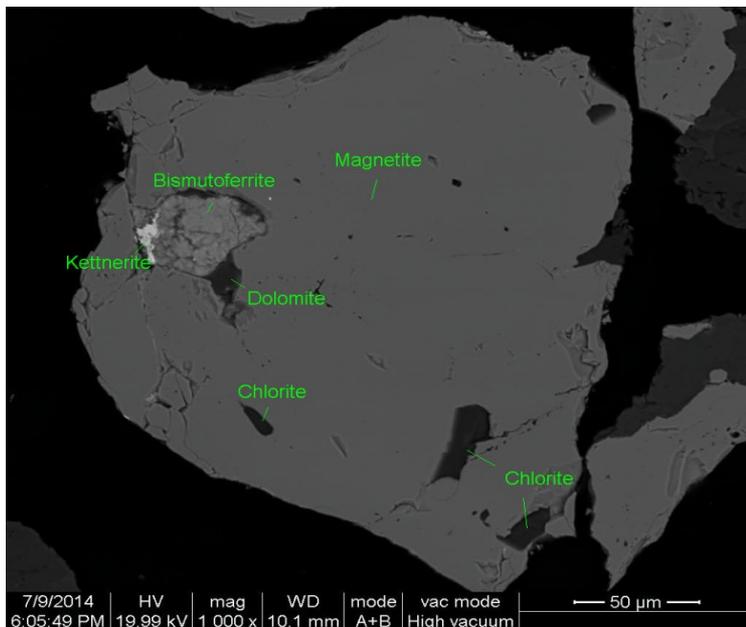


Photo 8 SEM, BSE image  
Magnetite contains kettnerite, ferrosilicon bismuth, chlorite, etc.

### 3.6.2 CoSbS Cobalt mineral - cobaltite coAsS and sulfur antimony cobalt CoSbS

Co grade in the ore reaches the requirements of industrial grade. Cobaltite and sulfur antimony cobalt ore are main cobalt minerals in the ore.

**Cobaltite** The theoretical composition of CoAsS is: Co 35.41%, As 45.26% and S 19.33%, and often part of cobalt is replaced by iron and nickel. Energy spectrum detection results of chemical composition of cobaltite in the ore are shown in Table 3.8. The results show that the cobaltite generally contains small amounts of iron, nickel and antimony, containing Co 31.66%, As 44.75% and S 19.20% on average. Cobaltite is tin white, black streak, metallic luster, fracture uneven to conchoidal, brittle, Mohs hardness of 5.5, density of 6.0 ~ 6.5g/cm<sup>3</sup> and with conductivity.

**Sulfur antimony cobalt** The content of CoSbS is less, the theoretical chemical composition as follows: 27.71% Co, Sb, 57.24% and S 15.05%. Energy spectrum detection results of chemical composition of sulfur antimony cobalt in the ore are shown in Table 3.9. The sulfur antimony cobalt contains a small amount of iron, nickel, arsenic, etc., containing Co 24.98%, 55.03% Sb and 14.54% S on average. The sulfur antimony cobalt is gray, metal luster and density of 6.89 g/cm<sup>3</sup>.

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

Measure point	Chemical composition and content/%					
	Co	Fe	Ni	As	Sb	S
1	29.52	3.49	2.73	44.85	0.58	18.83
2	31.69	3.33	0.77	45.08	0.46	18.67
3	30.36	3.04	1.93	45.51	0.49	18.67

4	31.90	1.63	1.79	45.70	0.56	18.42
5	30.60	2.69	2.61	44.19	0.48	19.43
6	33.36	1.59	0.76	43.94	0.51	19.84
7	33.52	1.73	0.73	43.86	0.00	20.16
8	32.31	2.21	1.04	44.87	0.00	19.57
Average	31.66	2.46	1.55	44.75	0.39	19.20

**Table 3.9 Energy spectrum detection results of chemical composition of sulfur antimony cobalt**

Measure point	Chemical composition and content/%					
	Co	Fe	Ni	Sb	As	S
1	23.71	3.00	1.98	55.63	1.04	14.64
2	25.23	1.03	2.15	54.96	1.92	14.71
3	26.01	2.62	0.44	54.51	2.14	14.28
Average	24.98	2.22	1.52	55.03	1.70	14.54

The cobaltite and sulfur antimony cobalt in the ore is mainly euhedral~subhedral crystals, distributing in serpentine, dolomite and other gangue minerals (Photos 9 and 10); A small amount of cobaltite is associated with magnetite or presents fine particles containing in magnetite (Photos 11 and 12); A small amount of cobaltite contains fine native bismuth or born with native bismuth forming a complex body (Photos13 and 14).

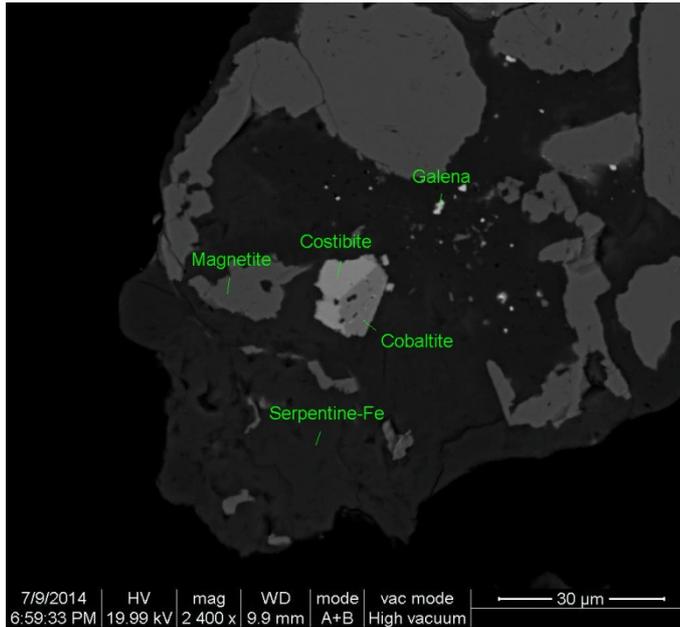


Photo 9 SEM, BSE image  
Cobaltite and sulfur  
antimony cobalt are  
euhedral-subhedral crystals,  
distributing in serpentine,  
and both present separation  
structures of solid solution.

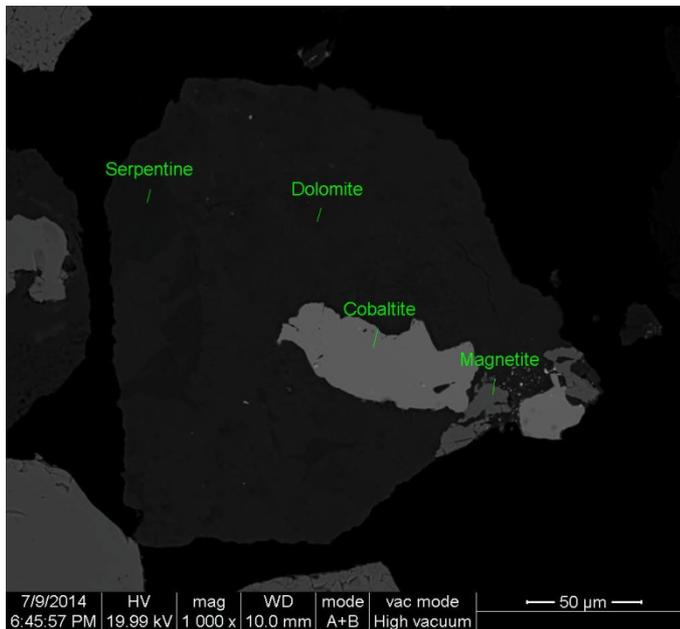


Photo10 SEM, BSE image  
Cobaltite is euhedral crystal,  
embedding in dolomite.

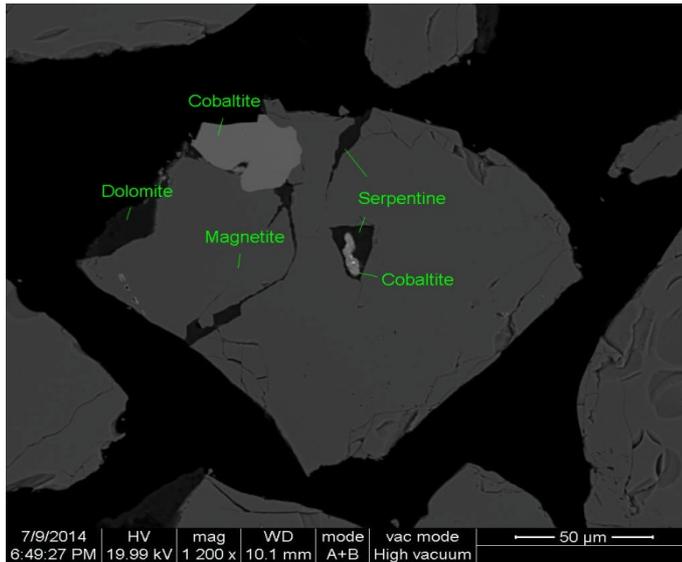


Photo11 SEM, BSE image  
Cobaltite is associated with magnetite.

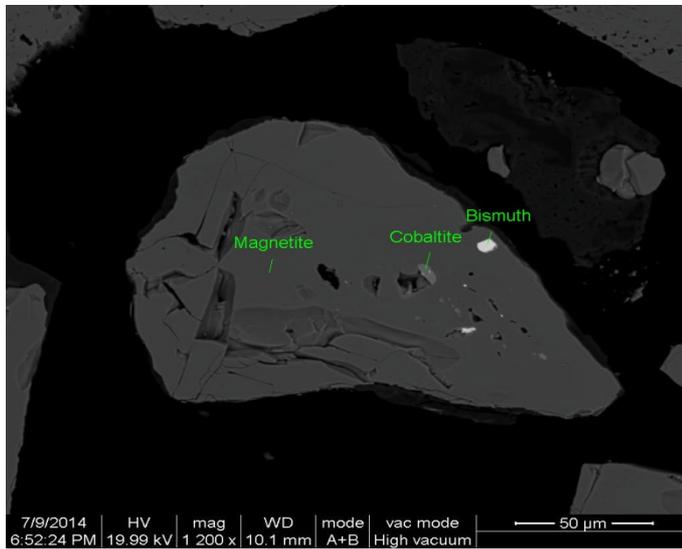


Photo12 SEM, BSE image  
Fine cobaltite contains in magnetite.

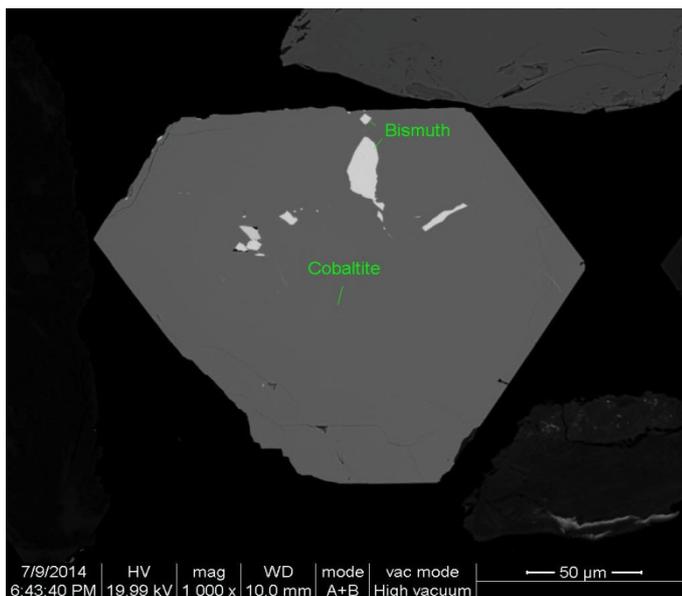


Photo13 SEM, BSE image  
Cobaltite is subhedral crystals, containing native bismuth particle size.

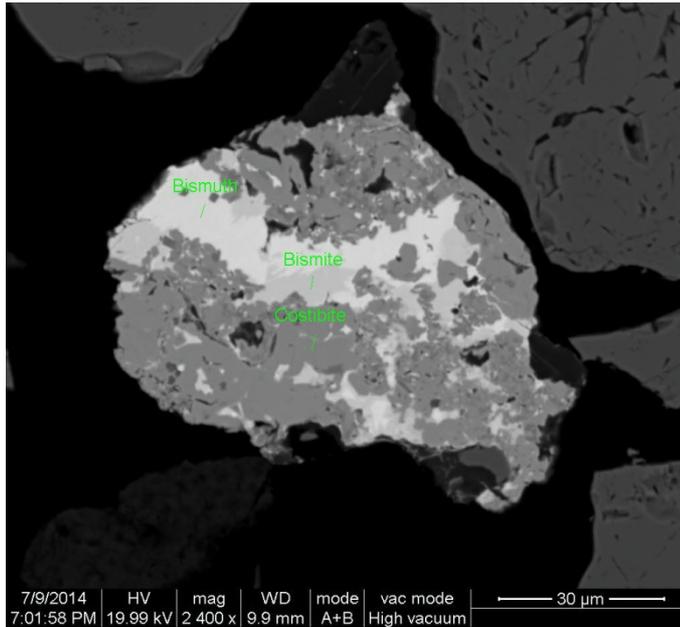


Photo14 SEM, BSE image Cobaltite, native bismuth and bismite form a complex conjunction.

### 3.6.3 Bismuth minerals

The types of bismuth minerals in the ore are more, including native bismuth, bismuthinite ( $\text{Bi}_2\text{S}_3$ ), bismite ( $\text{Bi}_2\text{O}_3$ ), kettnerite ( $\text{CaBi}(\text{CO}_3)\text{OF}$ ) and ferrosilicon bismuth ( $\text{BiFe}_2[\text{SiO}_4]_2\text{OH}$ ). Energy spectrum detection results of chemical composition of bismite, ferrosilicon bismuth, kettnerite and bismuthinite are shown in Tables 3.10, 3.11, 3.12 and 3.10, respectively.

**Table 3.10 Energy spectrum detection results of chemical composition of bismuthinite**

Measure point	Chemical composition and content/%		
	Bi	Fe	S
1	79.99	3.01	17

**Table 3.11 Energy spectrum detection results of chemical composition of bismite**

Measure point	Chemical composition and content/%			
	Bi <sub>2</sub> O <sub>3</sub>	MgO	Al <sub>2</sub> O <sub>3</sub>	FeO
1	98.07	0.00	0.32	1.61
2	99.05	0.00	0.00	0.95
3	98.19	0.89	0.00	0.92
4	99.29	0.00	0.12	0.59
Average	98.65	0.22	0.11	1.02

**Table 3.12 Energy spectrum detection results of chemical composition of kettnerite**

Measure point	Chemical composition and content/%							
	Bi <sub>2</sub> O <sub>3</sub>	CaO	FeO	MgO	SiO <sub>2</sub>	UO <sub>2</sub>	F	CO <sub>2</sub>
1	66.91	8.91	3.80	0.76	4.89	0.85	0.97	12.91
2	71.00	11.18	0.86	0.41	0.49	0.96	1.82	13.28
3	74.25	8.09	1.86	0.31	0.38	0.87	0.00	14.24
Average	70.72	9.39	2.17	0.50	1.92	0.89	0.93	13.48

**Table 3.13 Energy spectrum detection results of chemical composition of ferrosilicon bismuth**

Measure point	Chemical composition and content/%					
	Bi <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>
1	30.62	29.34	0.41	3.71	1.14	34.78
2	33.57	30.45	0.00	1.24	0.00	34.74
Average	32.10	29.90	0.21	2.48	0.57	34.76

The types of bismuth minerals in the ore are more and disseminated state complex. Native bismuth is general granular, embedding in the

gangue and granularity uneven thickness (Photos 15 and 16). As we can see that the edge of native bismuth oxidizes into bismite (Photo 17), and a small amount of fine native bismuth contain in cobaltite, magnetite, sphalerite and other minerals (Photo 18). Bismuthinite often presents irregular granular, distributing in the gangue (Photo 19); about 20% of the bismuthinite is very fine particle, disseminated distributing in serpentine (Photo 20), forming bismuthinite - serpentine aggregation. They can be dissociated with serpentine by grinding and the floatability of this part of bismuthinite is poorer; And a small amount of bismuthinite are contact metasomatic sphalerite (Photo 21). Bismite is secondary change product of native bismuth, bismuthinite and kettnerite (Photos 22 and 23). Similar to bismuthinite, about 50% of bismite is very fine particle, disseminated distributing in serpentine (Photo 24), forming bismite - serpentine aggregation. And it can't be dissociated with serpentine by grinding. Trace of monomer particles of ferrosilicon bismuth in the ore can be seen (Photo25).

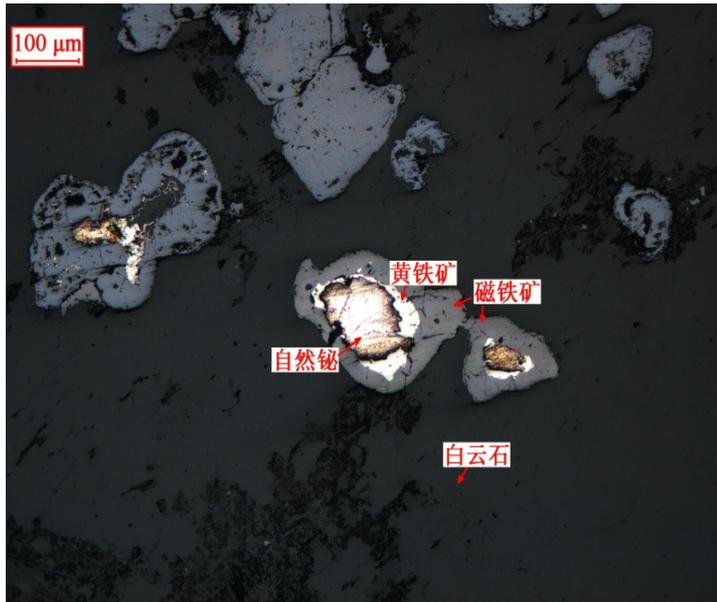


Photo 15 microscope, reflection  
 Native bismuth is replaced by pyrite and  
 pyrite is replaced by magnetite. The three  
 present concentric ring structures and  
 together embed in dolomite.

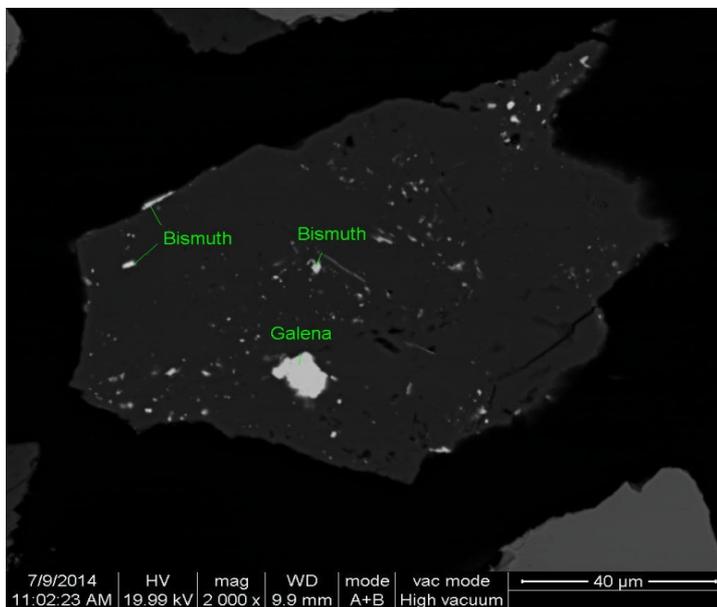


Photo 16 SEM, BSE image  
 Fine native bismuth  
 particle distributes in the  
 gangue.

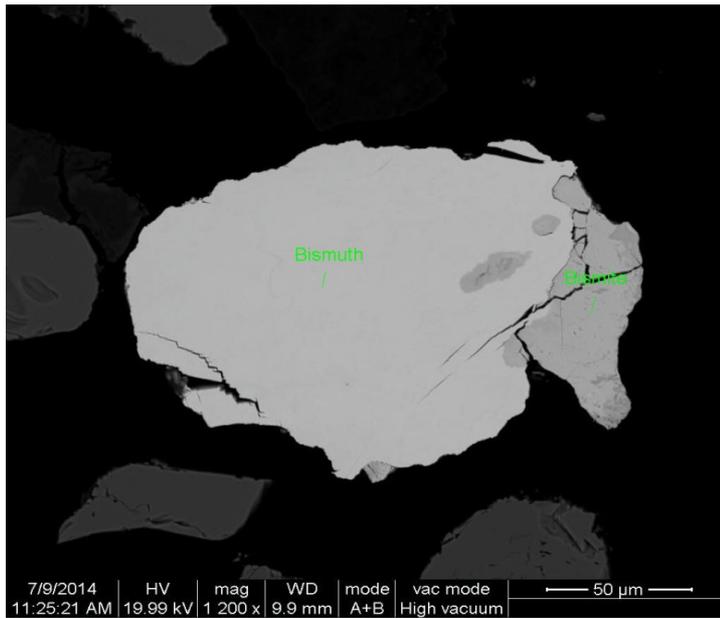


Photo 17 SEM, BSE image  
The edge of native bismuth oxidizes into bismite.

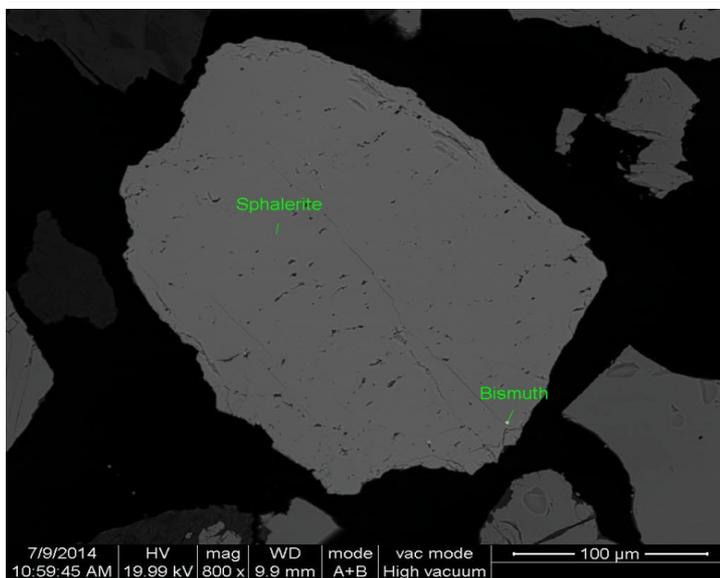


Photo 18 SEM, BSE image  
Fine native bismuth contains in sphalerite.

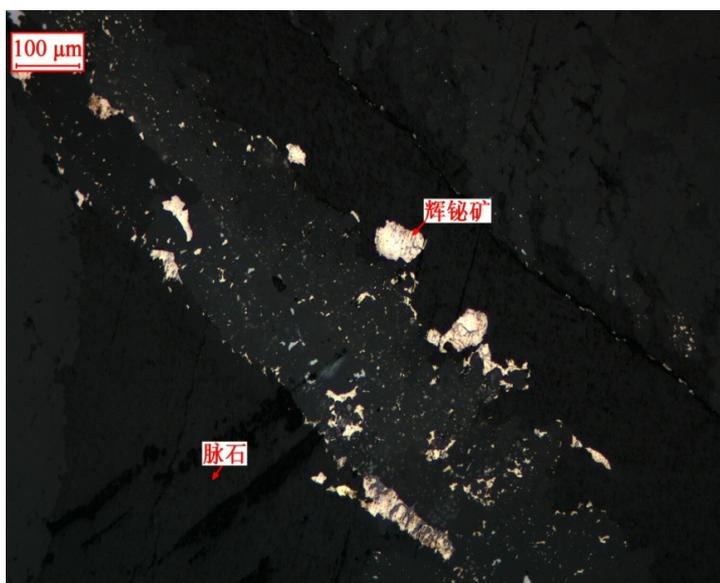


Photo 19 microscope, reflection  
Bismuthinite presents irregular granular, distributing in the gangue.

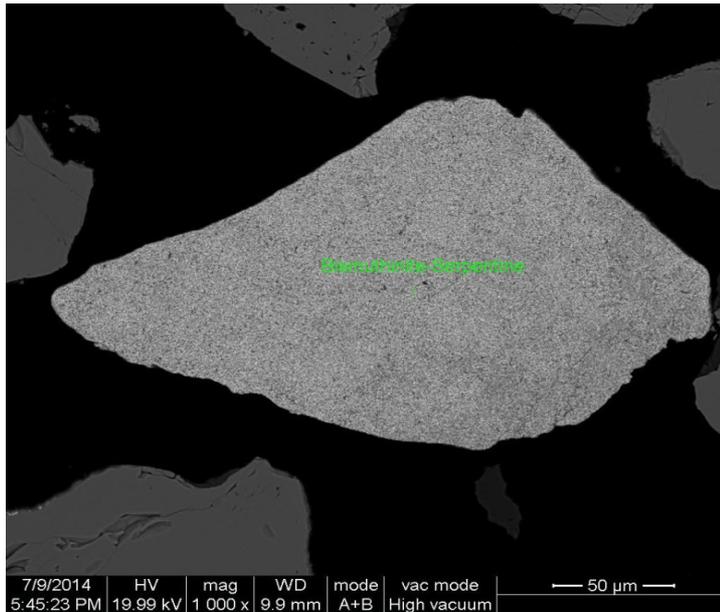


Photo 20 SEM, BSE image  
Bismuthinite is very fine  
particle, disseminated  
distributing in serpentine,  
forming bismuthinite -  
serpentine aggregation.

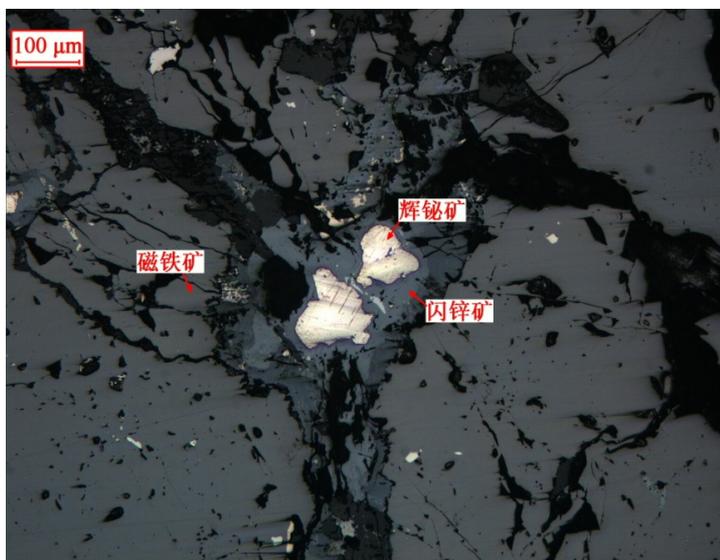


Photo 21 microscope, reflection  
Bismuthinite are contact  
metasomatic sphalerite and  
residual bismuthinite contains  
in sphalerite.

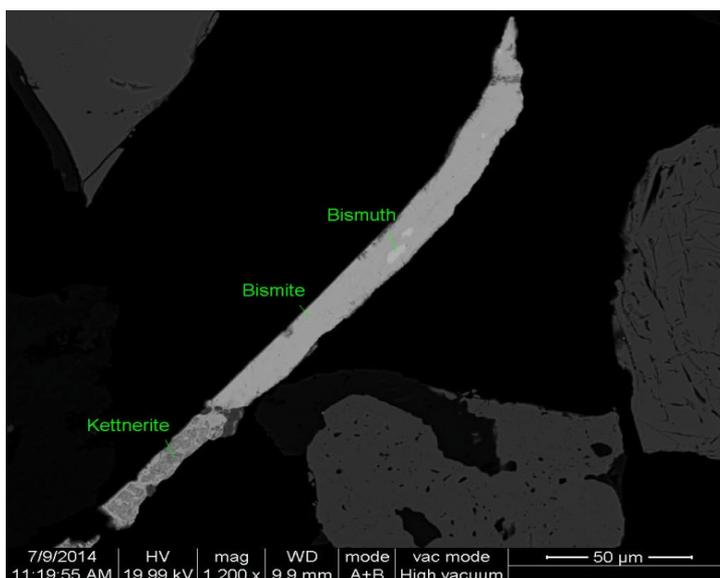


Photo 22 SEM, BSE image  
Native bismuth and  
kettnerite oxidize into  
bismite and residual  
native bismuth contains  
in bismite.

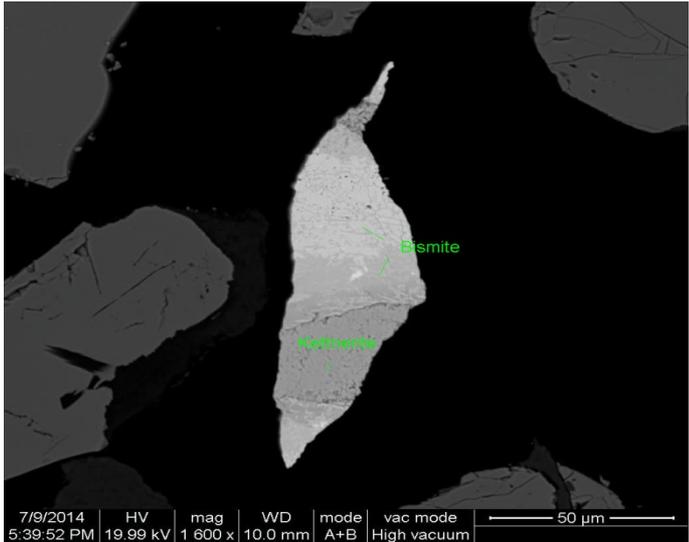


Photo 23 SEM, BSE image  
Part particles of kettnerite  
have oxidized into bismite.

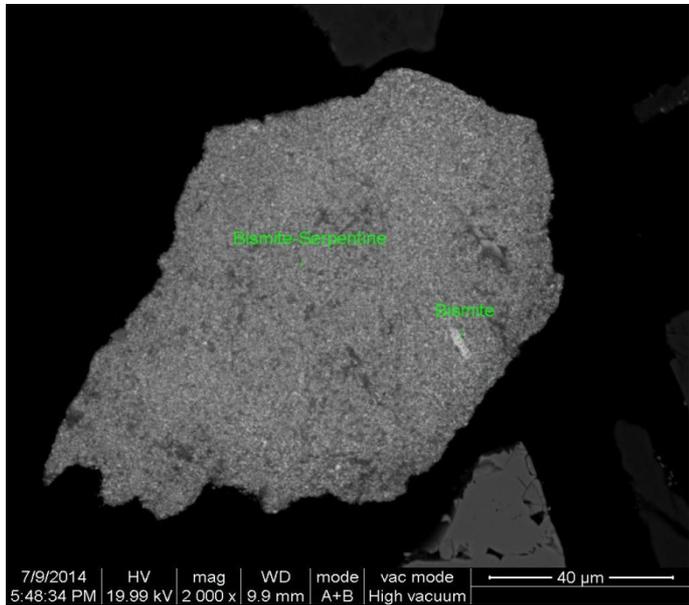


Photo 24 SEM, BSE image  
Bismite is very fine  
particle, disseminated  
distributing in serpentine,  
forming bismite -  
serpentine aggregation.

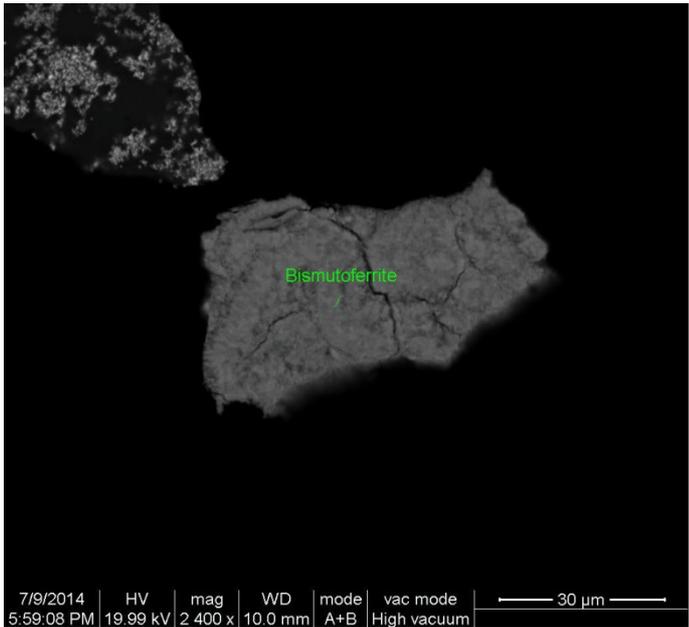


Photo 25 SEM, BSE image  
Monomer particles of  
ferrosilicon bismuth.

### **3.7. Brief summary**

( 1 ) Valuable element in the ore is Fe and associated valuable elements are Co and Bi. MLA determination results show that iron minerals in the ore are mainly magnetite, a small amount of limonite and siderite; cobalt minerals are mainly cobaltite and trace of sulfur antimony cobalt; the types of bismuth minerals are more, mainly including bismite, bismuthinite, native bismuth, ferrosilicon bismuth and kettnerite.

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

( 3 ) Part of magnetite is fine particles, embedding in the gangue, and difficult to disintegrate. This part of the magnetite entering into concentrate has a certain effect on the grade of iron concentrate.

( 4 ) The types of bismuth minerals are variety, including native bismuth, sulfide bismuth minerals, oxide bismuth mineral, bismuth carbonate mineral and bismuth silicate minerals. And about 20% of the bismuthinite and about 50% of bismite are very fine particle, disseminating in serpentine and forming bismuth minerals - serpentine aggregation which can't be dissociated by grinding.

### **4 Beneficiation test**

Process mineralogy research results indicate that the deposit is a

typical of iron ore mainly containing magnetite, which is one of 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, magnetic separation test about the ore conducted, magnetic analysis test, fineness test, one-time roughing - one-time cleaning - one-time scavenging whole process of magnetic separation test and ore matching of different proportion of samples C and S test are carried out, respectively. At the same time, experimental study of cobalt exploration beneficiation aiming in raw ore are also carried out.

#### **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 Fig. 4.1 and Table 4.1, respectively:

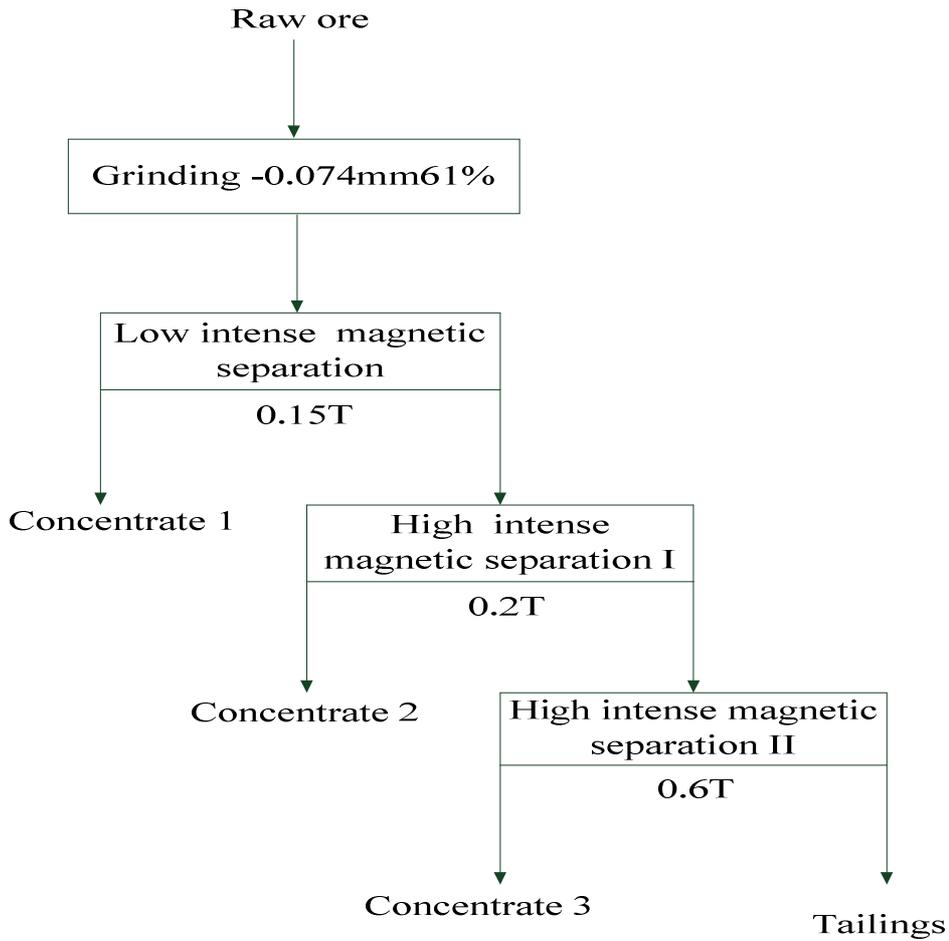


Figure 4.1 Flow chart of magnetic analysis test

**Table 4.1 Results of magnetic analysis test**

Product name	Yield/ %	Fe grade/%	Fe recovery/%
Concentrate 1 ( iron concentrate )	76.63	<b>65.19</b>	<b>96.68</b>
Concentrate 2	8.62	9.98	1.67
Concentrate 3	8.19	6.31	1.00
Tailings	6.55	5.17	0.66
Raw ore	100.00	51.67	100.00

Results show that various mineral in the ore present obvious magnetic differences, iron concentrate can be obtained with a grade of

65.19% at the recovery of 96.68% using low intense magnetic separation at 0.15 T. Further adopting high intense magnetic separation, iron content of magnetic product is lower than 10%, indicating that high intense magnetic separation mainly obtains gangue minerals which contain low iron, 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:

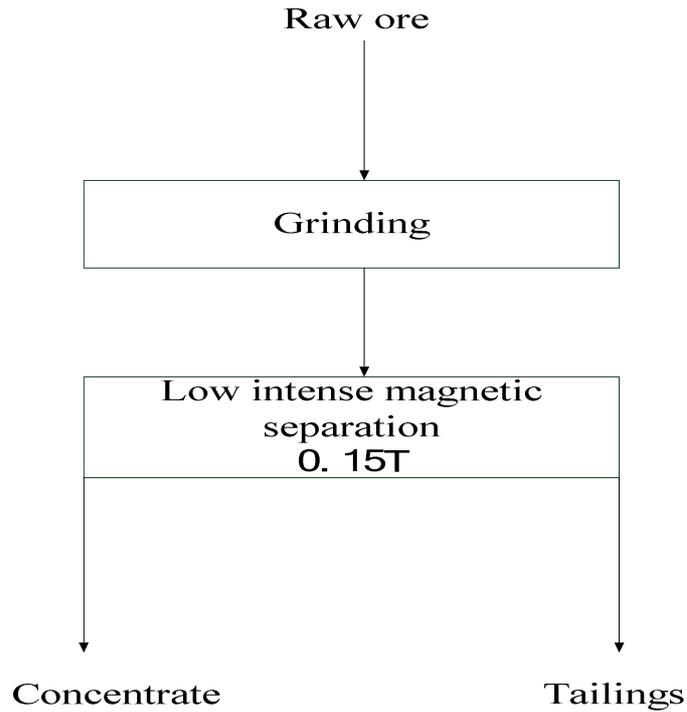


Figure 4.2 Flow chart of magnetic separation fineness test

**Table 4.2 Fineness test results of ore sample**

-0.074mmcontent/%	Product name	Yield /%	Fe grade /%	Fe recovery /%
50	Concentrate	76.54	<b>64.20</b>	<b>96.14</b>
	Tailings	23.46	8.41	3.86
	Raw ore	100.00	51.11	100.00
61	Concentrate	76.97	<b>65.25</b>	<b>96.73</b>
	Tailings	23.03	7.36	3.27
	Raw ore	100.00	51.92	100.00
72	Concentrate	75.18	<b>65.59</b>	<b>96.28</b>
	Tailings	24.82	7.68	3.72
	Raw ore	100.00	51.22	100.00
77	Concentrate	73.56	<b>67.24</b>	<b>95.92</b>
	Tailings	26.44	7.96	4.08
	Raw ore	100.00	51.56	100.00
91(-0.043mm 68.5% )	Concentrate	72.47	<b>68.11</b>	<b>95.62</b>
	Tailings	27.53	8.21	4.38
	Raw ore	100.00	51.62	100.00

Test result indicates 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.

In order to ensure iron concentrate grade (over 65%) and simultaneously reduce grinding cost, - 0.074 mm accounting for 61% or so grinding fineness is recommended.

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

Regrinding and re-election tests are conducted after magnetite rough concentrate adopting 0.15T magnetic separation, and examine the influence on beneficiating iron indicators after improving grinding fineness.

Test process and results are shown in Figure 4.3 and Table 4.3, respectively.

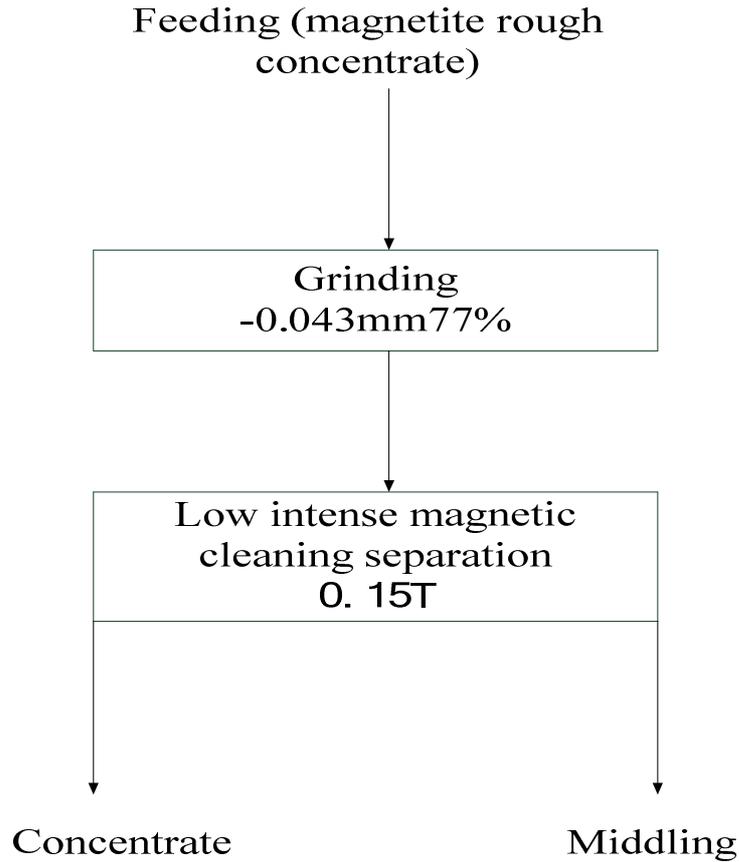


Figure 4.3 Flow chart of regrinding and cleaning test of magnetite rough concentrate

**Table 4.3** Regrinding and cleaning 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
62	Concentrate	96.32	74.14	<b>67.28</b>	<b>99.31</b>	96.07
	Middling	3.68	2.83	12.13	0.68	0.66
	Feeding	100.00	76.97	65.25	100.00	96.73
71	Concentrate	95.83	73.76	<b>67.67</b>	<b>99.39</b>	96.14
	Middling	4.17	3.21	9.59	0.61	0.59
	Feeding	100.00	76.97	65.25	100.00	96.73
80	Concentrate	95.04	73.15	<b>68.13</b>	<b>99.24</b>	95.99
	Middling	4.96	3.82	10.06	0.76	0.74
	Feeding	100.00	76.97	65.25	100.00	96.73

Result shows that magnetite concentrate grade is further improved by regrinding -cleaning tests and the recovery of iron operation remains more than 99%, indicating that cleaning has a small effect on iron recovery. But considering regrinding -cleaning process is relatively complex and high cost, and feeding grade (magnetic rough concentrate) itself has reached 65.25 % as higher grade magnetite concentrate. Therefore, regrinding-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 the Fe recovery and cleaning effect on improving the 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 4.3 and Table 4.4, respectively:

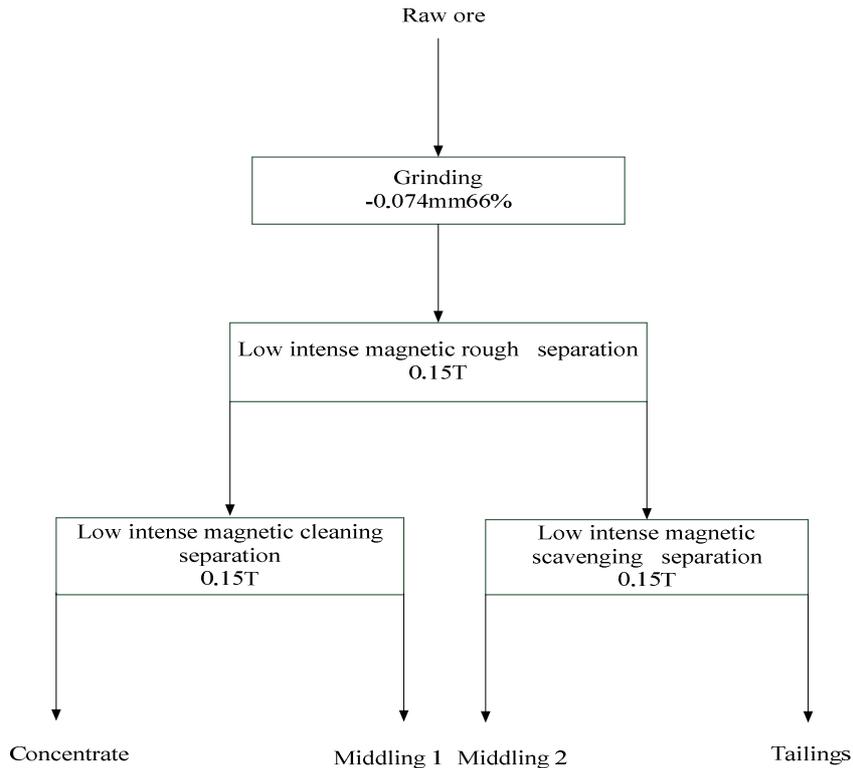


Figure 4.4 Flow chart of “one-time roughing, one-time scavenging and one-time cleaning” whole process test

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

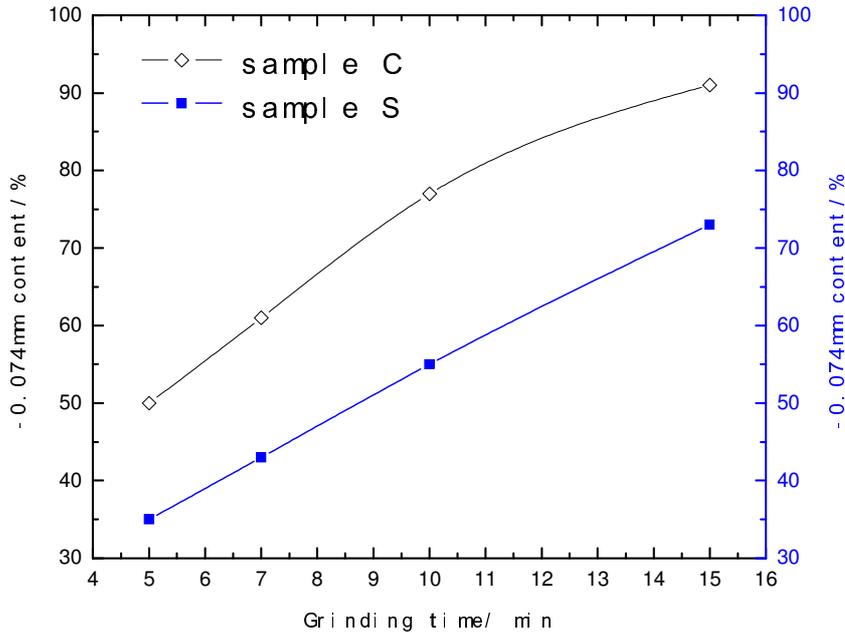
Product name	Yield /%		Fe grade/%		Fe recovery/%	
	Individual	Accumulation	Individual	Average	Individual	Accumulation
Concentrate	73.74	74.91	<b>66.01</b>	<b>65.71</b>	<b>95.14</b>	96.22
Middling 1	1.18		47.08		1.08	
Middling 2	0.31		14.81		0.09	
Tailings	24.78		7.61		3.69	
Raw ore	100.00		51.16		100.00	

Results indicate that cleaning effect is not obvious, grade is only increased by 0.30% (from 65.71% to 66.01%), and recovery is decreased by 1.08%; Under the experimental conditions, due to basic and effective recovering of magnetite in roughing, so scavenging yield of only 0.31%

and Fe recovery of only 0.09%, scavenging significance is not big. Magnetite concentrate assaying 65% to 66% Fe at the recovery of 96% to 97% can be obtained under laboratory conditions, but considering many influencing factors of actual production, in order to ensure the stability of the on-site production, “one-time roughing, one-time cleaning and one-time scavenging” whole low intense magnetic separation process flow sheet is recommended.

#### **4.5 Ore matching of different proportions of samples C and S**

According to information provided by the client, sample C is main sample and sample S is duplicate sample in the mining area , so ore marching tests are carried out under the condition of C: S = 2:1 and 3:1. Grinding properties of samples C and S are large difference (grinding curve shown in Figure 4.5).



**Figure 4.5 Grinding curve of samples C and S**

We can see clearly that under the same grinding conditions, in order to achieve the same grinding fineness, sample S need longer milling time, indicating that compared to sample C, sample S is more difficult to grind. The main reason is that gangue minerals of sample S are mainly serpentine, gangue minerals of sample C are mainly dolomite, talc, chlorite, and relative to dolomite, talc, chlorite and so on, serpentine is more difficult to grind. According to the feature of ore, fineness experimental study for ore matching of different proportion is carried out.

#### **4.5.1 Fineness test**

Test process is shown in Figure 4.6, under the condition of C: S = 2:1, fineness experiment results is shown in Table 4.5, and under the condition of C: S = 3:1, fineness experiment results is shown in Table 4.6.

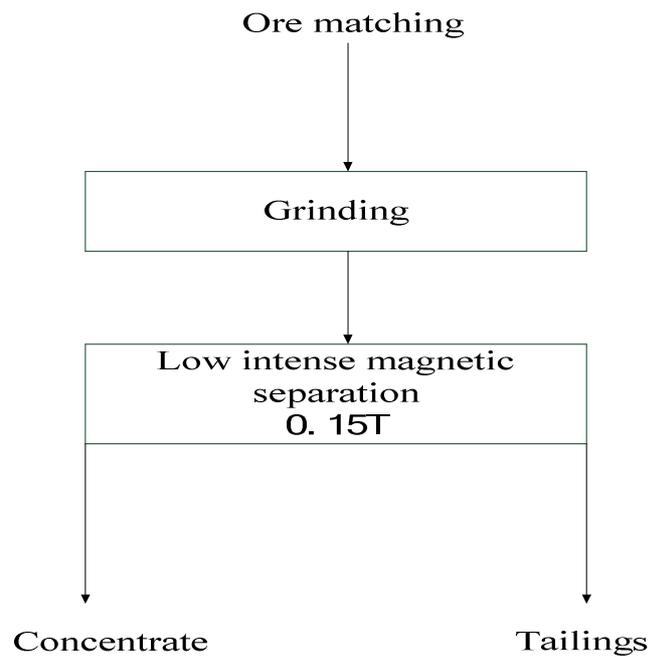


Figure 4.6 Flow chart of fineness test of magnetic separation

**Table 4.5 Fineness experiment results under the condition of C:S = 2:1**

-0.074mmcontent/ %	Product name	Yield /%	Fe grade /%	Fe recovery /%
49	Concentrate	70.92	<b>60.20</b>	<b>95.75</b>
	Tailings	29.08	6.51	4.25
	Ore matching	100.00	44.59	100.00
65	Concentrate	65.37	<b>65.22</b>	<b>95.24</b>
	Tailings	34.63	6.15	4.76
	Ore matching	100.00	44.77	100.00
78	Concentrate	63.98	<b>66.74</b>	<b>95.04</b>
	Tailings	36.02	6.19	4.96
	Ore matching	100.00	44.93	100.00

Test results indicate that due to magnetite monomer dissociation more fully, so the grade of magnetite concentrate is improved after the increase of fineness, but the amplitude of increase will be decreased after

the fineness of more than -0.074mm 65%; and with the increase of fineness, the recovery will be reduced.

**Table 4.6 Fineness experiment results under the condition of C:S = 3:1**

-0.074mmcontent/ %	Product name	Yield /%	Fe grade /%	Fe recovery /%
45	Concentrate	70.52	<b>63.20</b>	<b>95.71</b>
	Tailings	29.48	6.78	4.29
	Ore matching	100.00	46.57	100.00
<b>62</b>	Concentrate	68.29	<b>65.32</b>	<b>95.49</b>
	Tailings	31.71	6.65	4.51
	Ore matching	100.00	46.72	100.00
74	Concentrate	65.59	<b>67.01</b>	<b>94.69</b>
	Tailings	34.41	7.16	5.31
	Ore matching	100.00	46.42	100.00

Test results indicate that due to magnetite monomer dissociation more fully, so the grade of magnetite concentrate is improved after the increase of fineness, but the amplitude of increase will be decreased after the fineness of more than -0.074mm 62%; and with the increase of fineness, the recovery will be reduced.

Overall, under the condition of sample C accounting for more than 2/3, suitable fineness of beneficiating magnetite is - 0.074 mm accounting for 61% to 65%. With the increase of the proportion of sample S, the requirements of the grinding fineness will be higher.

#### 4.5.2 “one-time roughing, one-time cleaning and one-time scavenging” whole process tests

Experimental studies aiming at ore matching are carried out adopting “one-time roughing, one-time cleaning and one-time scavenging” whole low intense magnetic separation process, test process and results as shown in Figure 4.7 and Table 4.7, respectively.

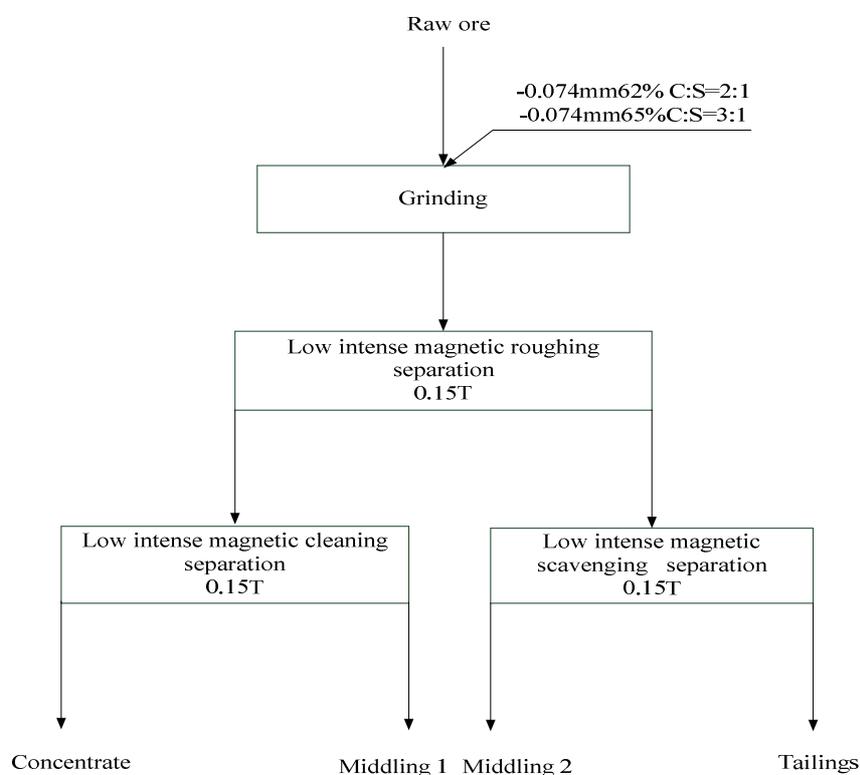


Figure 4.7 Flow chart of “one-time roughing, one-time scavenging and one-time cleaning” whole process test

**Table 4.7 Results of “one-time roughing, one-time cleaning and one-time scavenging” whole process tests**

Proportion of ore matchin	Product name	Yield /%		Fe grade /%		Fe recovery/ %	
		Individual	Accumulation	Individual	Average	Individual	Accumulation

g ( C:S )							
2:1	Concentrate	63.23	65.37	<b>66.21</b>	65.22	<b>93.51</b>	95.23
	Magnetite middling	2.14		35.89		1.72	
	Scavenging middling	1.85		15.16		0.63	
	Low intense magnetic separation tailing	32.78		5.66		4.14	
	Raw ore	100.00		44.77		100.00	
3:1	Magnetite concentrate	66.08	68.29	<b>66.40</b>	65.32	<b>93.92</b>	95.48
	Magnetite middling	2.21		32.98		1.56	
	Scavenging middling	2.05		16.59		0.73	
	Weak magnetic separation tailing	29.66		5.98		3.80	
	Raw ore	100.00		46.72		100.00	

Results show that cleaning effect is not significance that grade only increases by 2.39% and recovery decreases by 1.6% or so. Due to basic and effective recovery of magnetite in roughing, so scavenging yield is only 2% with a grade of only 1% at the recovery of less than 1%, and scavenging significance is not big.

## 4.6 Exploration tests of beneficiating cobalt

The Co content in the ore of 0.031% has reached the standard of industrial grade 0.03% of cobalt deposits, so exploratory experiment research for cobalt is conducted. Test process and results are shown in Figure 4. 8 and Table 4.8, respectively:

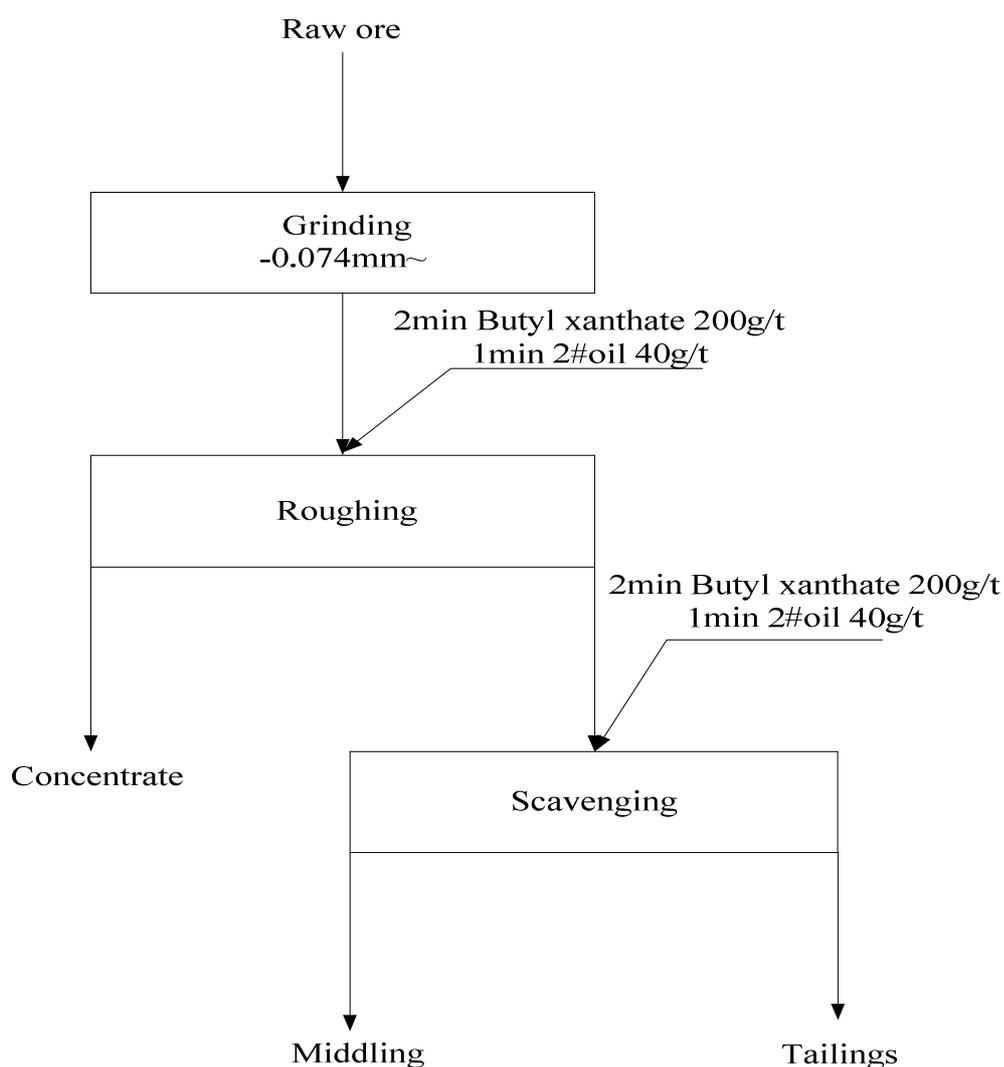


Figure 4.8 Flow chart of fineness test of choosing cobalt

**Table 4.8 Fineness experimental results of choosing cobalt**

Fineness -0.074mm content/%	Product name	Yield /%	Co grade/%	Co recovery/%
61	Concentrate	4.55	<b>0.076</b>	<b>12.04</b>
	Middling	1.55	0.055	2.97

	Tailing	93.90	0.026	84.99
	Raw ore	100.00	0.029	100.00
72	Concentrate	4.90	<b>0.070</b>	<b>11.37</b>
	Middling	1.98	0.033	2.17
	Middling	93.12	0.028	86.46
	Tailing	100.00	0.030	100.00
80	Concentrate	5.18	<b>0.053</b>	<b>9.33</b>
	Middling	2.80	0.033	3.13
	Middling	92.02	0.028	87.53
	Tailing	100.00	0.029	100.00
90	Concentrate	6.41	<b>0.046</b>	<b>10.26</b>
	Middling	3.57	0.041	5.10
	Middling	90.02	0.027	84.64
	Tailing	100.00	0.029	100.00

The results show that with the increase of the fineness, Co grade of the rough concentrate continues to decrease, the overall enrichment ratio is not high and the recovery is low. The recovery of Co should be further studied.

## 5 Multi-element analysis of iron concentrate

Multi-element analysis results of iron concentrate are shown in Table 5:

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

Element	Fe	Cu	Pb	Zn	P	Co	As
Content /%	65.25	<0.005	<0.005	<0.005	<0.005	0.018	0.031
Element	S	Sb	SiO <sub>2</sub>	CaO	MgO	Al <sub>2</sub> O <sub>3</sub>	
Content /%	0.026	<0.005		0.87	3.47	0.059	

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 C65 standards.

## 6 Recommended beneficiation flowsheet for the iron

The beneficiation flowsheet for the iron is recommended as shown in Table 6 :

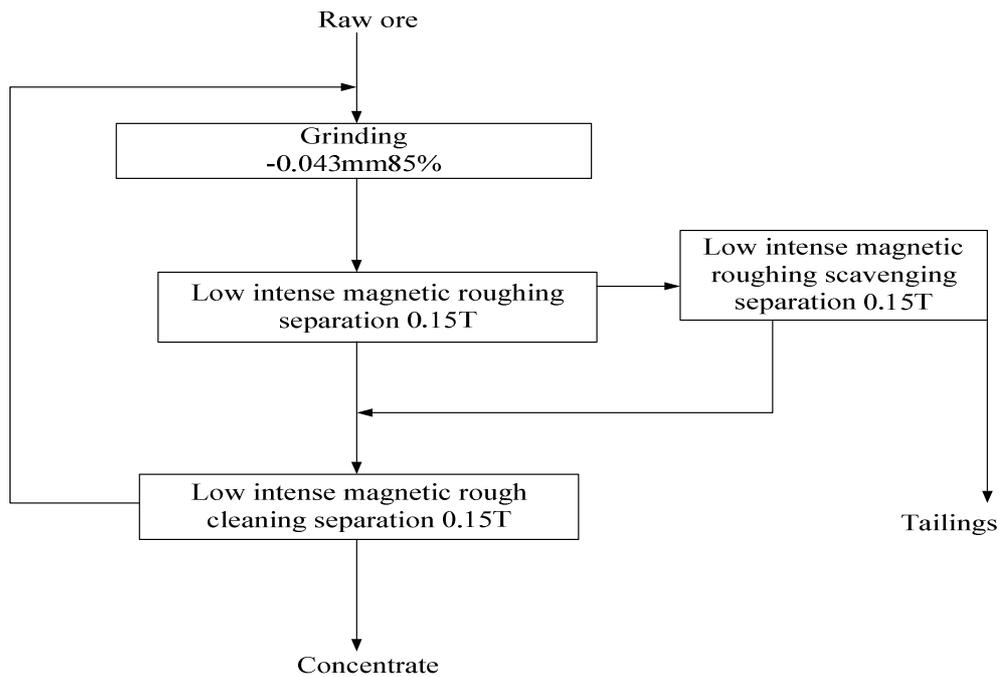


Figure 6 The beneficiation flowsheet for the iron

## 7 Conclusions

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

- ( 1 ) The main valuable element in the ore is Fe and associated valuable elements of Co.
- ( 2 ) Under experimental conditions, beneficiation technical indicators assay 65.25%Fe with an iron concentrate yield of 76.97% at the recovery of 96.73% is obtained by 0.15T low intense magnetic roughing separation. It indicates that the separability of the

resource is good, the grade and recovery of magnetite concentrate obtained are higher.

( 3 ) While under the condition of laboratory, test indexes with higher grade and recovery of magnetite concentrate can be obtained by low intense magnetic roughing separation. 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 weak magnetic separation process is recommended (see Figure 6).

( 4 ) The ore containing 0.031% Co has reached the standard of industrial grade 0.03% of cobalt deposit and has the recovery value; at the same time, the ore containing 0.30% Bi and 0.68g/t Au have the comprehensive recovery value. In order to comprehensive recovery of cobalt, bismuth and gold resources in the ore, suggest that the owner for cobalt, bismuth and gold resources conduct further detailed research.