



COPPER FLOTATION CIRCUIT AUDIT

RAPID ORE CHARACTERIZATION

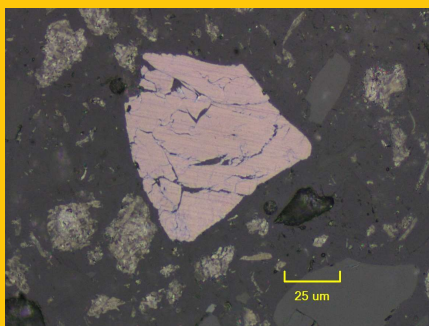
RAPID ORE CHARACTERIZATION

Rapid ore characterization involves the preparation of a single polished section from an "As Received" sample. The polished section is scanned by our TESCAN Integrated Mineral Analyzer (TIMA).

TIMA is a fully automated, analytical scanning electron microscope (SEM) system, similar to a QEMSCAN or MLA.

The rapid ore characterization provides the following information about each sample:

- Mineral Abundance
- Mineral Associations
- Liberation (% surface area)
- Elemental Department
- Grain Size Analysis



Rougher Tails: Coarse-grained, liberated bornite (brown/purple) showing features of alteration in the form of fine-grained veining and fractures.

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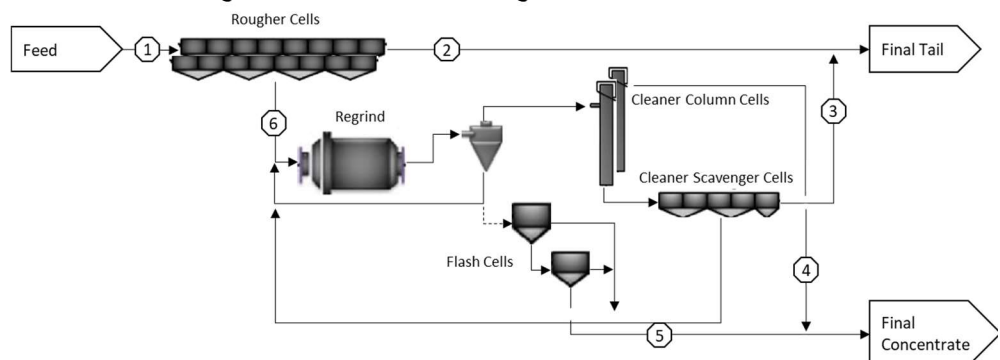
BACKGROUND

Our client experienced a sudden and unexpected decrease in copper recoveries. Initial suspicions were an increase in the proportion of secondary copper minerals or tarnished/oxidized copper species. Insufficient liberation of secondary copper minerals or the presence of swelling clays were also suspected causes.

Recoveries in the cleaner circuit decreased from mid-90s to low 80s and an extremely high frother addition was required in the cleaning circuit to bring recoveries back to expected levels.

Client Samples Submitted

1. Flotation Feed
2. Rougher Tail
3. Scavenger Tail
4. Final Concentrate
5. Flash Concentrate
6. Rougher Concentrate



FINDINGS

The **Flotation Feed** assayed as 0.42% Cu with copper hosted predominantly in liberated bornite (70.5% wt. Cu), and chalcopyrite (25.4% wt. Cu) which had a strong association with silicates and a P_{80} of 80µm. The remainder was primarily hosted in chalcocite/digenite/covellite (3.2%).

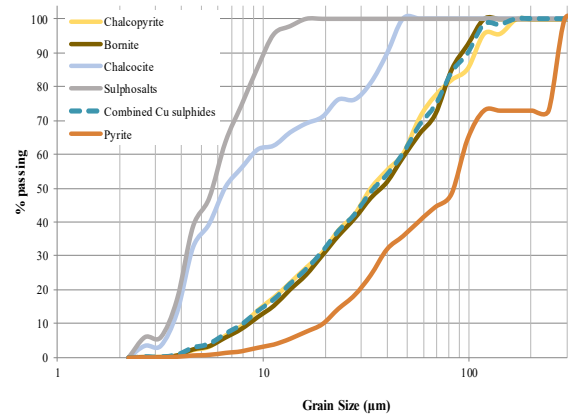
In the **Scavenger Tails** the copper department shifts towards chalcocite (8%) at the expense of bornite (66.5%). Copper sulphides were very fine grained with a P_{80} 20µm with 35%-38% of copper minerals occurring as free particles.

The copper department in the **Rougher Tails** showed a shift towards bornite which was coarser grained and more liberated than chalcopyrite. Approximately 44.7% of the bornite present was liberated with 19.7% occurring as free particles which showed **features of alterations such as veining and (micro-)fractures. These changed surface properties would be expected to have a negative impact on recovery.** The remainder of the bornite was mostly locked in non-opaque gangue (feldspars and pyriboles). These features could only be overcome with addition reagent usage but provided insight for feed planning and forecasting.

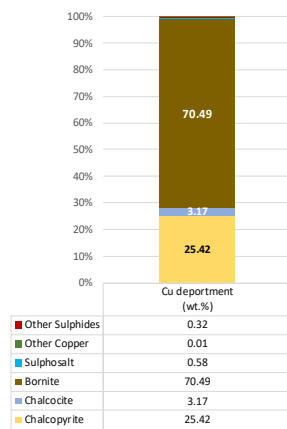
EXAMPLE STREAM REPORT - Flotation Feed

The copper is hosted predominantly in liberated (51.7% lib.) bornite (70.5% of Cu) and liberated (53.1% lib.) chalcocopyrite (25.4% of Cu) with minor amounts occurring as chalcocite/digenite/covellite (3.2% of Cu) which is closely associated with bornite. Trace amounts of sulphosalts (tetrahedrite) were also observed. The major Cu sulphides (bornite and chalcocopyrite) have a P_{80} of 80 μm and are characterized by a strong association with silicates with only 25% of chalcocopyrite and 19.5% of bornite occurring as free particles (including coarser grains with minor alteration). Non-Cu sulphides include chiefly pyrite which is distinctly coarser grained than the Cu sulphides ($P_{80} > 120 \mu\text{m}$) and predominantly liberated (75%), although a strong association with silicates is also observed ($>70\%$ as ternary and complex particles with NOG). The non-opaque gangue (NOG) includes mostly pyroxene and amphibole (pyribole: 39-44%, diopside and actinolite), feldspar (36-42%) and approximately 13.4% of sheet silicates such as chlorite and muscovite/sericite.

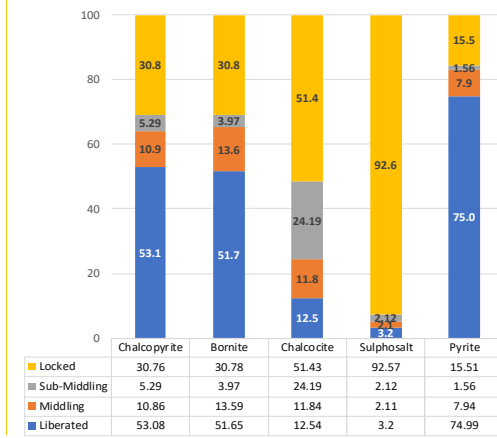
Grain Size Analysis



Cu department (%)

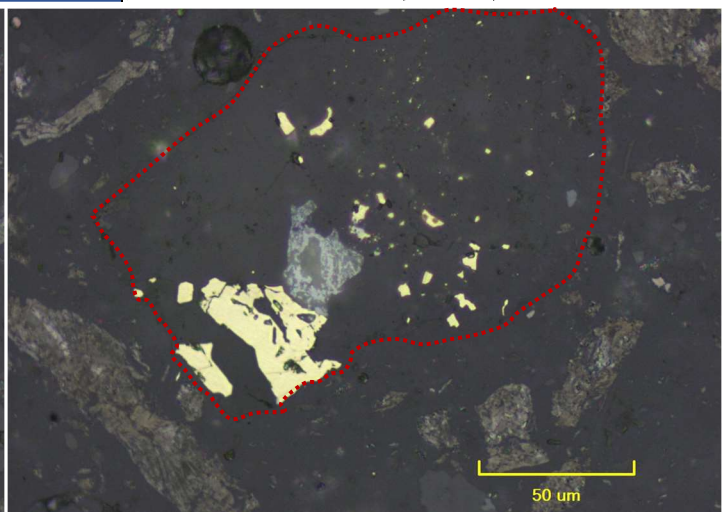
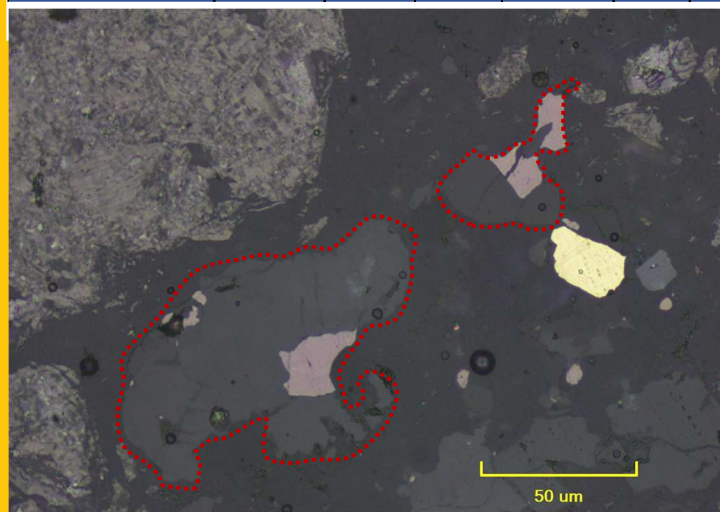


Liberation by % surface area



Modal Abundance	Float Feed		Analyte	Units
	TIMA	SQ-XRD		
Chalcocopyrite	0.39	2.40	Ag	ppm 2.00
Chalcocite	0.04		Cu	% 0.42
Bornite	0.57	0.10	Fe	% 4.60
Sulphosalts	0.03		S	% 0.38
Other Copper	0		Al	% 6.60
Pyrite	0.42	0	As	% <0.005
Other Sulphides	0.02		Ba	% 0.06
Quartz	2.97	3.20	Bi	% <0.005
Plagioclase	39.3		Ca	% 8.65
K-Feldspar	2.79	36.6	Cr	% 0.02
Muscovite	1.92	9.30	K	% 1.70
Biotite	4.29		Mg	% 3.79
Chlorite	0.98	4.10	Mn	% 0.13
Pyribole	39.2	43.5	Mo	% <0.001
		0.70	Na	% 2.35
Garnet	0.43		Ni	% 0
Epidote	0.23		P	% 0.14
Titanite	0.64		Pb	% <0.01
Clay	0.02		Sb	% <0.005
Carbonates	3.02		Sr	% 0.09
Sulphates	0		Ti	% 0.45
Apatite	0.51		Tl	% <0.005
Fe(hydr)Oxide	1.53	0	V	% 0.03
Fe-Ti Oxides	0.23		W	% <0.01
Other minerals	0.43		Zn	% <0.01
Total	100	100		

Association Summary Float Feed		Chalcocopyrite	Chalcocite	Bornite	Sulphosalts	Pyrite	Other Sulphides
Free particles		25.1	10.2	19.5	3.2	8.2	8.1
Binary particles	Chalcocopyrite	0.00	0.10	0.62	0.22	0.82	1.35
	Chalcocite	0.01	0.00	5.95	0.15	0.00	0.00
	Bornite	4.73	19.60	0.00	1.94	0.11	2.23
	Sulphosalts	0.43	0.17	1.61	0.00	0.00	0.00
	Pyrite	0.49	0.19	0.06	0.00	0.00	0.34
	Other Sulphides	0.33	0.00	0.29	0.00	0.00	0.00
	Silicates	11.63	4.51	11.51	3.94	14.25	1.85
	Other minerals	3.25	0.00	0.69	0.19	2.87	0.95
Ternary particles		20.0	22.8	17.9	11.3	25.2	12.4
Complex particles		34.0	42.5	41.9	79.1	48.6	72.8
Total		100	100	100	100	100	100



Photomicrographs (reflected light) showing typical occurrence of locked and exposed Cu sulphides in the Flotation Feed; *left*: NOG-bornite (purple/brown) binary particle (red dashed outlines) together with liberated chalcocopyrite (yellow); *right*: abundant locked chalcocopyrite in ternary NOG particle (red dashed outlines).