

# Report on the Ore Mineralogy of Concentrates from Footwall Zone, Ming Volcanogenic Massive Sulfide (VMS) Deposit, Baie Verte, Newfoundland

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## **Executive Summary**

Concentrate samples from the Ming Mine in the Rambler Camp are dominated by chalcopyrite, pyrite, sphalerite, and pyrrhotite with lesser pyrrhotite, galena, tetrahedrite, boulangerite, arsenopyrite, bornite, covellite, and chalcocite. The main ore minerals, chalcopyrite and sphalerite, are very well liberated (~80%) but do show mineral locking with other phases. Amstutz's (1961) classification for locking has been utilized to describe the locking of mineral phases and both chalcopyrite and sphalerite where locked have predominantly type 1a and 1b locking textures whereby other mineral phases (e.g., pyrite, pyrrhotite) reside upon the edges of the grains, suggesting the potential for further liberation of these locked ore mineral grains. In other cases sphalerite and chalcopyrite have type 1c, 1d, 3a and 3b locking textures with inclusions or complex intergrowths of other phases (e.g., chalcopyrite disease in sphalerite) – in these grains it will likely be harder to liberate the ore minerals. Fortunately, the latter locking textures are not the dominant locked textures in the ores.

## **Introduction, Samples and Methodology**

In this report concentrates from the Ming Mine of the Rambler Mining Camp have been studied to characterize their mineralogy and to decipher their mineral liberation and locking features for various ore-related minerals and elements. Concentrate samples are from the Ming Footwall Zone, a Cu-rich stringer zone and massive sulfide zone in the Ming VMS deposit, upon which original resource calculations for the deposit were undertaken. Concentrate samples were those that were originally processed and tested by Thibault and Associates Inc, New Brunswick, Canada. The concentrate samples include four samples ranging from rough concentrates to final concentrates. Concentrates were mounted in epoxy and polished to form thin sections, which were subsequently studied via reflected light microscopy. Mineral locking textures are classified following the classification of Amstutz (1961) (Fig. 1).

## **Thin Section Results**

The concentrates from the Ming Footwall Zone contain a variety of sulfides and sulfosalt minerals as outlined in Table 1. The dominant phases are chalcopyrite with lesser sphalerite, pyrite, and pyrrhotite, and there are trace phases of other sulfides and sulfosalts (Table 1). Outlined below are brief descriptions and the locking textures present in each concentrate. The minerals present and nature of locking of Cu and Zn in each sample is presented in Table 2.

**Table 1.** Key sulfide minerals present in concentrate samples as deduced from reflected light microscopy.

<b>Predominant Phases</b>	<b>Mineral Abbreviation</b>	<b>Formula</b>	<b>Moderate to Trace Phases</b>	<b>Mineral Abbreviation</b>	<b>Formula</b>
Chalcopyrite	Ccp	CuFeS <sub>2</sub>	Arsenopyrite	Asp	FeAsS
Pyrite	Py	FeS <sub>2</sub>	Bornite	Brn	Cu <sub>5</sub> FeS <sub>4</sub>
Pyrrhotite	Po	Fe <sub>1-x</sub> S	Boulangerite	Boul	Pb <sub>5</sub> Sb <sub>4</sub> S <sub>11</sub>
Sphalerite	Sp	ZnS	Chalcocite	Cc	Cu <sub>2</sub> S
			Covellite	Cov	CuS
			Galena	Gn	PbS
			Tetrahedrite	Tet	(Cu,Fe) <sub>12</sub> Sb <sub>4</sub> S <sub>13</sub>

All phases are listed in alphabetical order not in order of abundance

### **Sample: 6409-001**

**Description:** *Lock Cycle No. 8 Final Concentrate (LC8-CI2C)*

**Minerals:** Ccp>Py>>Sp>Tet>Gn>Boul

#### **Description:**

This sample is very fine-grained and many grains are difficult to decipher due to grain size (Fig. 2). The concentrate is dominated by chalcopyrite and lesser pyrite along with tetrahedrite, galena and boulangerite (Fig. 2). Chalcopyrite is well liberated and most is free with type 1a and 1b locking textures with pyrite and sphalerite (Fig. 2). Sphalerite also shows good liberation occurring as individual grains and as type 1a and 1b intergrowths with pyrite and chalcopyrite (Fig. 2). This sample contains minor grains of boulangerite and tetrahedrite, as well, and both of these phases are well liberated (Fig. 4).

### **Sample: 6409-002**

**Description:** *Ore Variability Test A Rougher Concentrate (R-V-A-RC).*

**Minerals:** Ccp>Py>Po≈Sp

#### **Description:**

This concentrate is dominated by angular to subrounded shards of well-liberated chalcopyrite with lesser pyrite, pyrrhotite, and sphalerite (Fig. 3). Most chalcopyrite is not locked, but when locked forms predominantly type 1a and 1b textures with pyrite and sphalerite (Fig. 3). Chalcopyrite and pyrite also have type 1c-d and 3a-b locking textures

as well, however, these are a relatively rare (Fig. 3). Sphalerite is well liberated and occurs on its own or with as type 1a-b locked grains with chalcopyrite and pyrite (Fig. 3). Sphalerite does, however, have chalcopyrite inclusions with chalcopyrite grains trapped within the sphalerite (e.g., type 1c-d locking)(Fig. 3). Pyrrhotite is present in this sample as well liberated grains but has some chalcopyrite and pyrite along its edges with type 1a-b locking.

### **Sample: 6408-003**

**Description:** *Ore Variability Test B Rougher Concentrate (R-V-B-RC)*

**Minerals:** Ccp≈Py>Po≈Sp>Cc>Brn

#### **Description:**

This sample consists of chalcopyrite and pyrite-dominated rough concentrate and contains well-liberated grains of chalcopyrite (~70-80% unlocked) and pyrite (70-80% unlocked) (Fig. 4). Chalcopyrite occurs as angular shards to subrounded grains that are well-liberated and dominated by type 1a and 1b locking textures with pyrite and to a lesser extent sphalerite and pyrrhotite (Fig. 4). There are some type 1c-d-type textures with intergrowths of pyrrhotite-pyrite-sphalerite-chalcopyrite where all phases are locked together (Fig. 4). Pyrite has some type 1c and 1d locking textures with chalcopyrite (Fig. 4). Abundant pyrrhotite as free grains but some have type 1b and 1c locking textures with chalcopyrite and pyrite (Fig. 4). Bornite and chalcocite are present as rare grains in the concentrate, but occur together with bluish chalcocite having wormy dendritic grains of bornite within it (Fig. 4)

### **Sample: Scoping Test 10-minute Rougher Concentrate (Rmbr-90(2)RC1)**

**Description:** *Scoping Test 10-Minute Rougher Concentrate (Rmbr-90(2)RC1)*

**Minerals:** Ccp>>Py≈Sp>Po>Tet≈Boul≈Gn≈Asp>Cov

#### **Description:**

This sample consists of coarse concentrate that is dominated by chalcopyrite with abundant angular shards to subhedral grains (Fig. 5). Chalcopyrite occurs primarily on its own and is relatively well liberated (e.g., 70-80%) and not significantly locked with other phases (Fig. 5). Where locked it shows type 1a and 1b textures with sphalerite and pyrite and minor 1d textures with inclusions of chalcopyrite within sphalerite and pyrite (Fig. 5). Pyrite show similar type 1a and 1b intergrowth textures with chalcopyrite and sphalerite and lesser 1c and 1d types. The sample also contains minor grains of pyrrhotite, tetrahedrite, covellite and boulangerite. Tetrahedrite is intergrown with sphalerite or on its own (Fig. 5). Boulangerite is found trapped as 1c-1d-type grains as inclusions in pyrite (Fig. 5). Covellite is relatively rare but found as solitary liberated grains (Fig. 5). Arsenopyrite is rare but occurs as inclusions, where present, in chalcopyrite or as diamonds that are liberated (Fig. 5). Like the chalcopyrite, sphalerite in

this sample is well liberated and shows predominantly 1a and 1b textures with other phases.

**Table 2.** Minerals present and nature of locking in concentrate samples.

Sample	Description	Asp	Boul	Brn	Ccp	Cc	Cov	Gn	Py	Po	Sp	Tet	Cu locking	Zn locking
6409-001	Lock cycle No. 8 final concentrate (LC8-C12C)												Mostly free. Type 1a and 1b with Sp, Py	Mostly free. Type 1a and 1b with Ccp, Py
	Ore Variability Test A Rougher Concentrate (R--A-RC)		X		X X			X	X X	X X	X		Mostly free. Type 1a and 1b locking with Sp, Py, Po and lesser other types.	Mostly free. Type 1a and 1b locking with Ccp, Py, Po. Some Ccp disease with 1c-1d locking.
6409-002	Ore Variability Test B Rougher Concentrate (R-V-B-RC)			X	X X	X			X	X	X		Mostly free. Type 1a and 1b>other types - with Sp, Py, Po	Mostly free. Type 1a and 1b>other types - with Ccp, Py
	Scoping Test 10-minute Rougher Concentrate (RMBR-90(2)RC1)	X	X		X		X	X	X	X	X	X	Mostly free. Type 1a and 1b>other types - with Sp, Py, +/- Tet	Mostly free. Type 1a and 1b>other types - with Ccp, Py, +/- Tet
6409-003														
6409-004														

### Concentrate Mineralogy: Summary

The concentrates, both rough and fine, are dominated by well-liberated chalcopyrite and sphalerite with lesser amounts of pyrrhotite, pyrite, arsenopyrite, tetrahedrite, galena, boulangerite, bornite, chalcocite, and covellite (Table 1). Furthermore, when chalcopyrite is locked with other phases it has a type 1a to 1b locking texture, a texture suggests that chalcopyrite should be further liberated (Fig. 6). Sphalerite exhibits similar textures and locking relationships.

### Recommendations

While original petrographic work does provide insight into the locking and nature of liberation of different phases, it would be highly recommended to undertake a concentrate imaging study using scanning electron microscopy (SEM). In addition, mineral liberation analysis of SEM data could be utilized to provide outstanding images

of locking of mineral phases and quantify the phases liberated and the abundance of liberated mineral phases. This could also provide insight into the potential distribution of trace phases, such as Au and electrum, and where they reside in these concentrates. In addition, it is suggested that the compositions of ore minerals be quantified to understand major and trace element distributions in ore phases to understand both the compositions of said phases but also potential deleterious elements that may be present in concentrates. Use of SEM-MLA and probe for metallurgical concentrates is standard practice in industry and would be advisable in the longer term. Such work could be undertaken either at commercial facilities or at a university facility (e.g., Inco Innovation Centre, Memorial University).

## Summary

Concentrate samples from the Ming Mine in the Rambler Camp are dominated by chalcopyrite, pyrite, sphalerite, and pyrrhotite with lesser pyrrhotite, galena, tetrahedrite, boulangerite, arsenopyrite, bornite, covellite, and chalcocite. The main ore minerals, chalcopyrite and sphalerite, are very well liberated (~80%) but do show mineral locking with other phases. Amstutz's (1961) classification for locking has been utilized to describe the locking of mineral phases and both chalcopyrite and sphalerite where locked have predominantly type 1a and 1b locking textures whereby other mineral phases (e.g., pyrite, pyrrhotite) reside upon the edges of the grains, suggesting the potential for further liberation of these locked ore mineral grains. In other cases sphalerite and chalcopyrite have type 1c, 1d, 3a and 3b locking textures with inclusions or complex intergrowths of other phases (e.g., chalcopyrite disease in sphalerite) – in these grains it will likely be harder to liberate the ore minerals. Fortunately, the latter locking textures are not the dominant locked textures in the ores.

## References

- Amstutz, G. C., 1961, Microscopy applied to mineral dressing: Quarterly Review of the Colorado School of Mines, v. 56, p. 443-484.
- Craig, J. R., and Vaughan, D. J., 1994, Ore Microscopy and Ore Petrography, Second Edition: New York, John Wiley and Sons, Inc.

## **Important Notice**

The quality of information, conclusions, and estimates contained herein is consistent with the level of effort involved in Stephen J. Piercey Geological Consulting's services, based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions, and qualifications set forth in this report. The results and opinions expressed in this report are based on Stephen J. Piercey Geological Consulting's interpretation of technical data cited in this report. While Stephen J. Piercey Geological Consulting has carefully reviewed all of the information provided by Rambler Metals and Mining Ltd., and believes the information to be reliable, Stephen J. Piercey Geological Consulting has not conducted an in-depth independent investigation to verify its accuracy and completeness.

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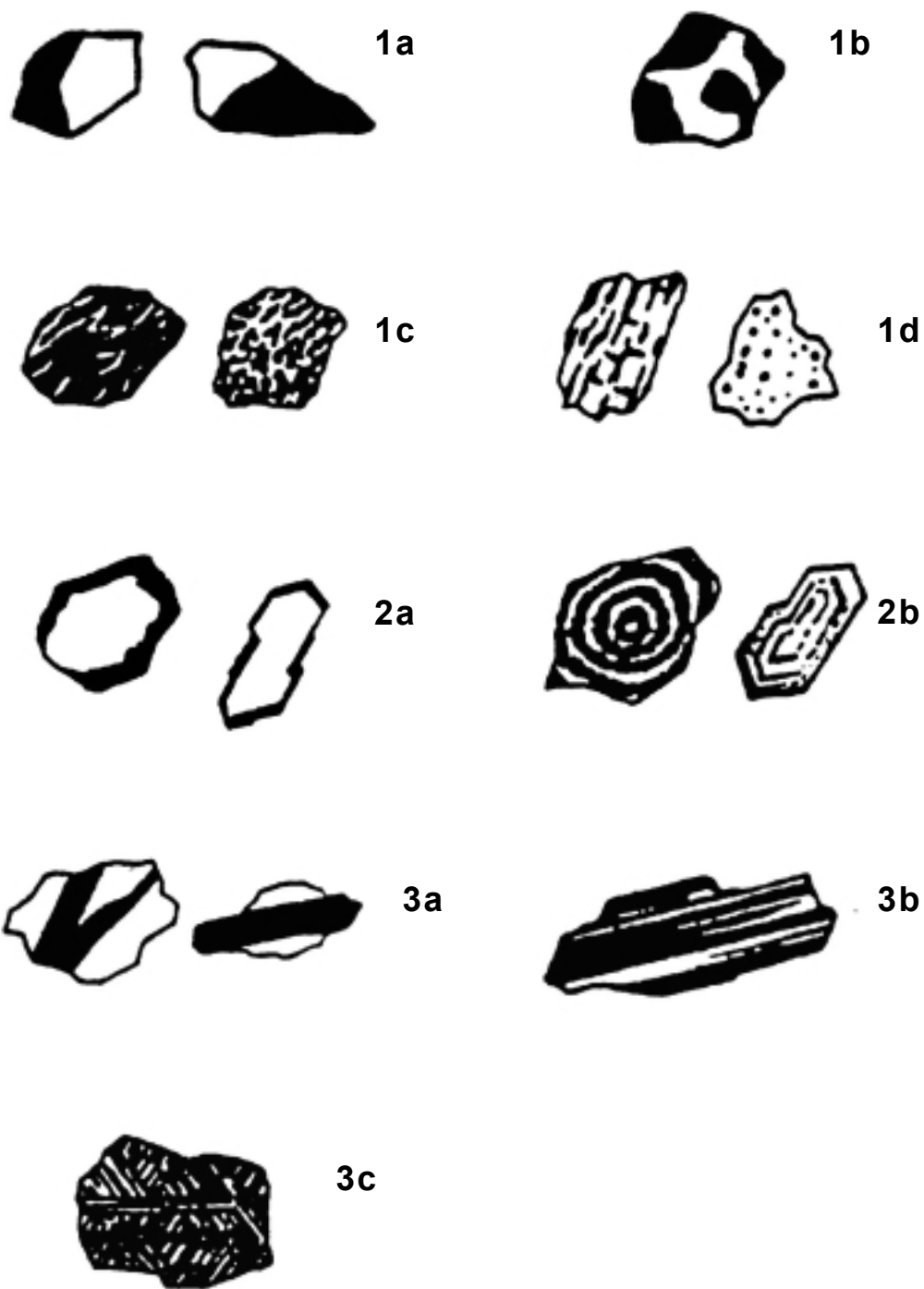


Figure 1. Geometric classification of mineral locking from Amstutz (1961).

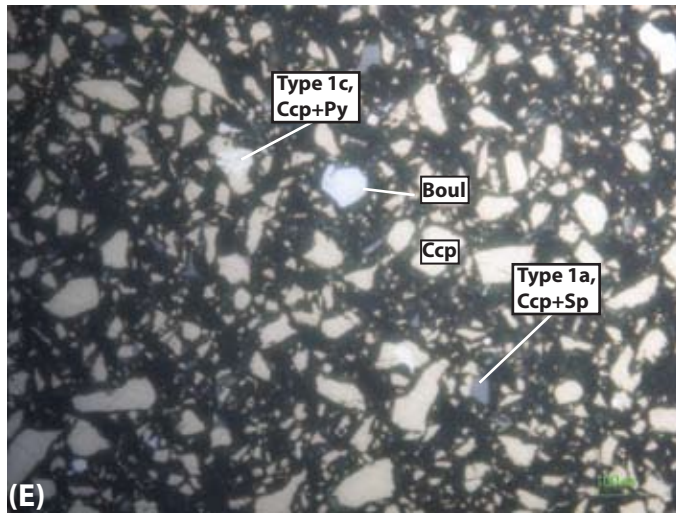
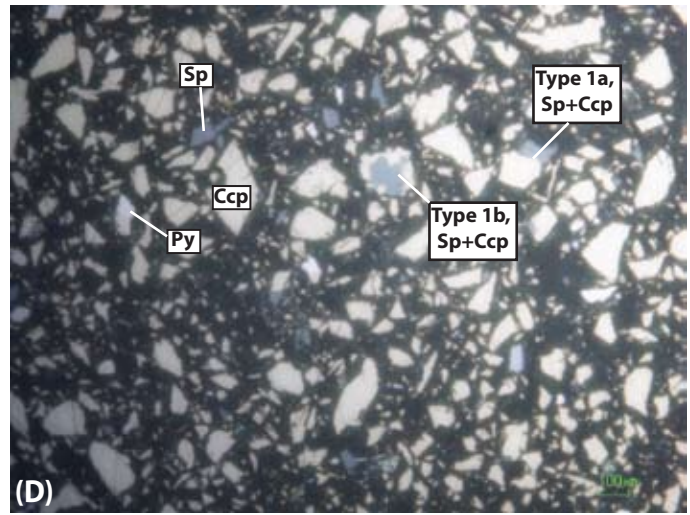
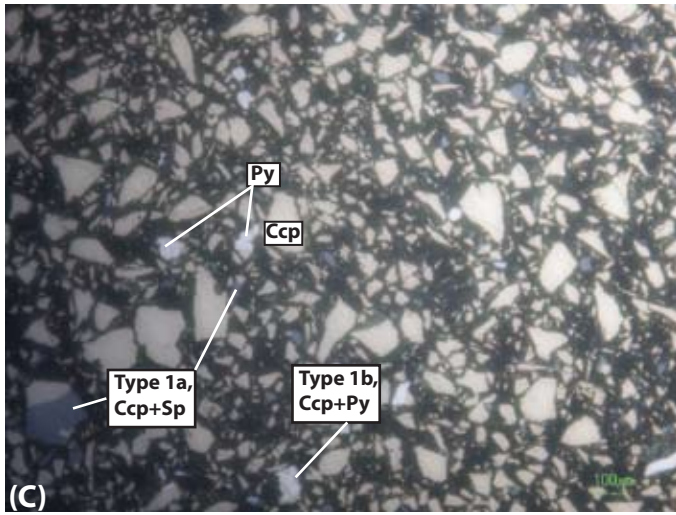
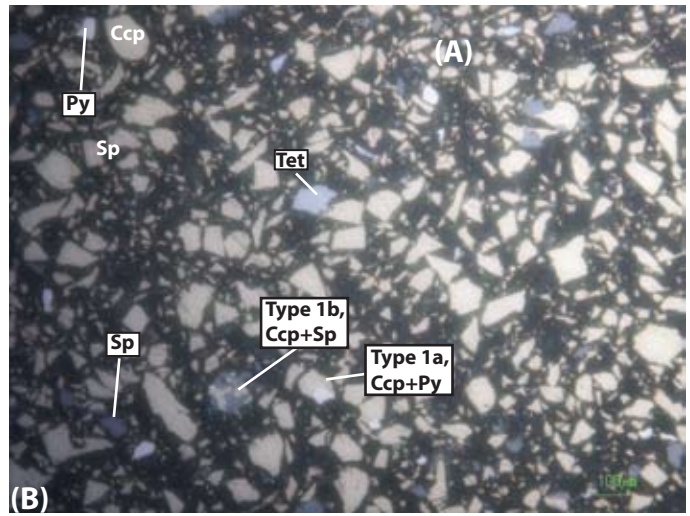
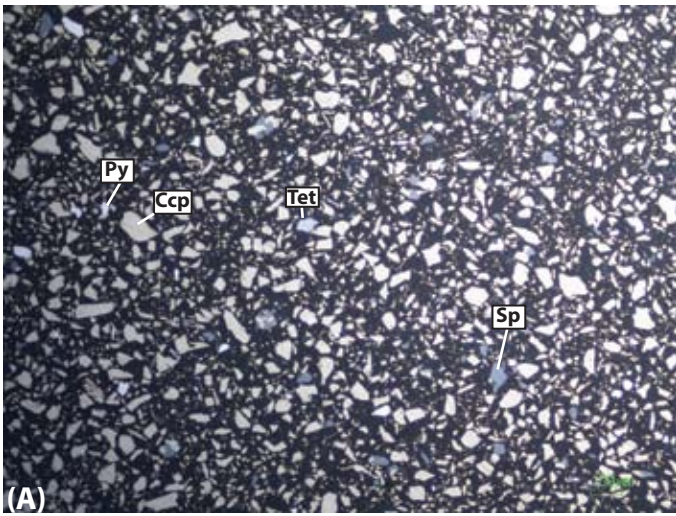


Figure 2. Concentrate 6409-001 (fine concentrate). A) distal shot of fine concentrates with abundant chalcopyrite and lesser pyrite, sphalerite, tetrahedrite, and galena. B) Close up of (A) with chalcopyrite-rich concentrate with lesser sphalerite, pyrite, and tetrahedrite. C, D) Chalcopyrite-rich concentrate with sphalerite and pyrite. E) Chalcopyrite-rich concentrate with boulangerite crystal. Note that the bulk of the chalcopyrite are well liberated and not locked up with other phases.

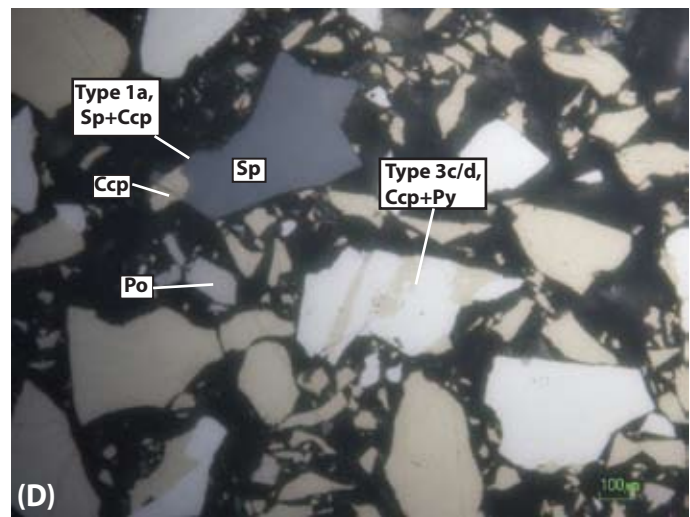
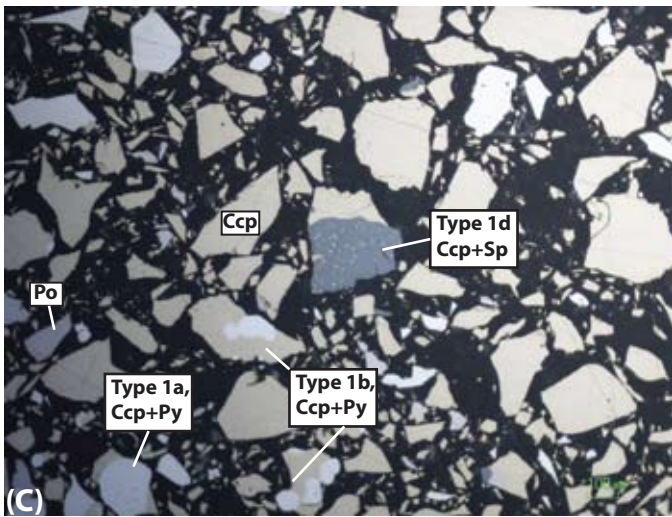
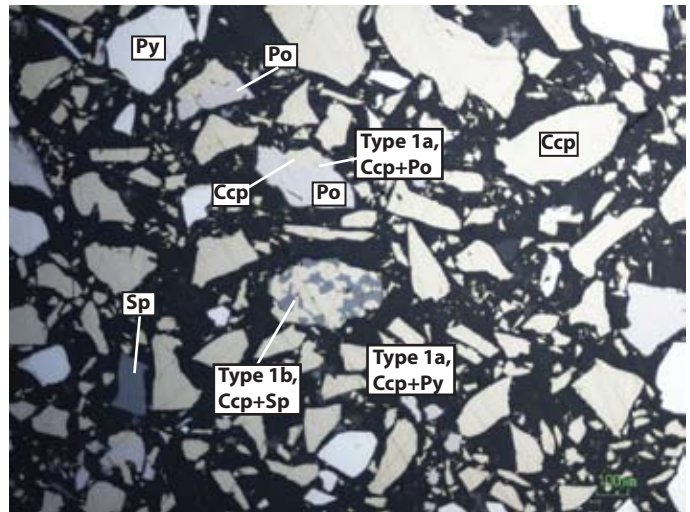
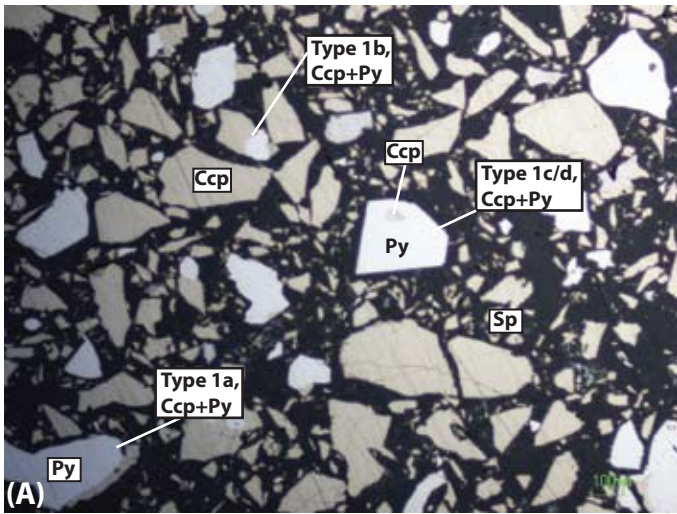


Figure 3. Concentrate 6409-002 (rough concentrate A). Various photos of Cu-rich concentrate and locking types. Notably most chalcopyrite is well liberated with dominantly type 1a and 1b locking textures.

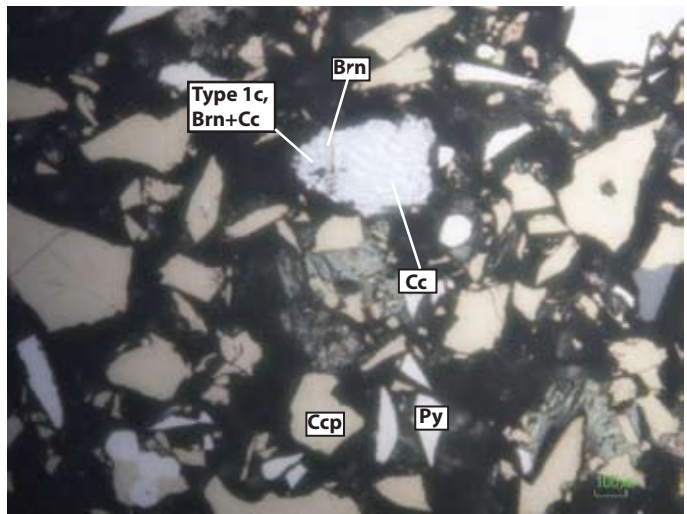
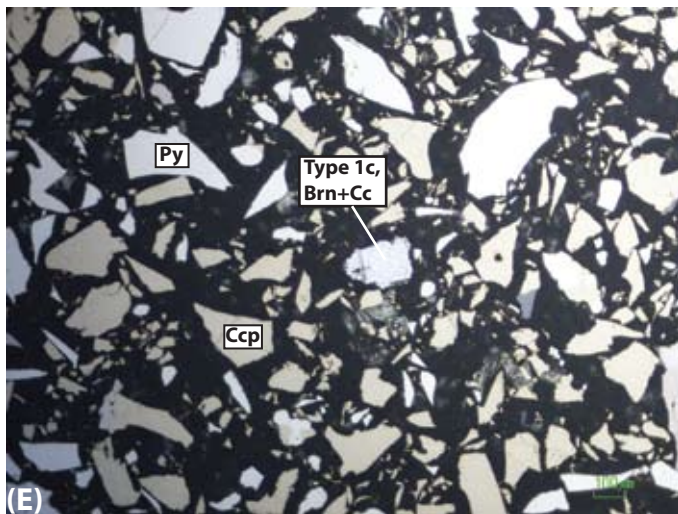
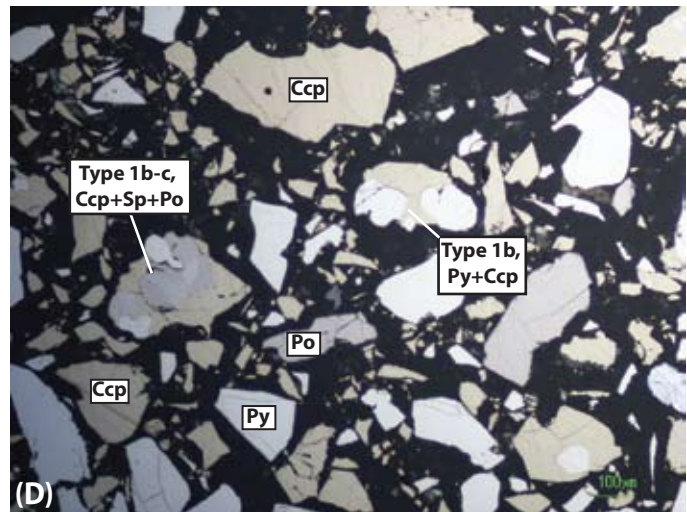
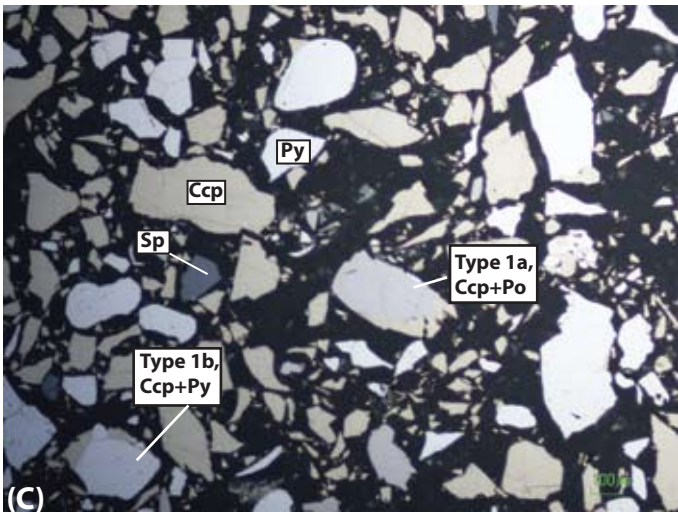
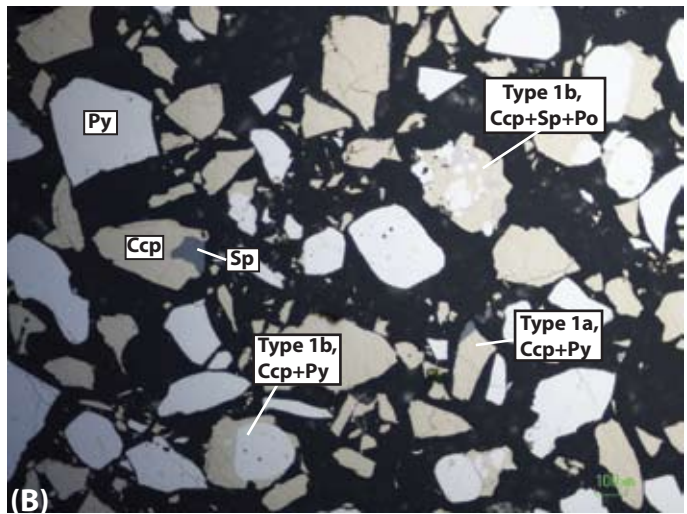
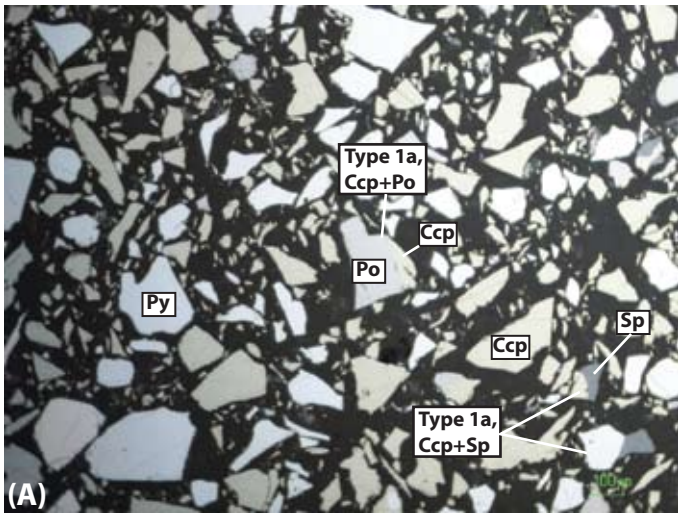


Figure 4. Concentrate 6409-003 (rough concentrate B). A, B, C, D) Chalcopyrite-rich concentrates with well liberated chalcopyrite with lesser pyrite, sphalerite, and pyrrhotite. E) similar material with chalcocite-bornite intergrowth with type 1c locking. F) close up of (E).

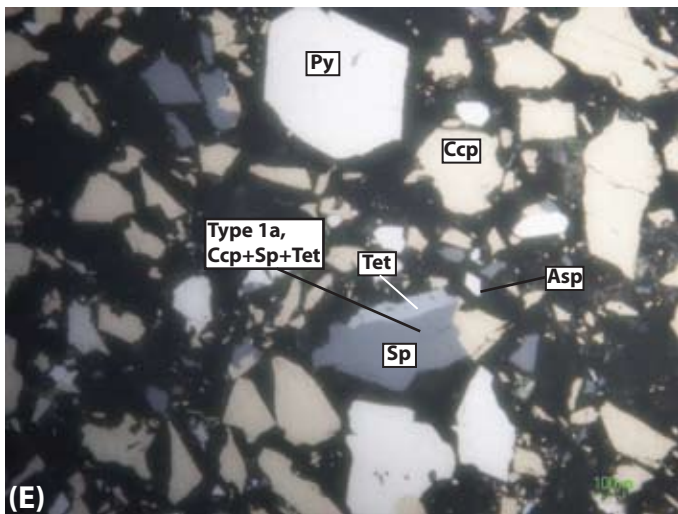
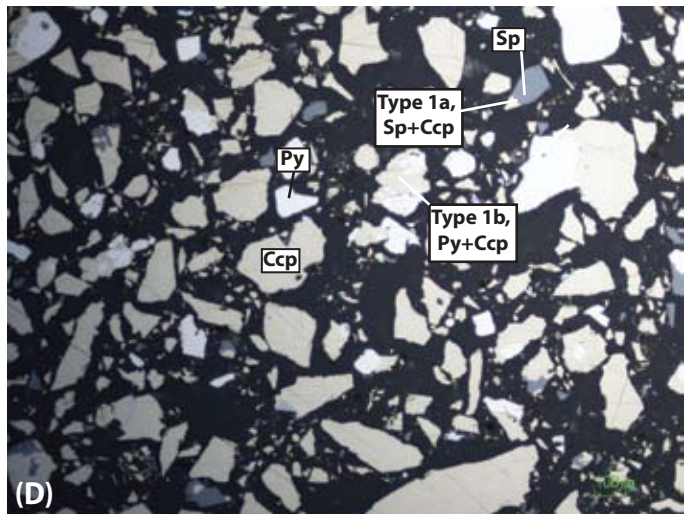
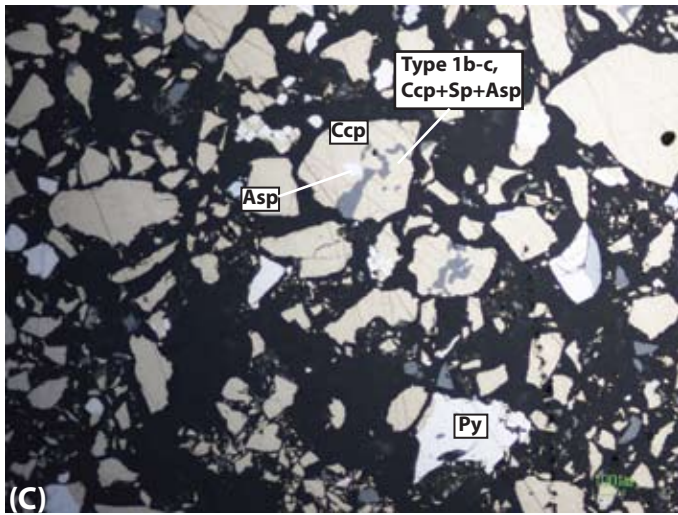
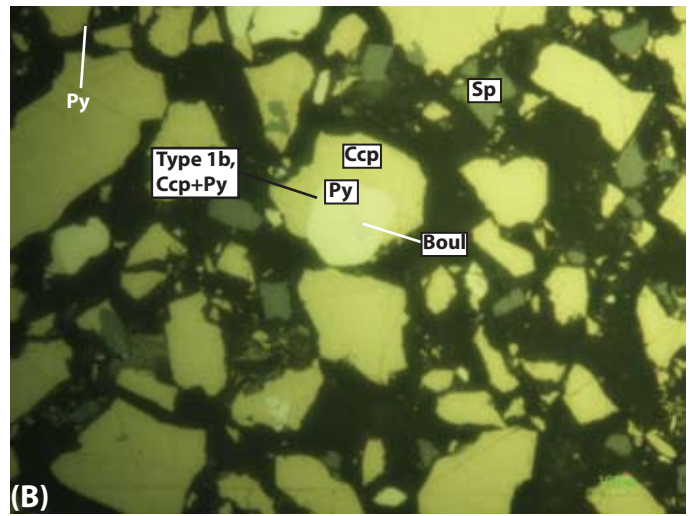
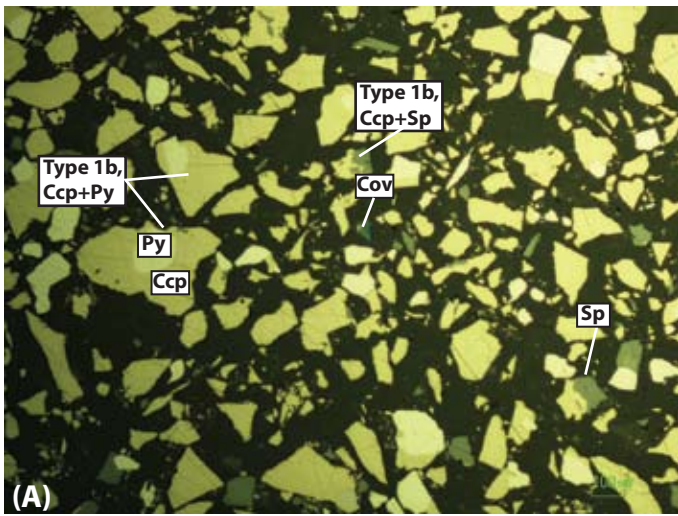


Figure 5. Concentrate 6409-004 (scoping test, rough concentrate). Chalcopyrite-rich concentrates with variable amounts of pyrite, sphalerite and other phases with variable locking textures.





Texture and Nature of Interlocking	Diagram	Liberation Properties in Relatively Large Particles, Examples of Ores
Equigranular. Straight, rectilinear, cusped margins. Simple locking.		Fairly easy liberation. Common occurrence especially in orthomagmatic and highly metamorphosed and recrystallized ores. Also in ores showing successive depositional sequence.
Mutually curving boundaries with negligible interpenetration. Simple locking.		Fairly easy liberation. Common occurrence in simultaneously crystallized ores where interfacial free energies are similar.
Mottled, spotty, careous, with partial penetration. Relatively simple locking.		Fairly easy liberation. Common occurrence in ores where interreplacement processes have been active.
Graphic, myrmekitic, visceral locking. Deep micropenetration.		Complete liberation difficult or impossible. Not common as a major texture in ores. Produced by exsolution and replacement. Examples: galena/sphalerite and chalcocite/bornite.

FIGURE 11.3 Geometric classification of ore mineral textures and their liberation characteristics.


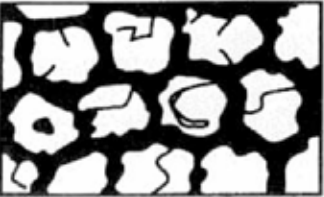


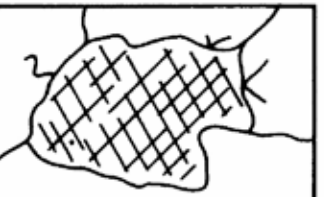
Texture and Nature of Interlocking	Diagram	Liberation Properties in Relatively Large Particles, Examples of Ores
Disseminated, droplike, emulsion, eutectoidal locking. Finely dispersed phases.		Complete liberation difficult or impossible; chemical treatment often required. Common occurrence by exsolution (left) Au/arsenopyrite chalcopyrite/sphalerite; by replacement (right) pyrite/sphalerite.
Intergranular rim; coating mantled, enveloped, atoll-like locking.		Liberation may be difficult if free grain is continuously enveloped by layer. Not uncommon; often formed by replacement reaction. Examples: hematite film on gold; chalcocite or covellite on pyrite, galena, or sphalerite.
Concentric, spherulitic, scalloped, colloform-layered locking.		Liberation fairly difficult or difficult; common occurrence in Fe, Mn, and Al ores. Also U (pitchblende) intergrained with sulfide. Usually associated with colloidal precipitation.
Planar, lamellar, sandwich-type locking. Lamellae may vary in size.		Liberation fairly easy to variable. Produced by exsolution (examples: cubanite/chalcopyrite, ilmenite/magnetite). Also by replacement. Examples: magnetite and hematite.
Reticulate (net-like) boxwork. Finely interpenetrating locking.		Liberation variable to difficult. Common occurrence by replacement. Examples: bornite/chalcopyrite, anglesite/covellite/galena. Also by exsolution. Examples: hematite/ilmenite/magnetite.

FIGURE 11.3 (Continued)

Figure 6. Textures of minerals and concentrates and the relative ease of liberation. Notably, most textures in the concentrates suggest that Cu should be liberated. From Craig and Vaughan (1994).