HELFORD GEOSCIENCE LLP

Consultant Geoscientists

Report HG-15-25a

QEMSCAN® mineralogy study – Beskauga Cu-Au study

Wardell Armstrong International

Ben Simpson

Report by: Holly Campbell

Checked by: Dr Duncan Pirrie

Date: 21/05/2015

For and on behalf of:
Helford Geoscience LLP
Trelowarren Mill Barn
Mawgan
Helston
Cornwall TR12 6AE

Telephone: 01326 221407 / 07557 537364

Summary

1.0 Four fractions labelled Starter Pit Comp +106 µm, Starter Pit Comp -106/+53 µm, Starter Pit Comp -53/+20 µm and Starter Pit Comp -20 µm from the Beskauga deposit were submitted by Wardell Armstrong International Ltd to Helford Geoscience LLP for mineralogical analysis using QEMSCAN® automated SEM-EDS analysis.

2.0 The samples were prepared and analysed at the University of Exeter QEMSCAN® facility. PMA mode was used with a beam stepping interval optimised to the size fraction being measured. Analytical results which are reported for chalcopyrite, bornite, chalcocite and Cu arsenides include modal mineralogy, Cu deportment, mineral liberation data, mineral association data and theoretical grade recovery curves. The data for gold minerals is not reported as Au minerals were only present at low trace levels in one fraction.

3.0 Ore/sulphide phases are gold minerals, chalcopyrite, bornite, chalcocite, Cu arsenides and pyrite. Gangue phases are quartz, muscovite, K-feldspar, plagioclase, ankerite, chlorite, Fe-Ox(Mn)/CO_3, biotite, kaolinite, barite, ilmenite, rutile, apatite, zircon and 'others'. Maximum values for the QEMSCAN® assay data are Cu 0.78% in the -20/+2 µm fraction and Au 0.01% in the -106/+53 µm fraction.

3.0 Liberation characteristics showed that liberation of chalcopyrite, chalcocite and Cu arsenides was best in the -20/+2 µm fraction, values for bornite show that liberation was best in the -106/+53 µm fraction.

4.0 Chalcopyrite, bornite, chalcocite and Cu arsenides are all dominantly associated with background and other ore/sulphide minerals plus a range of gangue minerals.

5.0 TGRC data showed that for recovery of 80% the grade is best in the -20/+2 µm fraction where it is ~97% for chalcopyrite, ~53% for bornite and ~95% for Cu arsenides. For chalcocite the grade was best in the -106/+53 µm fraction where it was ~93%.

Contents Page

1. Introduction

1.1 Samples submitted for analysis

One sample subdivided into four size fractions and labelled as Starter Pit Comp +106 µm, Starter Pit Comp -106/+53 µm, Starter Pit Comp -53/+20 µm and Starter Pit Comp -20/+2 µm from the Beskauga deposit were submitted by Wardell Armstrong International to Helford Geoscience LLP for QEMSCAN® analysis in order to determine their mineralogy, mineral association and liberation characteristics, mineral deportment and theoretical grade recovery curve data (Table 1).

Sample/Fraction	**QEMSCAN Laboratory Code**
Starter Pit Comp +106 µm	15HGD1
Starter Pit Comp -106/+53 µm	15HGD2
Starter Pit Comp -53/+20 µm	15HGD3
Starter Pit Comp -20/+2 µm	15HGD4

Table 1. Summary of samples submitted for mineralogical analysis.

The samples were prepared for analysis by Holly Campbell (Helford Geoscience LLP) and were analysed at the University of Exeter, Cornwall Campus, QEMSCAN® facility. The finalised data set is presented within report HG-15-25a; the data are also presented in excel file HG-15-25b. QEMSCAN® particle images are provided in powerpoint file HG-15-25c and also summarised in Appendix 2. Background information on the use of QEMSCAN® in this study and descriptions of analysis modes is provided in Appendix 1.

2. Sample preparation and analysis

2.1 Sample preparation

Approximately 1.0 g of a representative aliquot of each fraction was weighed out and placed into sample vials. The fractions were mixed with an appropriate grain size of graphite powder and then prepared as standard 30 mm diameter polished blocks. Initially the fractions were mixed with epoxy resin and allowed to de-gas overnight before being back-filled with araldite resin and cured at 50ºC. The fractions were then polished and carbon coated prior to analysis.

2.2 Sample analysis

The fractions were measured using the particle mineral analysis (PMA) measurement mode with a beam stepping interval optimised to the size fraction being analysed; the number of X-Ray analysis points and particles measured for each fraction is shown in Table 2.

Sample/Fraction	**Lab. Code**	**Beam interval µm**	**No. Particles**	**No. X Rays**
Starter Pit Comp +106 µm	15HGD1	6	6004	2209454
Starter Pit Comp -106/+53 µm	15HGD2	4	6671	1298955
Starter Pit Comp -53/+20 µm	15HGD3	2	6502	823273
Starter Pit Comp -20/+2 µm	15HGD4	1	5925	186654

Table 2. Summary of the number of particles analysed.

The QEMSCAN® mineral list used to process the data in this study is shown in Table 3. A description of QEMSCAN® processing parameters is contained in Appendix 1; note that where there are minerals with overlapping or very similar chemistries then they cannot always be discriminated.

Mineral Category	Mineral Description
Gold minerals	Any phase with Au.
Chalcopyrite	Chalcopyrite (Fe-Cu-S).
Bornite	Bornite (Cu-Fe-S).
Chalcocite	Any phase with Cu,S (chalcocite). May include trace covellite.
Cu Arsenides	Any phase with Cu,As,S (enargite) and As,Cu,Fe,S (tennantite).
Pyrite	Pyrite/marcasite, minor jarosite, trace pyrrhotite.
Barite	Any phase with Ba,S,O.
Ilmenite	Any phase with Fe,Ti,O.
Rutile	Any phase with Ti,O such as rutile, brookite and anatase.
Fe-Ox(Mn)/CO3	Fe oxides such as siderite, goethite, hematite, magnetite.
Quartz	Quartz and other silica minerals.
K-Feldspar	Any phase with K,Al,Si,O, includes orthoclase/microcline/sanidine.
Plagioclase feldspar	Plagioclase feldspars: phases with Na,Al,Si,O to Ca,Al,Si,O.
Biotite	Any phase with Fe,Al,K,Mg,Si,O.
Muscovite	Muscovite.
Chlorite	Includes chlorite and any phase with Fe-Al-Si (with or without Mg). May include trace tourmaline.
Kaolinite	Any phase with Al,Si,O. Includes kaolinite/halloysite/dickite.
Ankerite	Any phase with Ca,Fe,Mg,O,C.
Apatite	Any phase with Ca,P,O.
Zircon	Any phase with Zr, Si and O.
Others	Any other mineral not included above. Trace Al metal/Ox, arsenopyrite, monazite, xenotime, sphalerite, molybdenite.

Table 3. Summary of mineral categories used to process the QEMSCAN® data.

Results described for this study include modal mineralogy, mineral associations, mineral liberation data and mineral deportment and individual QEMSCAN® particle maps.

3. Results

Quantitative modal mineralogy data expressed as mineral mass % are presented in excel file HG-15-25b. Summary QEMSCAN® images are presented in Appendix 2; QEMSCAN® particle images are presented in powerpoint file HG-15-25c. Major phases are those forming >10% of the sample; minor phases are 1-10% of the sample and trace phases are <1% of the sample; the data are described on a per sample basis and as a combined dataset. QEMSCAN® assay data for Cu and Au are also indicated. It should be noted that the QEMSCAN® assay is calculated on the basis of the measured mineral abundance and an assumed mineral chemistry (normally the standard ideal formulae for each mineral), and as such is indicative only.

3.1 Modal mineralogy.

Ore/sulphide phases in the +106 µm fraction are minor pyrite (1.14%) and trace chalcopyrite (0.35%), Cu arsenides (0.20%), bornite (0.03%) and chalcocite (0.02%) (Table 4, Figure 1). Gangue phases in this sample are major quartz and muscovite along with minor K-feldspar, plagioclase feldspar, ankerite, FeOx(Mn)/CO_3, chlorite and biotite and trace barite, ilmenite, rutile, kaolinite, apatite, zircon and "others" (Table 4, Figure 2). The calculated QEMSCAN® assay values are: Cu 0.23% and Au 0.00%.

Ore/sulphide phases in the -106/+53 µm fraction are minor pyrite (1.08%) and trace chalcopyrite (0.32%), Cu arsenides (0.17%), chalcocite (0.16%), bornite (0.06%) and gold minerals (0.01%) (Table 4, Figure 1). Gangue phases in this sample are major quartz and muscovite along with minor ankerite, plagioclase feldspar, K-feldspar, FeOx(Mn)/CO_3, chlorite, biotite and kaolinite and trace barite, ilmenite, rutile, apatite, zircon and "others" (Table 4, Figure 2). The calculated QEMSCAN® assay values are: Cu 0.34% and Au 0.01%.

Ore/sulphide phases in the -53/+20 µm fraction are minor pyrite (1.46%) and trace chalcopyrite (0.49%), Cu arsenides (0.49%), bornite (0.09%) and chalcocite (0.01%) (Table 4, Figure 1). Gangue phases in this sample are major quartz and muscovite along with minor ankerite, plagioclase feldspar, K-feldspar, FeOx(Mn)/CO_3, chlorite, biotite and kaolinite and trace barite, ilmenite, rutile, apatite, zircon and "others" (Table 4, Figure 2). The calculated QEMSCAN® assay values are: Cu 0.46% and Au 0.00%.

Ore/sulphide phases in the -20/+2 µm fraction are trace chalcopyrite (0.89%), Cu arsenides (0.82%), pyrite (0.63%), bornite (0.08%) and chalcocite (0.08%) (Table 4,

Figure 1). Gangue phases in this sample are major quartz and muscovite along with minor plagioclase feldspar, ankerite, FeOx(Mn)/CO_3, K-feldspar, chlorite, kaolinite and biotite and trace barite, ilmenite, rutile, apatite, zircon and "others" (Table 4, Figure 2). The calculated QEMSCAN® assay values are: Cu 0.78% and Au 0.00%.

The data is also reported as a combined dataset, wighted by the reported mass in each fraction. Ore/sulphide phases in the combined dataset are minor pyrite (1.05%) and trace chalcopyrite (0.52%), Cu arsenides (0.42%), chalcocite (0.07%), bornite (0.06%) and gold minerals (0.002%) (Table 4, Figure 1). Gangue phases in this sample are major quartz and muscovite along with minor plagioclase feldspar, ankerite, K-feldspar, FeOx(Mn)/CO_3, chlorite, biotite and kaolinite and trace barite, ilmenite, rutile, apatite, zircon and "others" (Table 4, Figure 2). The calculated QEMSCAN® assay values are: Cu 0.46% and Au 0.00%.

	Lab Code	15HGD1	15HGD2	15HGD3	15HGD4	
	Size fraction	**+106**	**-106/+53**	**-53/+20**	**-20/+2**	**Combined dataset**
Elemental Mass (%)	Au assay % (QEMSCAN)	0.00	0.01	0.00	0.00	
	Cu assay % (QEMSCAN)	0.23	0.34	0.46	0.78	
Mineral Mass (%)	**Gold Minerals**	**0.00**	**0.01**	**0.00**	**0.00**	**0.002**
	Chalcopyrite	**0.35**	**0.32**	**0.49**	**0.89**	**0.52**
	Bornite	**0.03**	**0.06**	**0.09**	**0.08**	**0.06**
	Chalcocite	**0.02**	**0.16**	**0.01**	**0.08**	**0.07**
	Cu Arsenidess	**0.20**	**0.17**	**0.49**	**0.82**	**0.42**
	Pyrite	1.14	1.08	1.46	0.63	1.05
	Barite	0.04	0.06	0.10	0.07	0.06
	Ilmenite	0.16	0.21	0.19	0.34	0.23
	Rutile	0.36	0.43	0.31	0.35	0.37
	Fe-Ox(Mn)/CO3	3.69	3.96	4.53	6.19	4.60
	Quartz	48.12	46.93	44.56	30.65	42.36
	K-feldspar	7.73	6.80	6.52	5.69	6.70
	Plagioclase feldspar	7.25	6.90	7.08	8.54	7.48
	Biotite	1.67	1.56	1.36	1.13	1.44
	Muscovite	18.96	20.15	21.70	31.06	23.10
	Chlorite	2.15	1.97	1.97	3.29	2.38
	Kaolinite	0.94	1.11	1.06	1.77	1.23
	Ankerite	6.90	7.74	7.45	7.02	7.26
	Apatite	0.23	0.31	0.42	0.41	0.34
	Zircon	0.02	0.02	0.13	0.12	0.07
	Others	0.03	0.04	0.07	0.86	0.27

Table 4. Modal mineralogy QEMSCAN® data for the four fractions and the combined dataset.

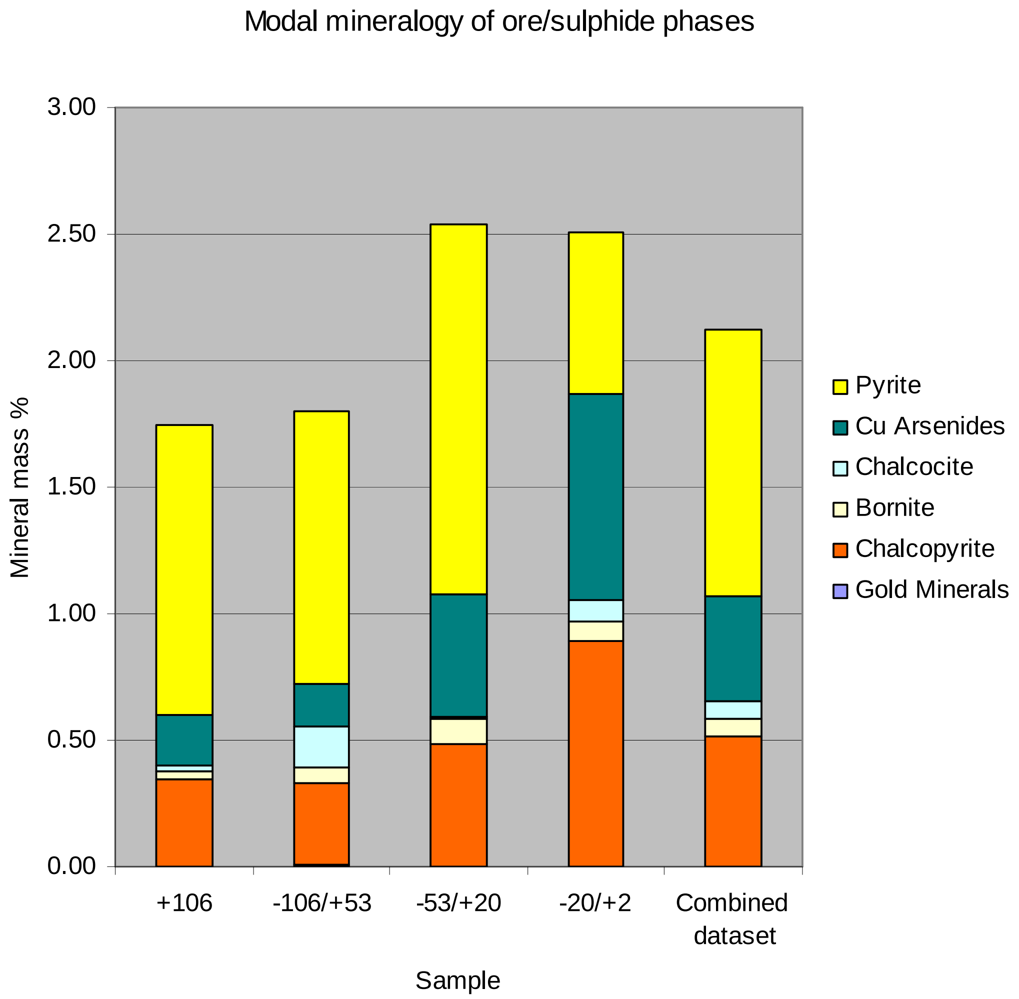


Figure 1. QEMSCAN® modal mineralogy for the ore/sulphide phases in the four fractions and the combined dataset

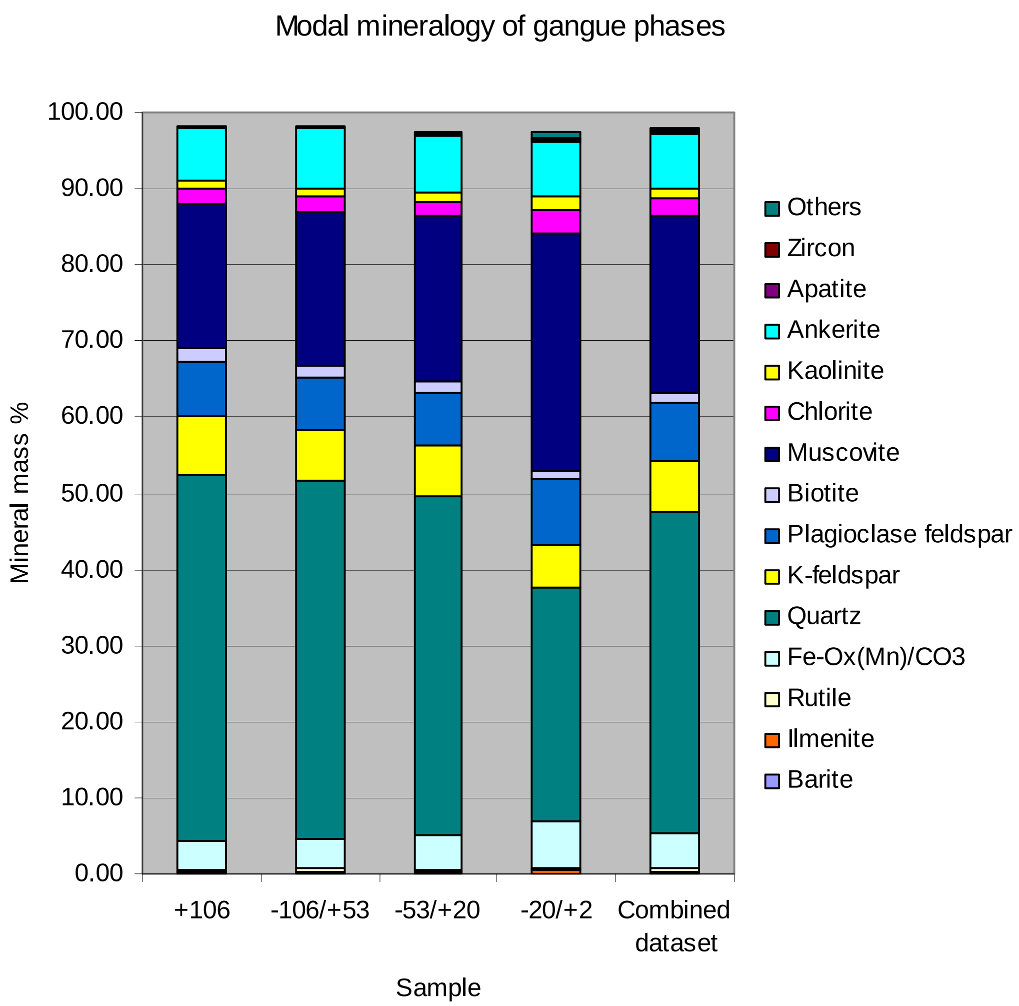


Figure 2. QEMSCAN® modal mineralogy for the gangue phases in the four fractions and the combined dataset.

3.2. Cu deportment

Cu deportment data are provided in excel file HG-15-25b and the percentage of Cu reporting to each mineral is shown in Figure 3 for each fraction.

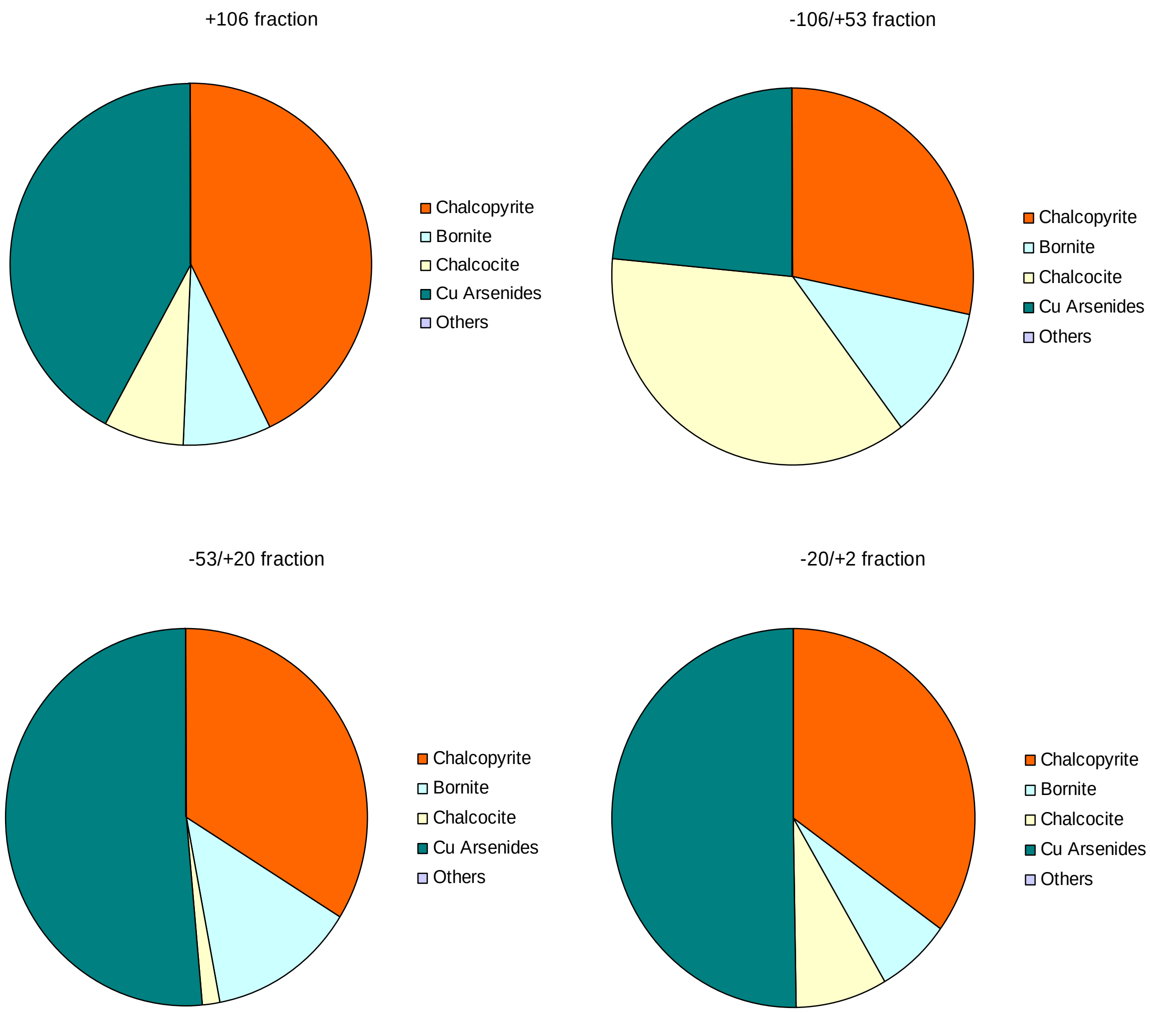


Figure 3. Cu deportment for the four fractions analysed.

3.3 Mineral liberation.

Mineral liberation data for gold minerals, chalcopyrite, bornite, chalcocite and Cu arsenides are contained in excel file HG-15-25b; representative images are shown in Appendix 2 and in powerpoint file HG-15-25c. In this report liberation data for chalcopyrite, bornite, chalcocite and Cu arsenides is described below. Data for chalcocite and bornite in some of the fractions is based on a small dataset where these minerals are present at low (<0.06%) modal abundance.

Chalcopyrite liberation

Chalcocpyrite liberation data for the +106 µm fraction shows that ~0.1% of the chalcopyrite is >70% chalcopyrite. In the -106/+53 µm fraction ~25.9% of the chalcopyrite is >70% chalcopyrite, in the -53/+20 µm fraction ~49.5% of the chalcopyrite is >70% chalcopyrite and in the -20/+2 µm fraction, ~85.7% of the chalcopyrite is >70% chalcopyrite (Table 5, Figure 4).

	<= 10%	**<= 20%**	**<= 30%**	**<= 40%**	**<= 50%**	**<= 60%**	**<= 70%**	**<= 80%**	**<= 90%**	**<= 100%**
-20/+2	3.73	2.46	0.51	2.96	3.47	0.18	0.98	10.64	0.00	75.06
-53/+20	17.28	8.23	4.92	1.73	10.72	1.72	5.95	8.98	0.00	40.47
-106/+53	37.94	21.28	3.14	0.26	5.17	0.12	6.23	0.00	6.56	19.30
+106	68.55	18.82	6.64	4.22	1.25	0.00	0.00	0.00	0.00	0.51

Table 5. Summary of mineral liberation data for chalcopyrite for the four fractions analysed.

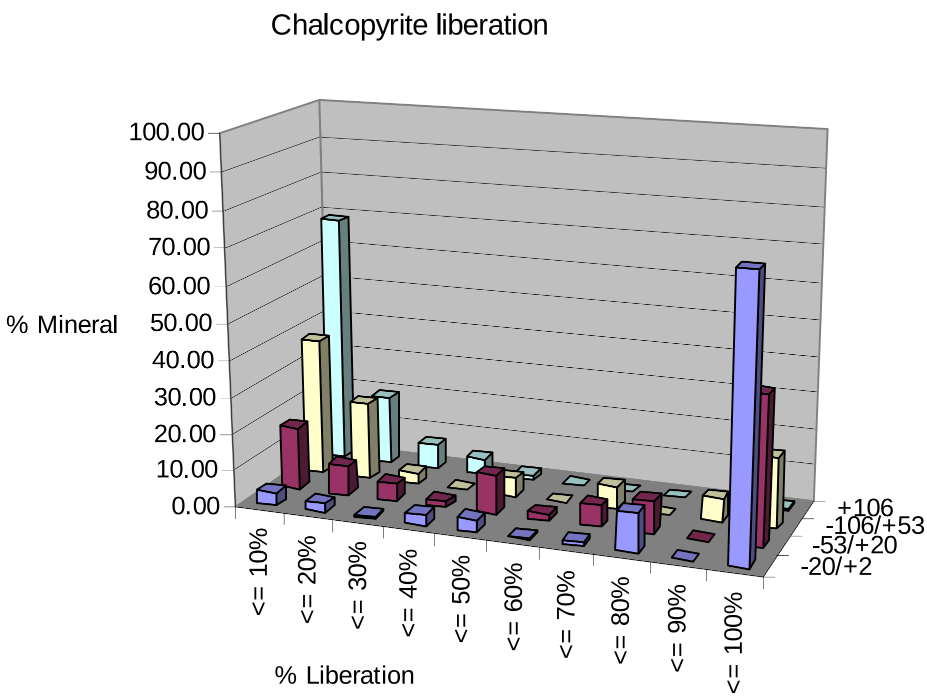


Figure 4. Mineral liberation data for chalcopyrite for the four fractions.

Bornite liberation

Bornite liberation data for the +106 µm fraction shows that ~0.0% of the bornite is >70% bornite. In the -106/+53 µm fraction ~0.0% of the bornite is >70% bornite, in the -53/+20 µm fraction ~27.4% of the bornite is >70% bornite and in the -20/+2 µm fraction ~68.2% of the bornite is >70% bornite (Table 6, Figure 5).

	<= 10%	**<= 20%**	**<= 30%**	**<= 40%**	**<= 50%**	**<= 60%**	**<= 70%**	**<= 80%**	**<= 90%**	**<= 100%**
-20/+2	28.24	3.53	0.00	0.00	0.00	0.00	0.00	0.00	25.88	42.35
-53/+20	25.71	1.89	0.00	19.10	2.83	0.00	23.11	0.00	0.00	27.36
-106/+53	33.71	12.58	9.89	0.00	0.00	43.82	0.00	0.00	0.00	0.00
+106	91.14	8.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6. Summary of mineral liberation data for bornite for the four fractions analysed.

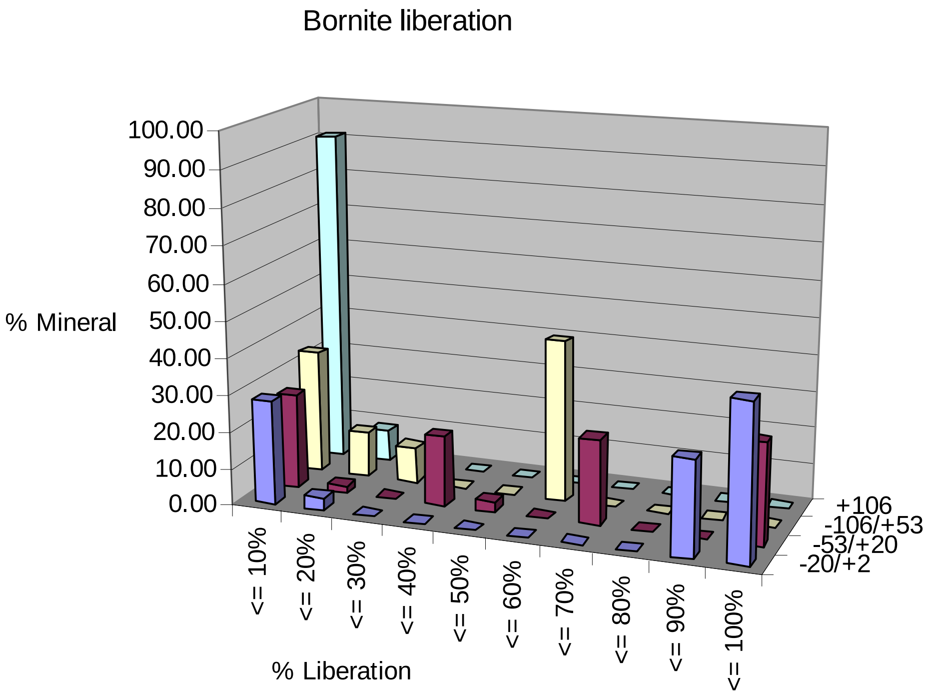


Figure 5. Mineral liberation data for bornite for the four fractions.

Chalcocite liberation

Chalcocite liberation data for the +106 µm fraction shows that ~0.0% of the chalcocite is >70% chalcocite. In the -106/+53 µm fraction ~89.6% of the chalcocite is >70% chalcocite, in the -53/+20 µm fraction ~0.0% of the chalcocite is >70% chalcocite and in the -20/+2 µm fraction ~27.4% of the chalcocite is >70% chalcocite (Table 7, Figure 6).

	<= 10%	**<= 20%**	**<= 30%**	**<= 40%**	**<= 50%**	**<= 60%**	**<= 70%**	**<= 80%**	**<= 90%**	**<= 100%**
-20/+2	12.31	20.64	2.56	11.07	22.36	3.62	0.00	0.00	0.00	27.44
-53/+20	91.88	0.00	8.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-106/+53	10.40	0.00	0.00	0.00	0.00	0.00	0.00	29.93	0.00	59.66
+106	99.14	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 7. Summary of mineral liberation data for chalcocite for the four fractions analysed.

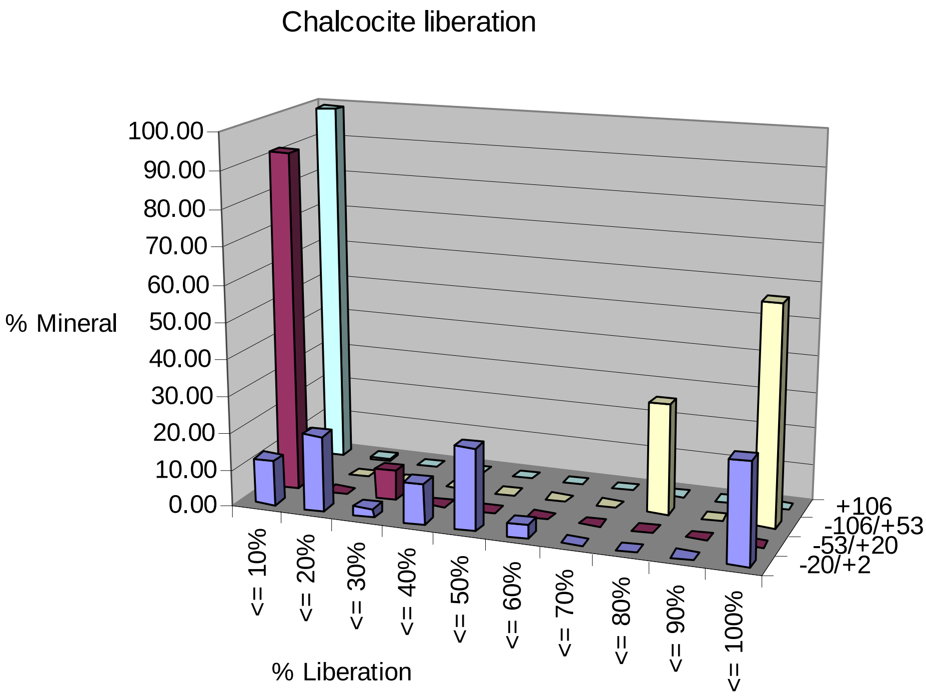


Figure 6. Mineral liberation data for chalcocite for the four fractions.

Cu arsenides liberation

Cu arsenides liberation data for the +106 µm fraction shows that ~10.7% of the Cu arsenides is >70% Cu arsenides. In the -106/+53 µm fraction ~12.9% of the Cu arsenides is >70% Cu arsenides, in the -53/+20 µm fraction ~56.4% of the Cu arsenides is >70% Cu arsenides and in the -20/+2 µm fraction ~87.6% of the Cu arsenides is >70% Cu arsenides (Table 8, Figure 7).

	<= 10%	**<= 20%**	**<= 30%**	**<= 40%**	**<= 50%**	**<= 60%**	**<= 70%**	**<= 80%**	**<= 90%**	**<= 100%**
-20/+2	0.00	0.41	1.25	0.82	0.00	2.42	7.47	7.10	16.28	64.24
-53/+20	7.05	1.16	3.27	0.17	12.18	3.48	16.28	2.99	15.34	38.08
-106/+53	30.77	8.14	9.72	7.92	6.54	13.76	10.24	0.00	0.00	12.92
+106	53.42	18.74	10.78	0.00	0.00	0.00	6.99	0.00	0.33	9.74

Table 8. Summary of mineral liberation data for Cu arsenides for the four fractions analysed.

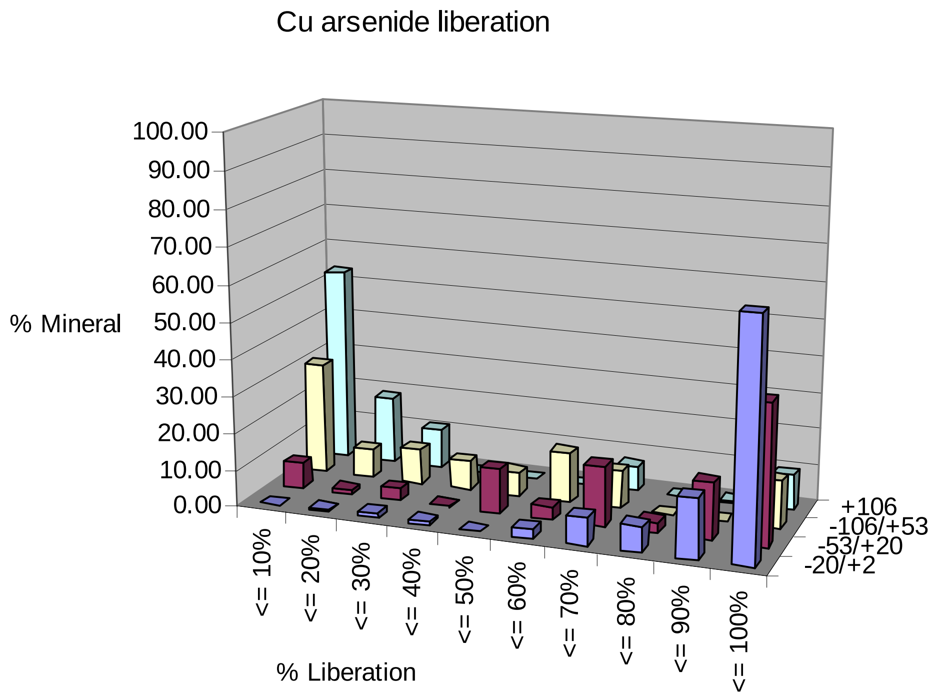


Figure 7. Mineral liberation data for Cu arsenides for the four fractions.

3.4. Mineral association.

Mineral association data for gold minerals, chalcopyrite, bornite, chalcocite and Cu arsenides are presented in excel file HG-15-25b. In this report mineral association data for chalcopyrite, bornite, chalcocite and Cu arsenides is described below. Data for chalcocite and bornite in some of the fractions is based on a small dataset where these minerals are present at low (<0.06%) modal abundance.

Chalcopyrite mineral association.

In the +106 µm size fraction chalcopyrite is associated with background (14%), bornite (3%), chalcocite (2%), Cu arsenides (12%), pyrite (9%), FeOx(Mn)/CO_3 (2%), quartz (26%), K-feldspar (7%), plagioclase (7%), biotite (2%), muscovite (9%), chlorite (2%), kaolinite (1%) and ankerite (4%).

In the -106/+53 µm size fraction chalcopyrite is associated with background (23%), bornite (6%), chalcocite (3%), Cu arsenides (11%), pyrite (7%), rutile (1%), FeOx(Mn)/CO_3 (2%), quartz (20%), K-feldspar (6%), plagioclase (6%), biotite (2%), muscovite (8%), chlorite (2%), kaolinite (1%), ankerite (2%) and ‘others’ (1%).

In the -53/+20 µm size fraction chalcopyrite is associated with background (39%), bornite (5%), chalcocite (1%), Cu arsenides (16%), pyrite (13%), FeOx(Mn)/CO_3 (1%), quartz (11%), K-feldspar (3%), plagioclase (2%), biotite (1%), muscovite (4%), chlorite (1%) and ankerite (1%).

In the -20/+2 µm size fraction chalcopyrite is associated with background (79%), bornite (1%), chalcocite (3%), Cu arsenides (8%), pyrite (2%), quartz (2%), K-feldspar (1%), biotite (1%) and muscovite (2%) (Figure 8).

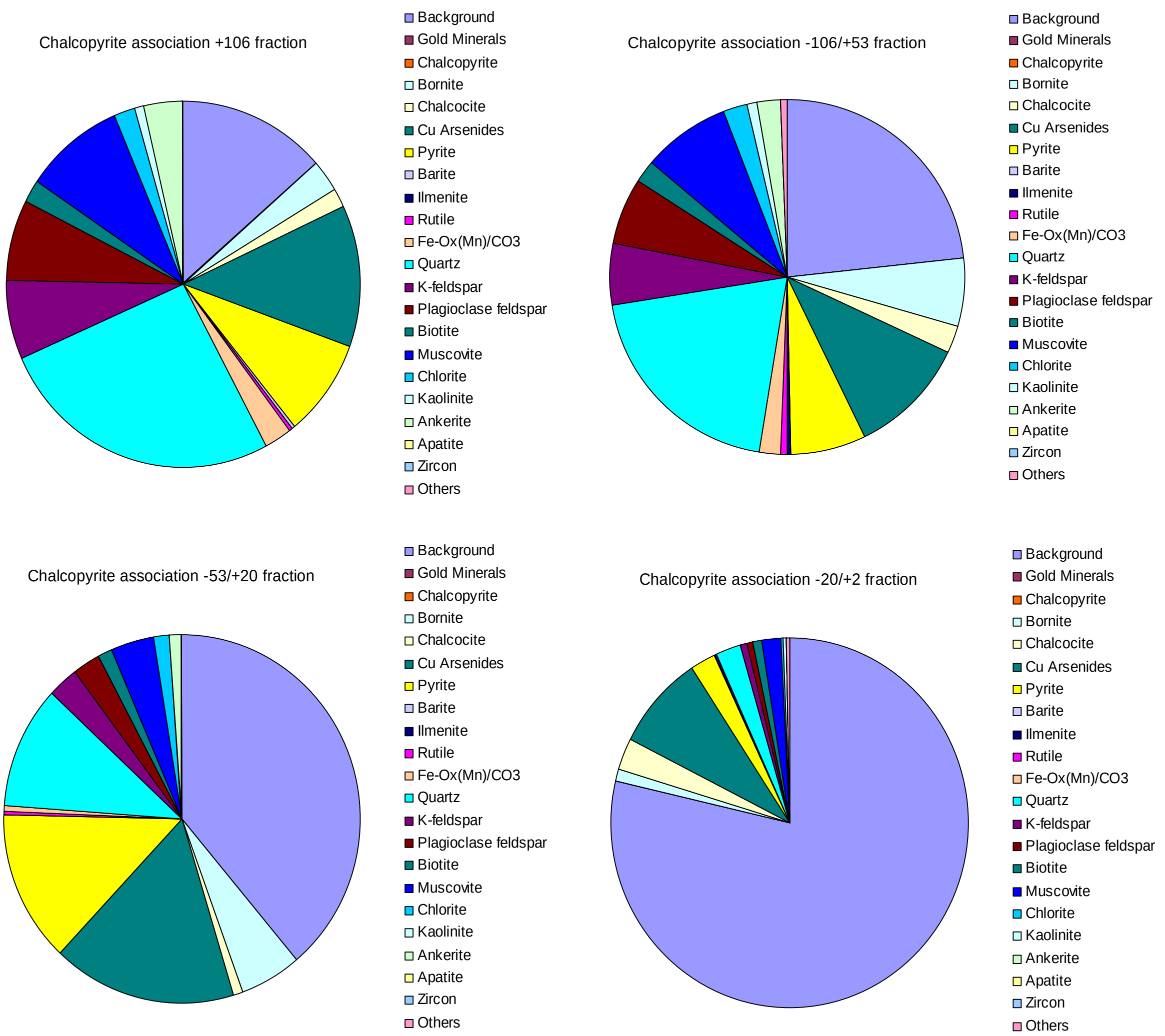


Figure 8. Chalcopyrite mineral association for the four fractions analysed.

Bornite mineral association.

In the +106 µm size fraction bornite is associated with background (11%), chalcopyrite (44%), chalcocite (4%), Cu arsenides (29%), pyrite (3%), FeOx(Mn)/CO_3 (1%), quartz (4%), K-feldspar (1%), plagioclase (1%), muscovite (2%) and ankerite (1%).

In the -106/+53 µm size fraction bornite is associated with background (14%), Au minerals (1%), chalcopyrite (47%), chalcocite (8%), Cu arsenides (24%),

$FeOx(Mn)/CO_3$ (1%), quartz (2%), K-feldspar (1%), plagioclase (1%), and muscovite (1%).

In the -53/+20 µm size fraction bornite is associated with background (34%), chalcopyrite (33%), chalcocite (1%) and Cu arsenides (32%).

In the -20/+2 µm size fraction bornite is associated with background (40%), chalcopyrite (13%), chalcocite (4%) and Cu arsenides (44%) (Figure 9).

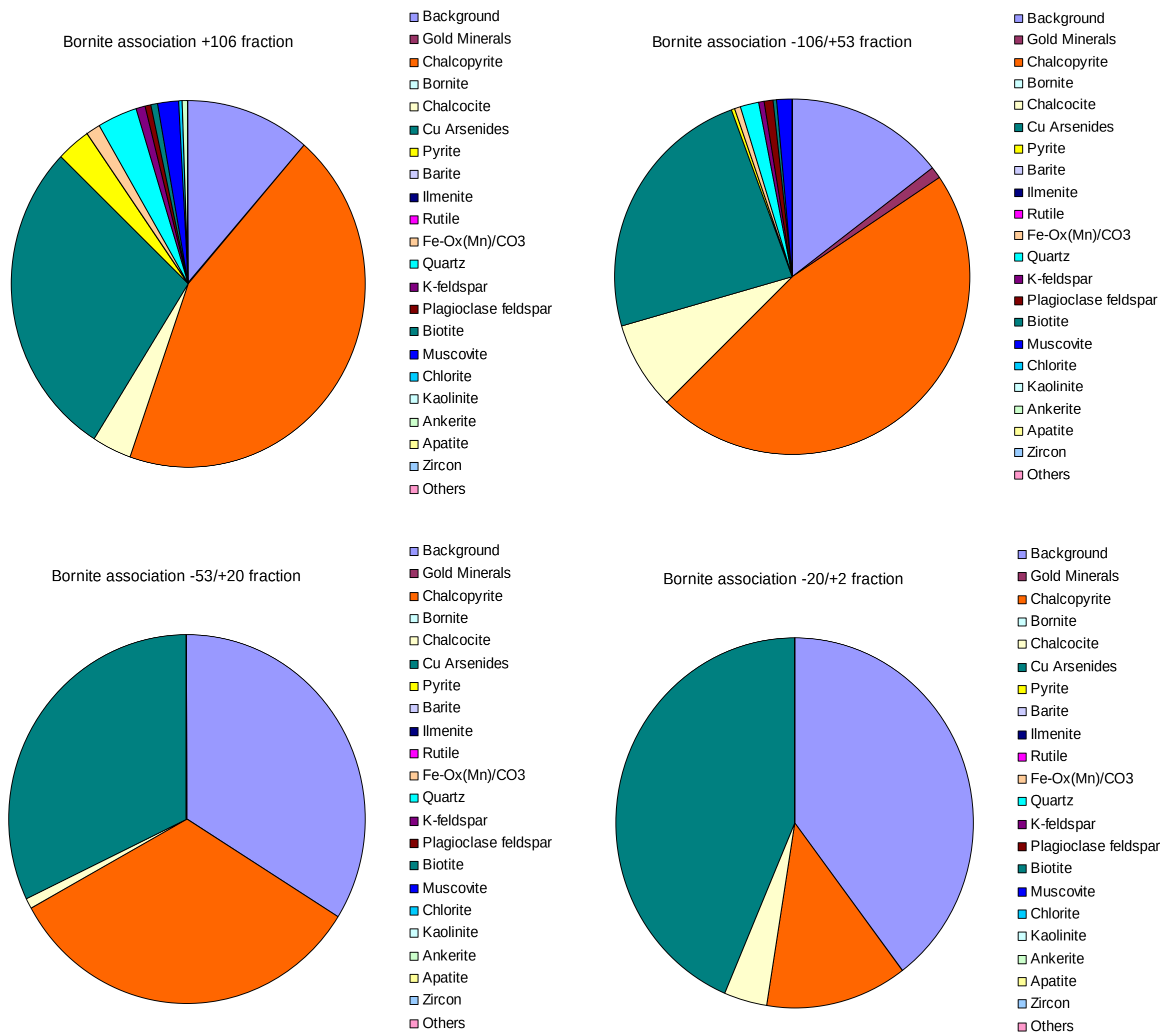


Figure 9. Bornite mineral association for the four fractions analysed.

Chalcocite mineral association.

In the +106 µm size fraction chalcocite is associated with background (23%), chalcopyrite (38%), bornite (6%), Cu arsenides (4%), FeOx(Mn)/CO_3 (1%), quartz (12%), K-feldspar (5%), plagioclase (2%), biotite (1%), muscovite (6%), kaolinite (1%) and ankerite (1%).

In the -106/+53 µm size fraction chalcocite is associated with background (51%), Au minerals (2%), chalcopyrite (24%), bornite (9%), Cu arsenides (8%), quartz (1%), K-feldspar (1%), plagioclase (2%), biotite (1%) and muscovite (2%).

In the -53/+20 µm size fraction chalcocite is associated with background (38%), chalcopyrite (30%), bornite (5%), Cu arsenides (23%), quartz (2%), plagioclase (2%) and muscovite (2%).

In the -20/+2 µm size fraction chalcocite is associated with background (52%), chalcopyrite (27%), bornite (3%), Cu arsenides (17%) and K-feldspar (1%) (Figure 10).

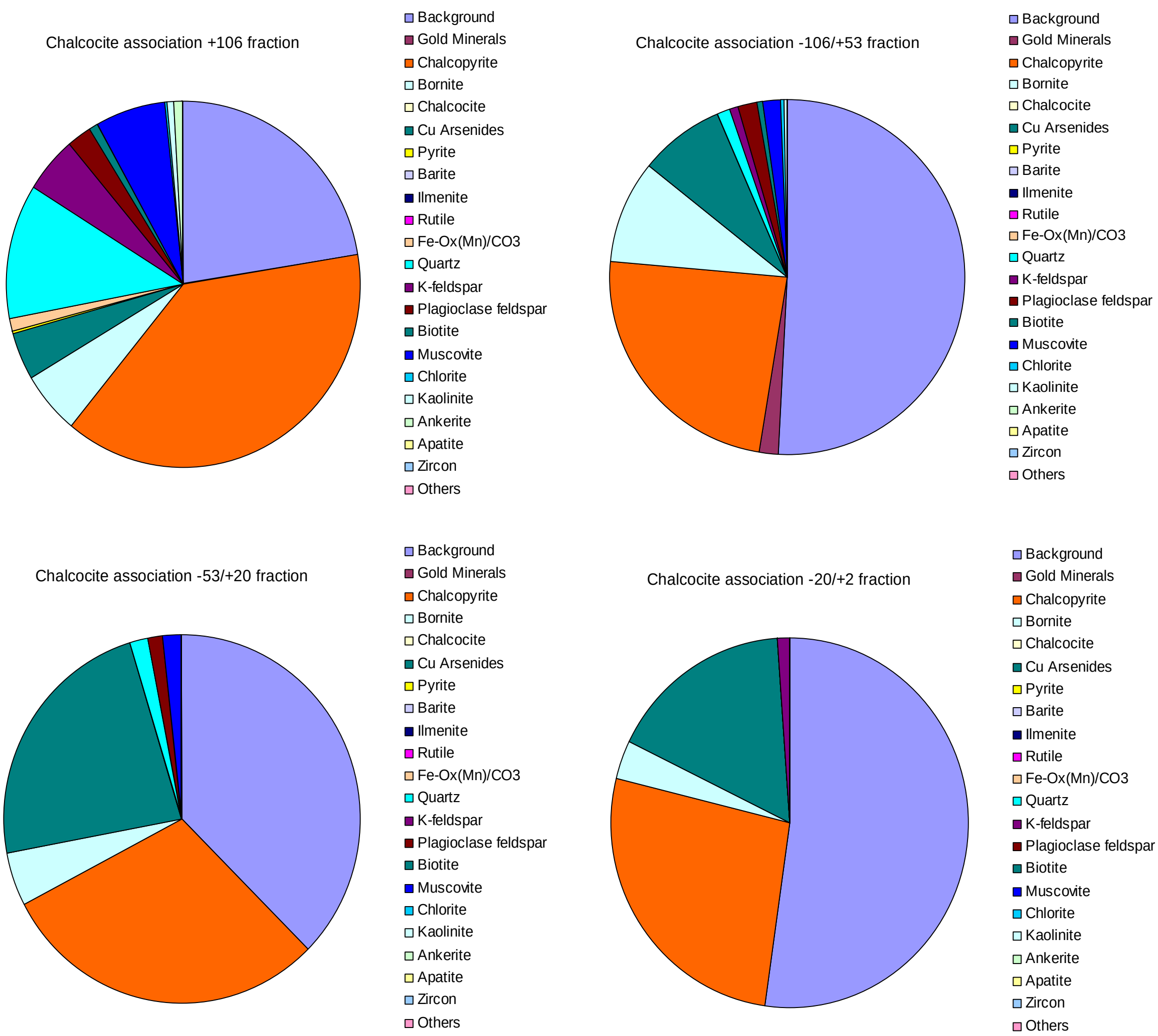


Figure 10. Chalcocite mineral association for the four fractions analysed.

Cu arsenides mineral association.

In the +106 µm size fraction Cu arsenides are associated with background (19%), chalcopyrite (47%), bornite (7%), chalcocite (1%), pyrite (4%), FeOx(Mn)/CO_3 (2%), quartz (8%), K-feldspar (2%), plagioclase (2%), biotite (1%), muscovite (5%), chlorite (1%), ankerite (2%) and ‘others’ (1%).

In the -106/+53 µm size fraction Cu arsenides are associated with background (34%), chalcopyrite (40%), bornite (11%), chalcocite (3%), pyrite (2%), FeOx(Mn)/CO_3 (1%), quartz (2%), K-feldspar (1%), plagioclase (2%) and muscovite (3%).

In the -53/+20 µm size fraction Cu arsenides are associated with background (46%), chalcopyrite (37%), bornite (12%), chalcocite (2%), pyrite (1%) and muscovite (1%).

In the -20/+2 µm size fraction Cu arsenides are associated with background (73%), chalcopyrite (15%), bornite (7%) and chalcocite (3%) (Figure 11).

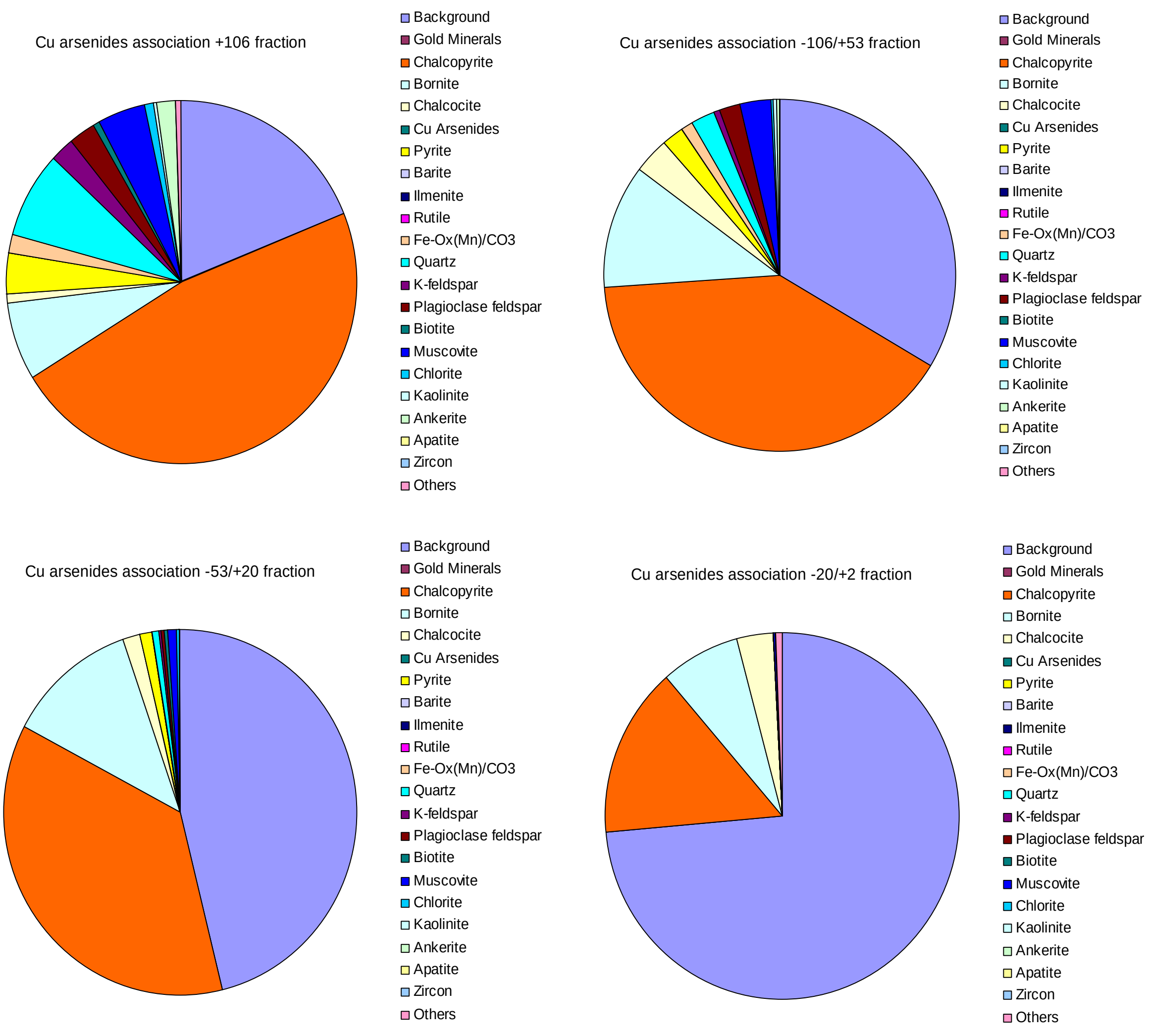


Figure 11. Cu arsenides mineral association for the four fractions analysed.

3.5. Theoretical Grade Recovery Curve data.

The theoretical grade recovery curves are calculated from the QEMSCAN® data. When the recovery mechanism is only accepting fully liberated particles, the grade of the recovered ore will be 100%, but the amount recovered is almost certainly going to be very poor, with partially liberated and barren particles being discarded. As the recovery process accepts particles of a lower grade, the recovery increases, but the grade of the concentrate decreases. This continues to the point where all of the target mineral is accepted giving 100% recovery. As even more particles (barren of the target mineral) are accepted by the recovery process, then the grade will continue to fall. Theoretical grade recovery data for chalcopyrite, bornite, chalcocite and Cu arsenides are provided in excel file HG-15-25b and described below. Data for chalcocite and bornite in some of the fractions is based on a small dataset where these minerals are present at low (<0.06%) modal abundance.

TGRC Chalcopyrite.

In the +106 µm size fraction a recovery of 80% chalcopyrite results in a grade of ~5%. In the -106/+53 µm size fraction a recovery of 80% chalcopyrite gives a grade of ~14%, in the -53/+20 µm size fraction a recovery of 80% gives a grade of ~48% and in the -20/+2 µm size fraction a recovery of 80% gives a grade of ~97% (Figure 12).

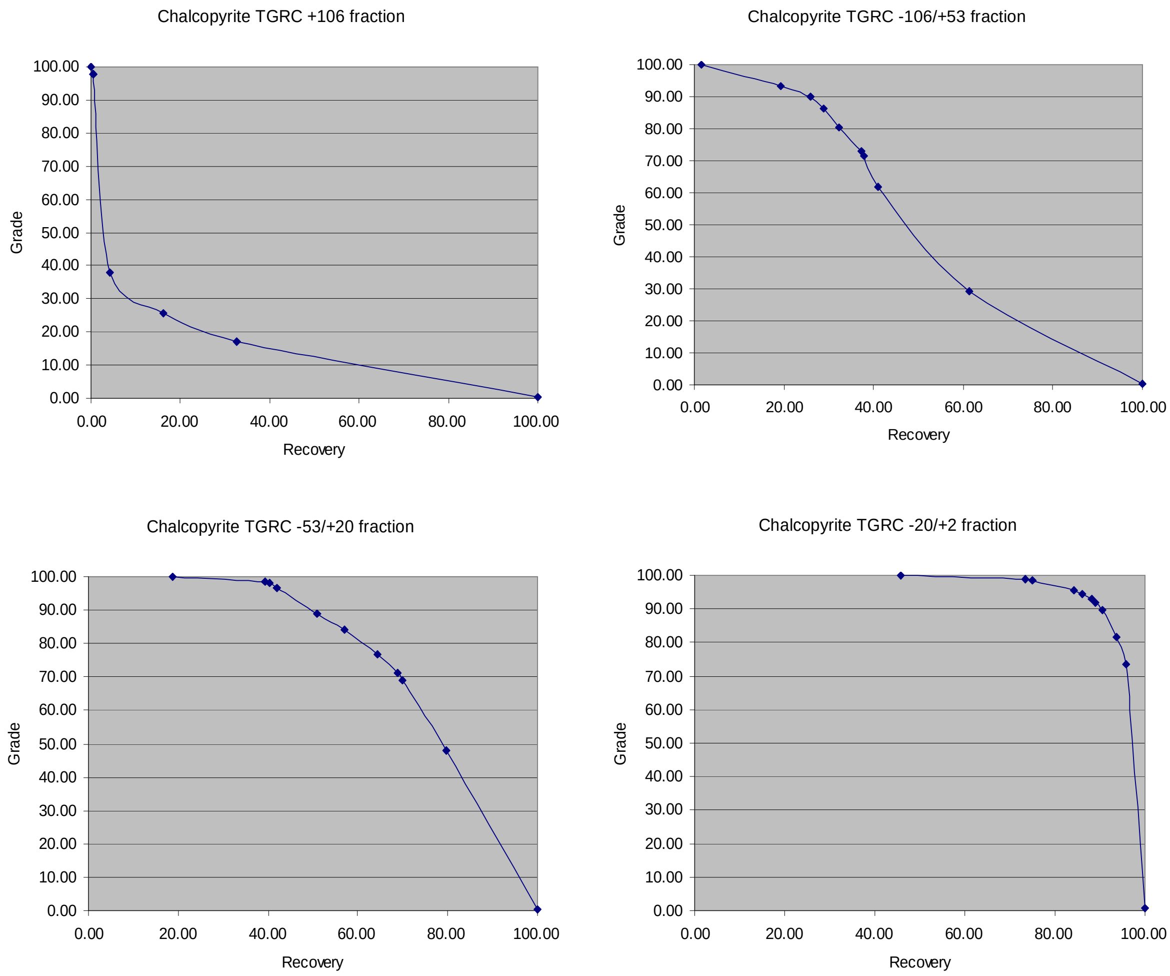


Figure 12. TGRC data for chalcopyrite for the four fractions analysed.

TGRC Bornite.

In the +106 µm size fraction a recovery of 80% bornite results in a grade of ~5%. In the -106/+53 µm size fraction a recovery of 80% bornite gives a grade of ~26%, in the -53/+20 µm size fraction a recovery of 80% gives a grade of ~51% and in the -20/+2 µm size fraction a recovery of 80% gives a grade of ~53% (Figure 13).

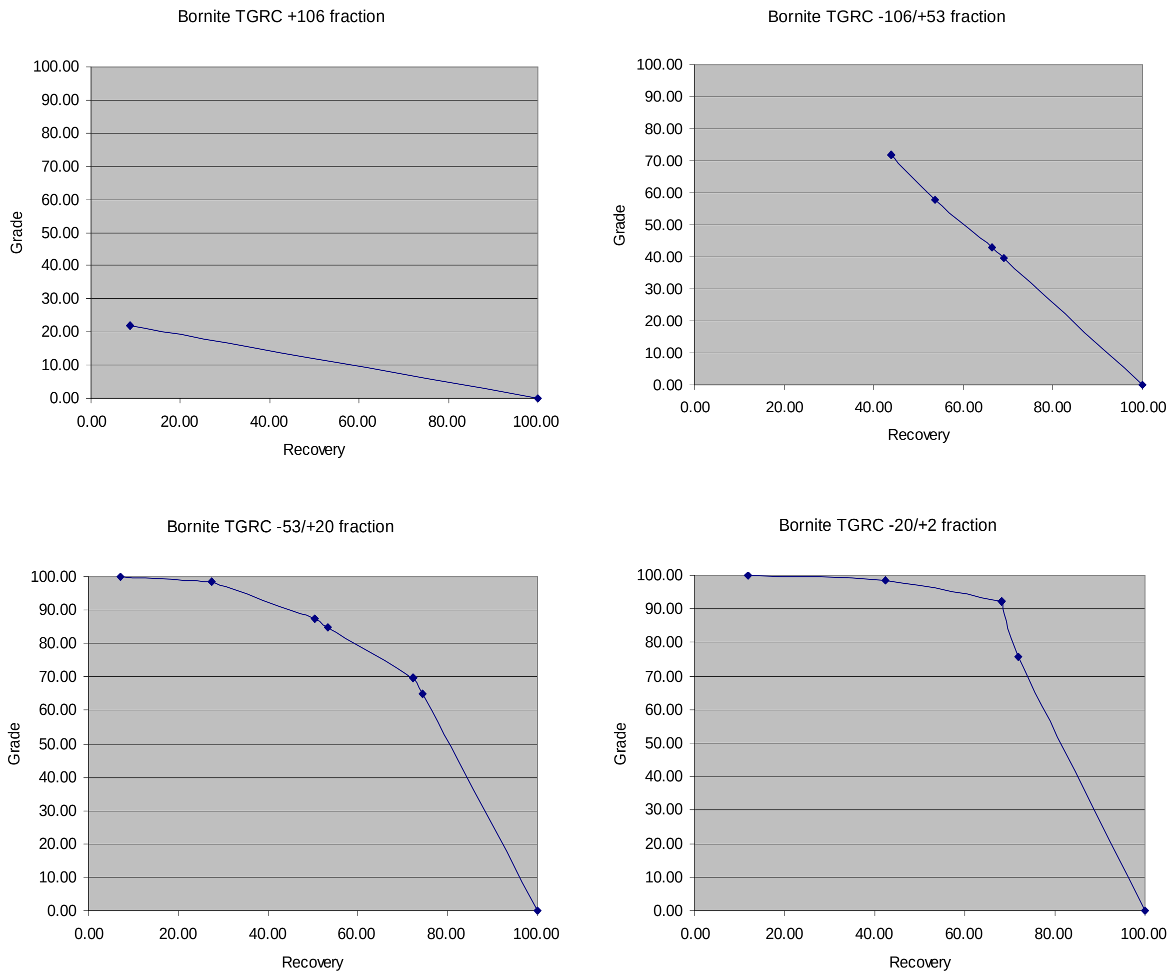


Figure 13. TGRC data for bornite for the four fractions analysed.

TGRC Chalcocite.

In the +106 µm size fraction a recovery of 80% chalcocite results in a grade of ~4%. In the -106/+53 µm size fraction a recovery of 80% chalcocite gives a grade of ~93%, in the -53/+20 µm size fraction a recovery of 80% gives a grade of ~8% and in the -20/+2 µm size fraction a recovery of 80% gives a grade of ~51% (Figure 14).

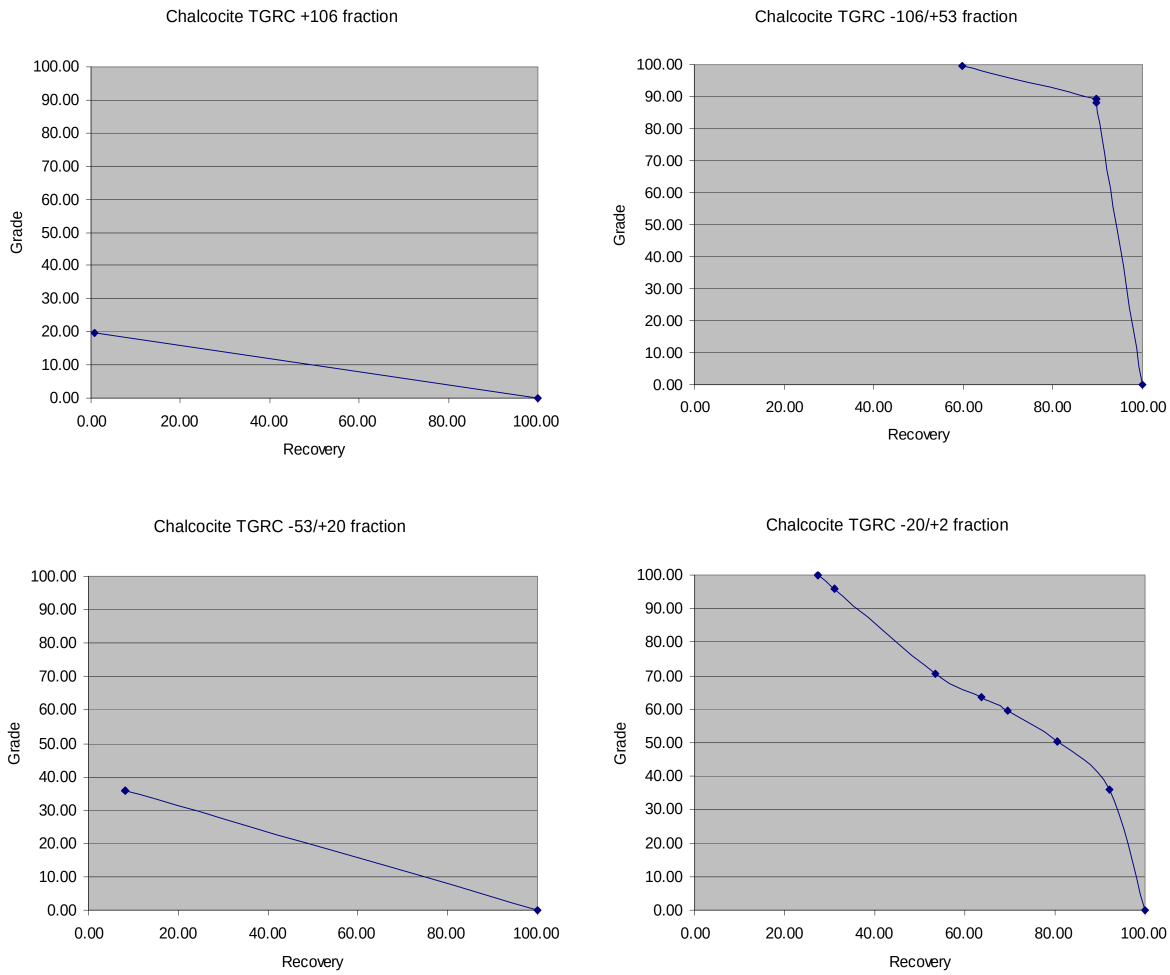


Figure 14. TGRC data for chalcocite for the four fractions analysed.

TGRC Cu arsenides.

In the +106 µm size fraction a recovery of 80% Cu arsenides results in a grade of ~11%. In the -106/+53 µm size fraction a recovery of 80% Cu arsenides gives a grade of ~39%, in the -53/+20 µm size fraction a recovery of 80% gives a grade of ~86% and in the -20/+2 µm size fraction a recovery of 80% gives a grade of ~95% (Figure 15).

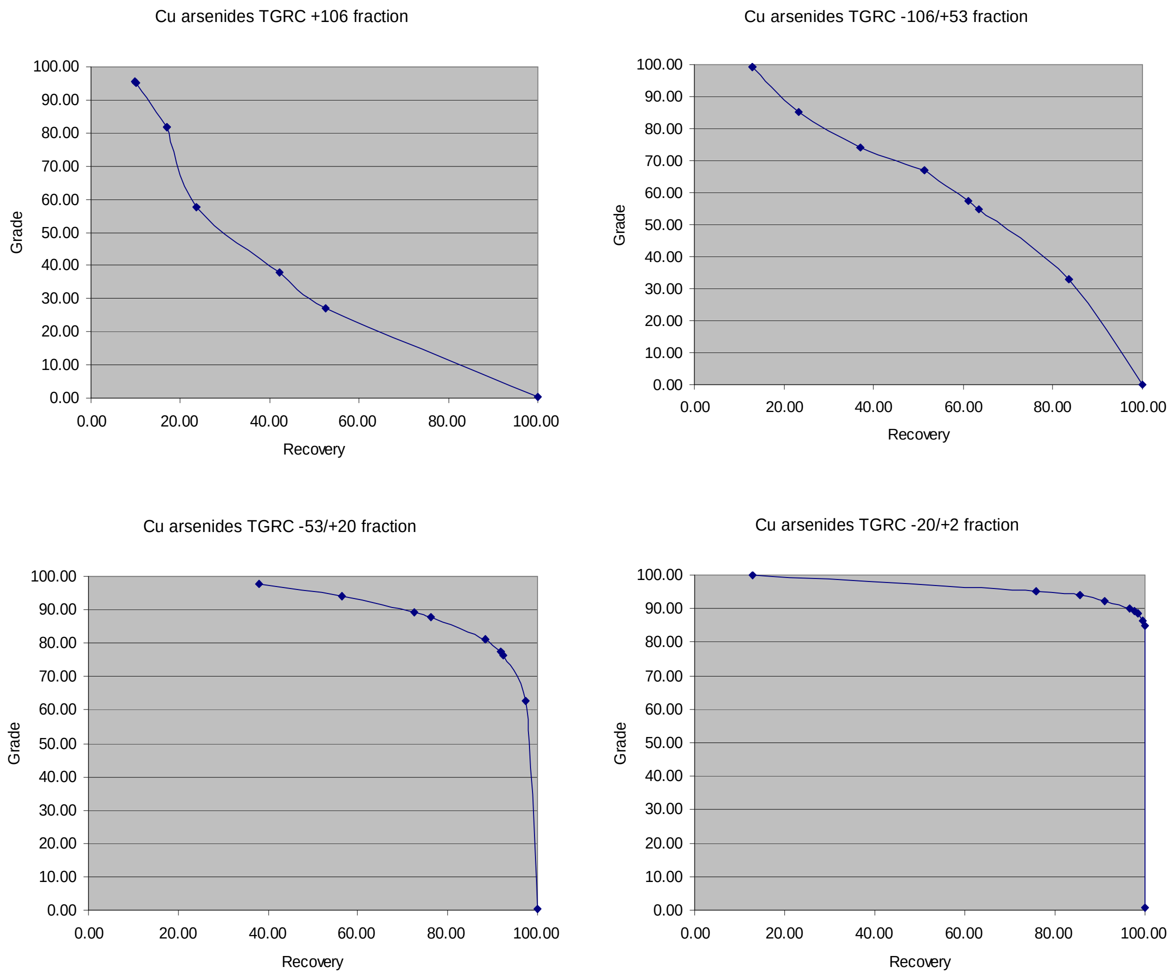


Figure 15. TGRC data for Cu arsenides for the four fractions analysed.

Appendix 1
QEMSCAN® technical information

1.1 Justification for using QEMSCAN® to analyse mineral products

QEMSCAN® is an automated mineral analysis system that provides rapid, statistically reliable, repeatable data from virtually any mineralogical sample containing particulates. This method is particularly well-suited to the analysis of mineral products where it is critical to accurately quantify the mineralogy, chemistry, texture and degree of liberation of the sample. Analysis of this type of mineral product can be difficult and time consuming using traditional methods of analysis such as light microscopy and manual scanning electron microscopy, which often do not provide quantitative or statistically reliable data.

1.2 What is QEMSCAN®?

QEMSCAN® is an automated mineral analysis system based on a scanning electron microscope that provides rapid determination and quantification of the mineralogy, chemical composition, grain size and shape of a variety of sample types (Figure 1). It is optimised to analyse particulate materials (such as mill feeds and concentrates) but can also analyse virtually any inorganic material including rock chips, mineral products, soil samples and air-borne particulates. Data collection is operator independent and routinely involves the analysis of several thousand particles (each one comprising a large number of data points) and therefore results in statistically reliable and reproducible mineralogical analyses.

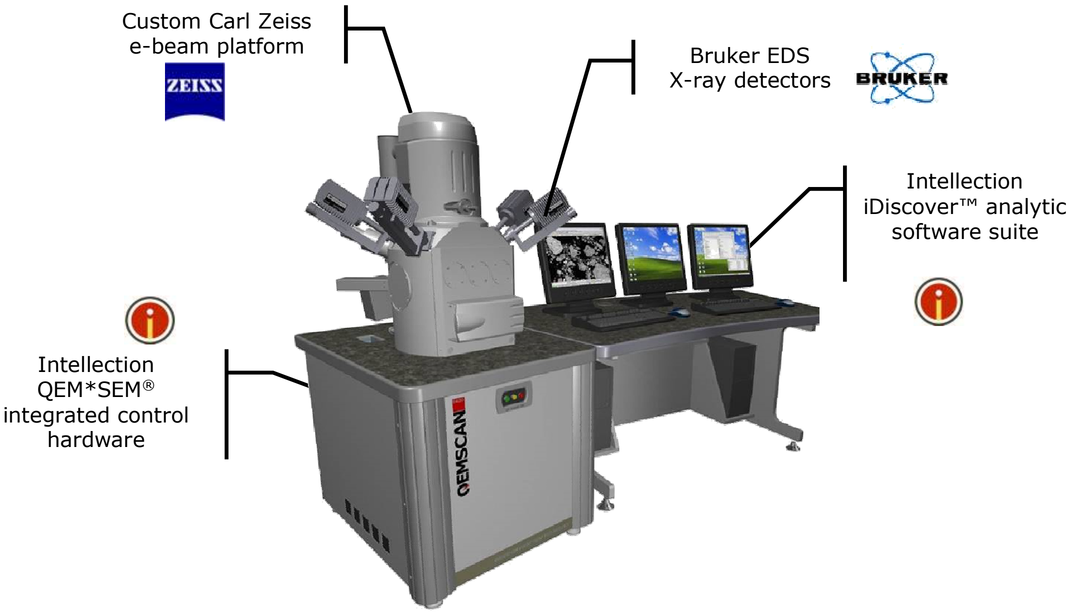


Figure 1. Summary of the QEMSCAN® system (FEI Ltd).

1.3 QEMSCAN® analysis modes

There are various modes in which the QEMSCAN® can be operated including particle mineral analysis (PMA) mode where individual particles are mineralogically mapped, fieldscan mode where the entire area of the block is scanned and then through a software routine the separate particle images are generated, and specific mineral search (SMS) where a backscatter electron threshold is applied to the sample, and only phases with an average atomic number above that threshold are analysed. Once a particle is found, the electron beam is automatically rastered across it (Figure 2). Mineral identification is based on the resulting X-ray spectrum for each pixel. Individual analysis and mineral identification takes about a millisecond and therefore mineralogical, textural and grain size data are acquired very rapidly allowing a very large number of particles to be analysed in a relatively short time (typically in the order of 1000 particles per hour).

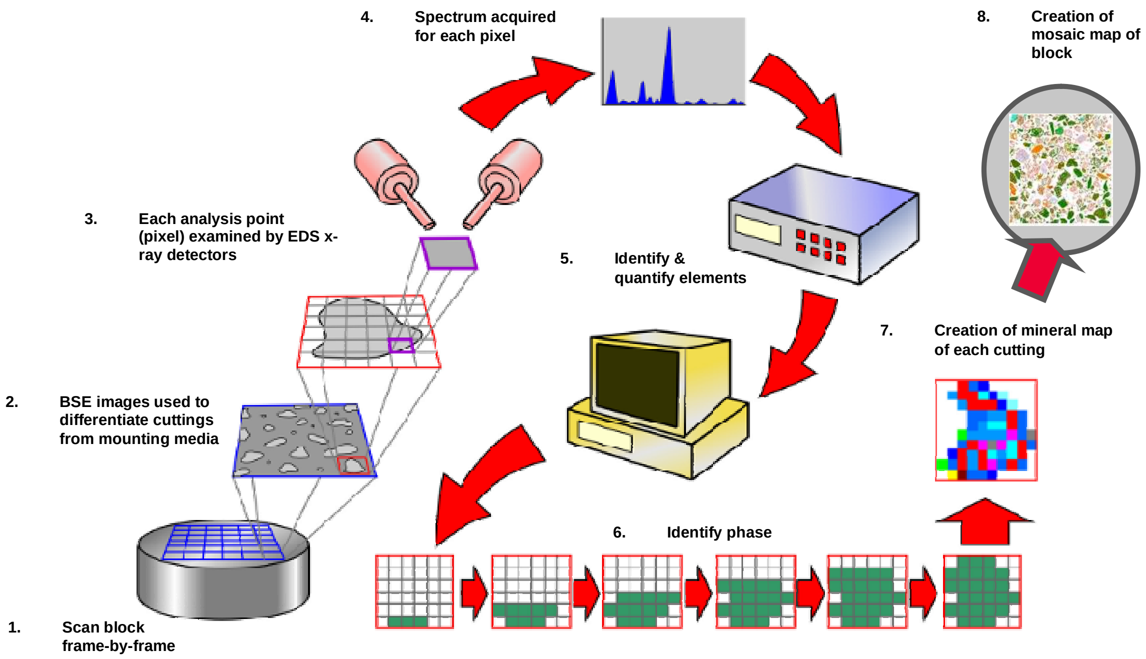


Figure 2. How QEMSCAN® identifies minerals/chemical phases (FEI Ltd).

The results are output in the form of numerical data which can include quantitative modal mineralogy along with liberation, mineralogical association, particle and grain size data and mineral deportment together with individual particle maps.

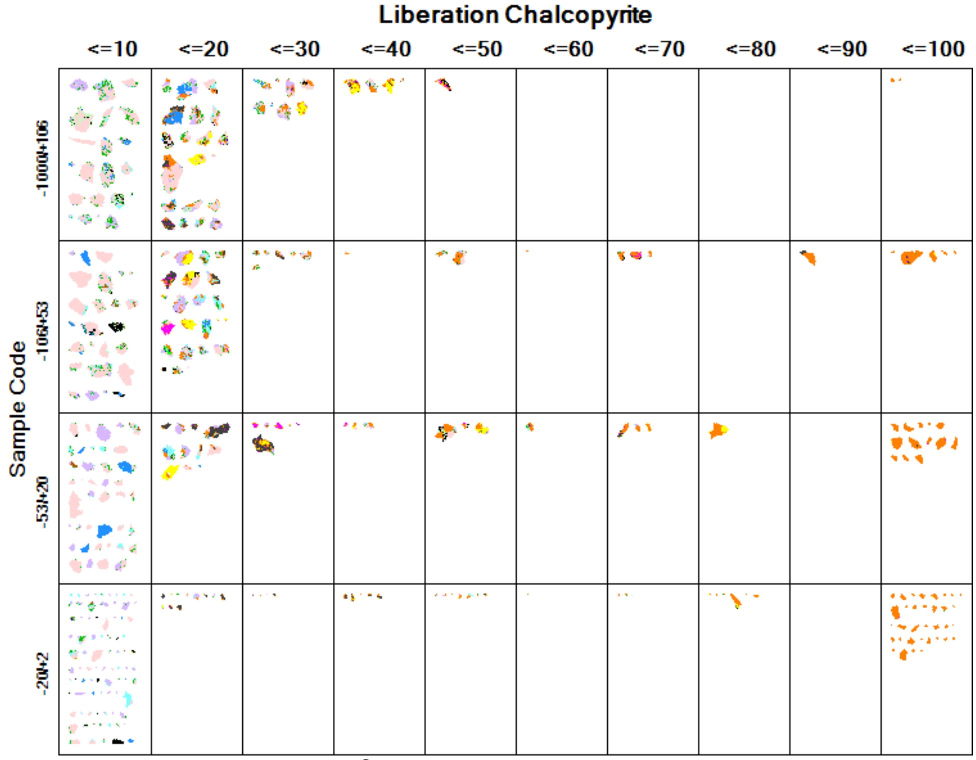
1.4 Processing parameters

The raw data acquired during QEMSCAN® analysis is based upon classification of the individual X-ray spectra by using a look-up table containing in excess of 600 known mineral phases and chemical compositions. Spectra that cannot be matched to known phases at this point are classified as “others” and the coordinates stored (they can be assigned to a chemical phase at a later date). The raw data are processed by assigning similar pixel types to single categories which may be a mineral phase, chemical composition or any other category. Note that where there are minerals with overlapping or very similar chemistries then they cannot always be discriminated.

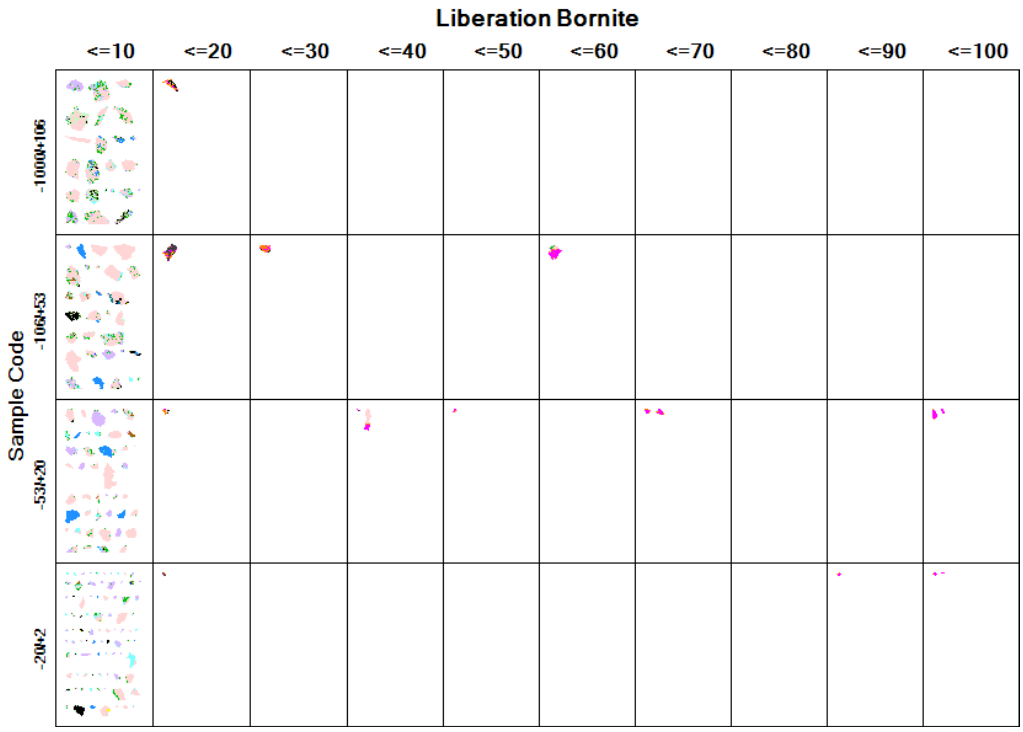
Appendix 2

Representative QEMSCAN® particle images

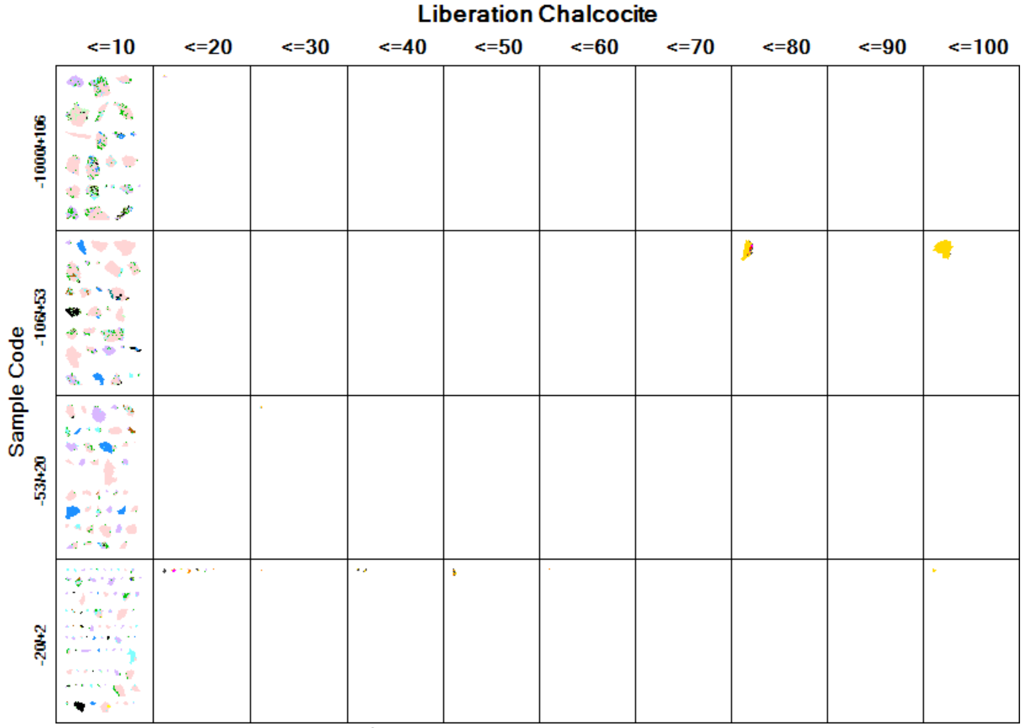
(See also powerpoint file HG-15-25c)



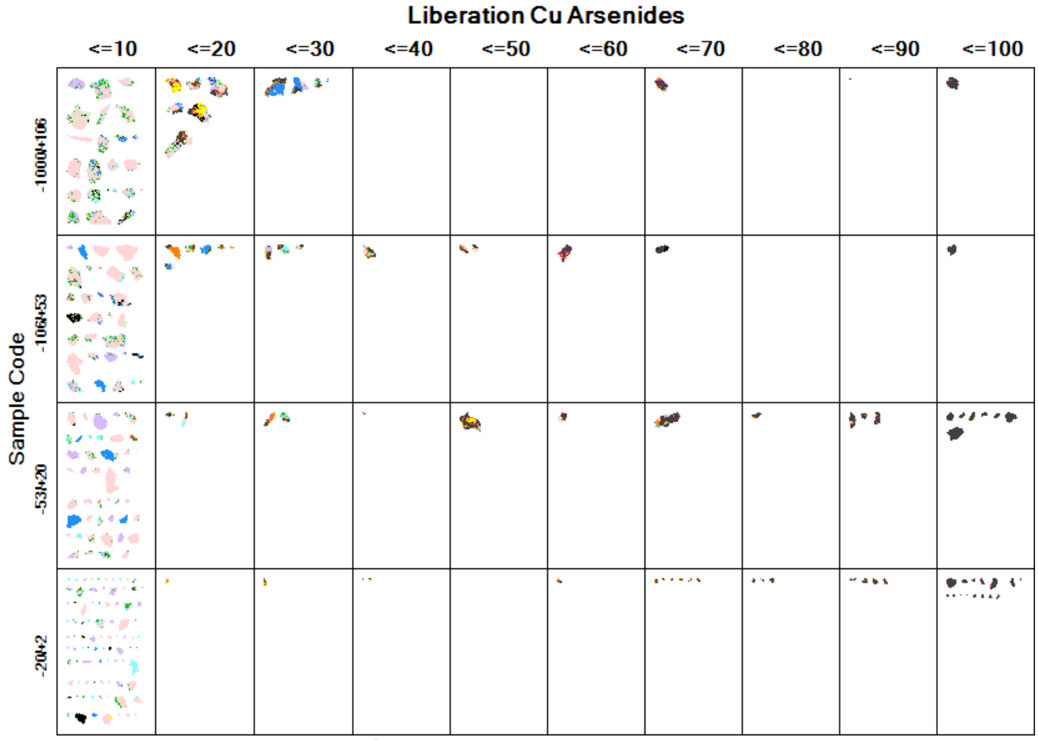
Appendix 2.1. QEMSCAN® image grid showing the liberation of chalcopyrite in the four fractions analysed.



Appendix 2.2. QEMSCAN® image grid showing the liberation of bornite in the four fractions analysed.



Appendix 2.3. QEMSCAN® image grid showing the liberation of chalcocite in the four fractions analysed.



Appendix 2.4. QEMSCAN® image grid showing the liberation of Cu arsenides in the four fractions analysed.

Appendix 2.3. Key to QEMSCAN® false colour images.