An Investigation by High Definition Mineralogy into

THE MINERALOGICAL CHARACTERISTICS OF THREE SAMPLES OF NICKEL MINERALIZATION FROM THE MANIITSOQ PROJECT, SOUTHWEST GREENLAND

prepared for

NORTH AMERICAN NICKEL INC

Project 14021-001 (MI5010-APR13) – Final Report

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Table of Contents

List of Figures

List of Tables

Introduction

This summary report describes a mineralogical test program using High Definition Mineralogy, including QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy) and electron microprobe (EMP) analyses conducted on three nickel ore samples from Greenland. The samples were submitted by John Pattison of North American Nickel Inc. The main purposes of this test program were to (i) identify and quantify the nickel- and copper-bearing minerals within the samples; (ii) determine the liberation and association characteristics of the Ni- and Cu-sulphides and (iii) assess any factors which may aid or hinder the success of metallurgical processes.

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Testwork Summary

1. Sample Receipt and Preparation

Three samples labelled L163593, L163163 and L163164 were received by the SGS Advanced Mineralogy Facility and assigned the LIMS number MI5010-APR13. The samples were stage-ground to 90% passing 150 µm (~80% passing 106 µm) and then sub-sampled for polished section preparation and chemical analysis. One graphite-impregnated polished epoxy grain mount was prepared from each sample. A total of three graphite-impregnated polished sections were submitted for quantitative modal analysis by QEMSCAN. QEMSCAN results are summarized in the body of this report. QEMSCAN field images were also acquired from analysis of core pieces of the three samples under LIMS number MI5015-FEB13. These are included in Appendix D.

Sub-samples were also submitted for analysis of Cu and Ni by XRF and Si by AA. The certificate of analysis is provided in Appendix A. One sample (L163163) was also submitted for sulphur analysis for QA/QC purposes.

One polished section from each sample was sent to McGill University for Electron Microprobe (EMP) analysis to determine the solid-solution Ni- carriers for proper Ni accounting purposes and overall mineral chemistry. Electron microprobe results are summarized in Section 4 and full EMP results are given in Appendix B.

2. QEMSCAN Operational Modes and Quality Control

The Particle Mineral Analysis (PMA) measurement mode of operation was used for QEMSCAN analysis of each sample to determine the mineral speciation, distribution and quantitative modal data. The electron microprobe mineral chemistries were entered into the QEMSCAN software in order to calculate the Ni, Cu and Co deportment for each sample.

PMA is a two-dimensional mapping analysis aimed at resolving liberation and locking characteristics of a generic set of particles. A pre-defined number of particles are mapped at a point spacing selected in order to spatially resolve and describe mineral textures and associations. This mode is often selected to characterize concentrate and feed products, as both gangue and value minerals report in statistically abundant quantities to be resolved. Further information on the operational modes of QEMSCAN analysis is given in Appendix C.

2.1. Operational Statistics

Operational statistics for the QEMSCAN analyses of the three samples are presented in Table 1. For each sample, a minimum of 81,000 particles were measured in the particle mineral analysis (PMA) mode, generating over 1 million X-ray data points per sample from which the mineralogical data has been derived.

Table 1: Operational Statistics

Batch ID	14021-001 / MI5010-APR13			
SIP ID	TONO 1			
Analysis Type	PMA			
Sample	**Section ID**	**Pixel Size (µm)**	**No. Particles**	**No. X-Ray Data Points**
L163593	11B	3.5	81,264	1,073,673
L163163	21B	3.5	97,948	1,134,417
L163164	31B	3.5	109,239	1,193,167

2.2. QEMSCAN QA/QC

Key QEMSCAN mineralogical assays have been regressed with the chemical assays, as presented in Figure 1. Overall correlation, as measured by R-squared criteria is 0.987 with a slope of 0.852. The overall results are within acceptable ranges. The data is presented in tabular form in Table 2. Please note that SGS analyzed for Cu, Ni and Si. All other assays were provided by the North American Nickel Inc.

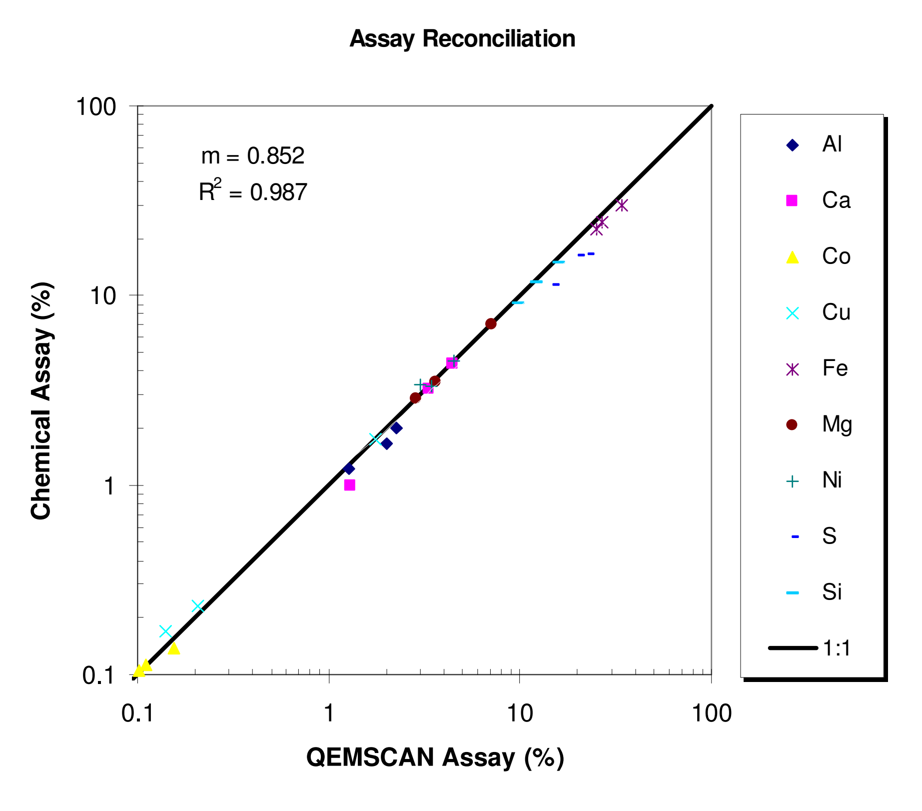


Figure 1 QEMSCAN Calculated Assays vs. Direct Chemical Assays

Table 2. QEMSCAN and Direct Chemical Assay Reconciliation

Sample	L163593	L163163	L163164
Element	**-300/+3um**	**-300/+3um**	**-300/+3um**
Al (QEMSCAN)	1.28	2.02	2.25
Al (NAN Chemical)	1.21	1.66	2.01
Ca (QEMSCAN)	1.28	3.31	4.41
Ca (NAN Chemical)	1.00	3.24	4.40
Co (QEMSCAN)	0.11	0.10	0.15
Co (NAN Chemical)	0.11	0.11	0.14
Cu (QEMSCAN)	0.21	0.14	1.76
Cu (SGS Chemical)	0.23	0.17	1.75
Fe (QEMSCAN)	25.3	33.9	26.7
Fe (NAN Chemical)	22.3	29.8	24.5
Mg (QEMSCAN)	7.09	2.84	3.62
Mg (NAN Chemical)	7.00	2.84	3.50
Ni (QEMSCAN)	2.98	4.53	3.47
Ni (SGS Chemical)	3.36	4.52	3.30
S (QEMSCAN)	14.9	22.7	20.2
S (NAN Chemical)	11.4	16.4	16.2
Si (QEMSCAN)	15.9	9.73	12.1
Si (SGS Chemical)	14.8	9.06	11.8

Note: SGS analyzed L163163 for total %S for QA/QC purposes. The assay result was 24.0% S as compared to the supplied value of 16.4%.

3. Modal Analysis

The modal analyses (in wt%) are presented in tabular form in Table 3 and are presented graphically in Figure 2. All samples contain significant quantities (>20 wt%) of pyrrhotite and pentlandite. Sample L163593 differs from the other two mainly in the fact that it contains abundant orthopyroxene. Very little orthopyroxene is present in L163163 and L163164; however, amphibole is dominant.

Sample L163593 contains major orthopyroxene (52.0%); moderate pyrrhotite (20.9%); and minor pentlandite (8.2%), pyrite (7.1%), feldspars (4.8%), amphibole (2.8%) and clinopyroxene (2.1%). Trace amounts (<1%) of biotite/phlogopite, chalcopyrite, quartz and carbonates are also present.

Sample L163163 contains major pyrrhotite (45.0%) and amphibole (29.5%); moderate amounts of pentlandite (12.4%); and minor amounts of feldspars (6.3%) and orthopyroxene (2.6%). Trace amounts (<2%) of pyrite, quartz, carbonates, chalcopyrite and biotite/phlogopite are also present.

Sample L163164 contains major amphibole (35.3%); moderate pyrrhotite (23.1%) and pyrite (11.6%); and minor amounts of pentlandite (9.5%), feldspars (6.2%), chalcopyrite (5.2%) and clinopyroxene (4.0%). Trace amounts (<2%) of orthopyroxene, quartz, carbonates and biotite/phlogopite are also present.

Table 3. Bulk Modal Analysis of Samples

Sample		**L163593**	**L163163**	**L163164**
Calculated ESD Particle Size		25	23	22
Mineral Mass (%)	Pentlandite	8.18	12.3	9.52
	Chalcopyrite	0.61	0.42	5.19
	Pyrrhotite	20.9	45.0	23.1
	Pyrite	7.06	1.48	11.6
	Quartz	0.22	1.20	1.59
	Feldspars	4.83	6.31	6.16
	Orthopyroxene	52.0	2.57	1.91
	Clinopyroxene	2.06	0.02	4.03
	Amphibole	2.84	29.5	35.3
	Biotite/Phlogopite	0.99	0.12	0.47
	Other Silicates	0.17	0.17	0.24
	Carbonates	0.19	0.85	0.71
	Apatite	0.01	0.04	0.01
	Other	0.03	0.04	0.16
	Total	100.0	100.0	100.0
Mean Grain Size by Frequency (µm)	Pentlandite	15	16	16
	Chalcopyrite	11	11	13
	Pyrrhotite	21	23	19
	Pyrite	25	12	25
	Quartz	6	7	8
	Feldspars	26	27	25
	Orthopyroxene	29	11	11
	Clinopyroxene	24	6	21
	Amphibole	13	24	22
	Biotite/Phlogopite	16	10	10
	Other Silicates	6	7	7
	Carbonates	10	11	11
	Apatite	10	35	8
	Other	7	8	14

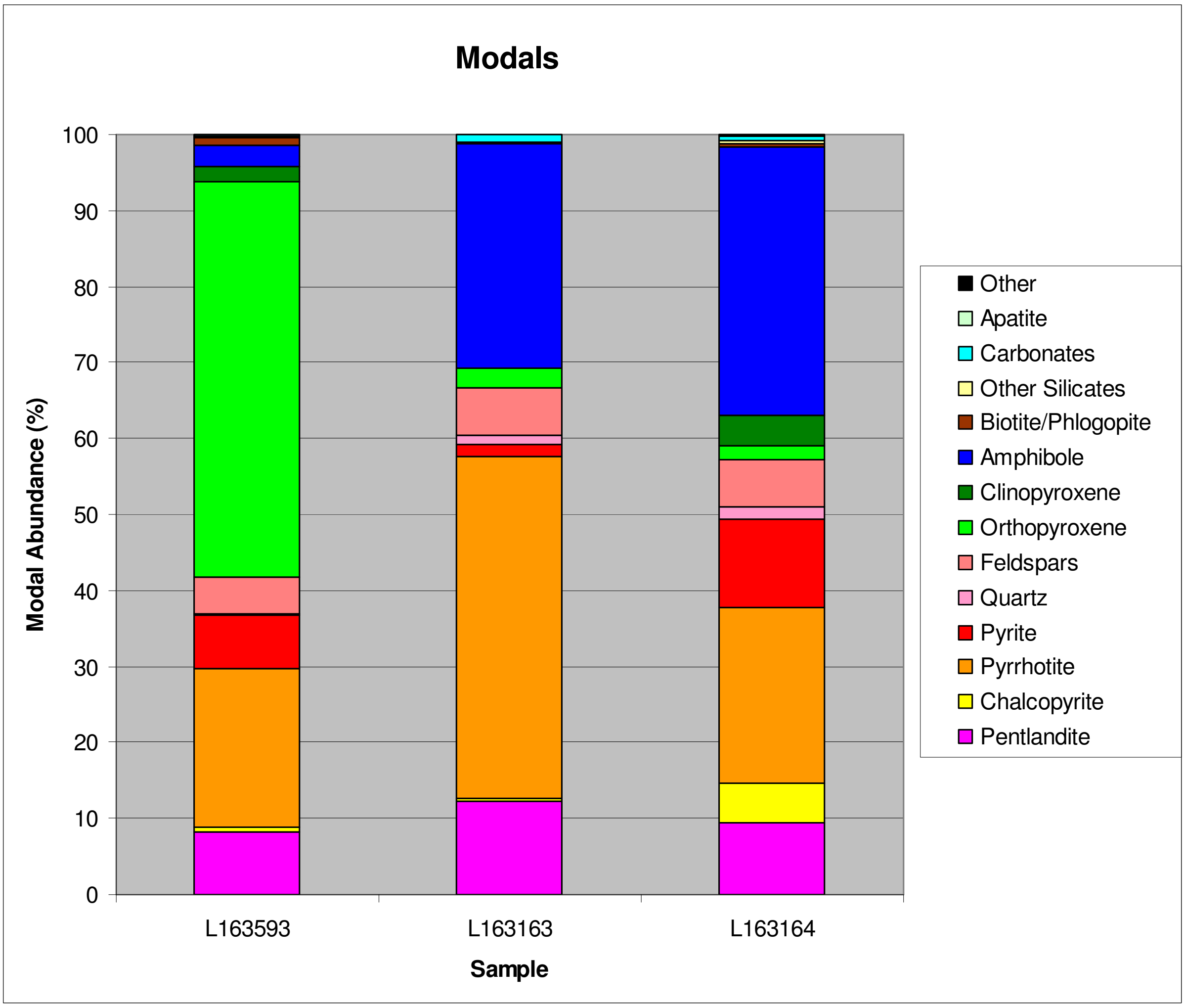


Figure 2: Mineral Distribution of Samples

4. Electron Microprobe (EMP) Results

The samples were submitted for electron microprobe (EMP) analyses to determine the solid solution Ni host minerals and overall mineral chemistries. In total, approximately 235 mineral grain analyses were acquired from various silicate and sulphide minerals. Average mineral compositions of silicates and sulphides from the EMP study are provided below in Table 4. The average elemental Ni contents of the various phases are highlighted in yellow. Complete EMP results are presented in Appendix B.

Table 4. Average Chemistries of Minerals Analyzed by EMP

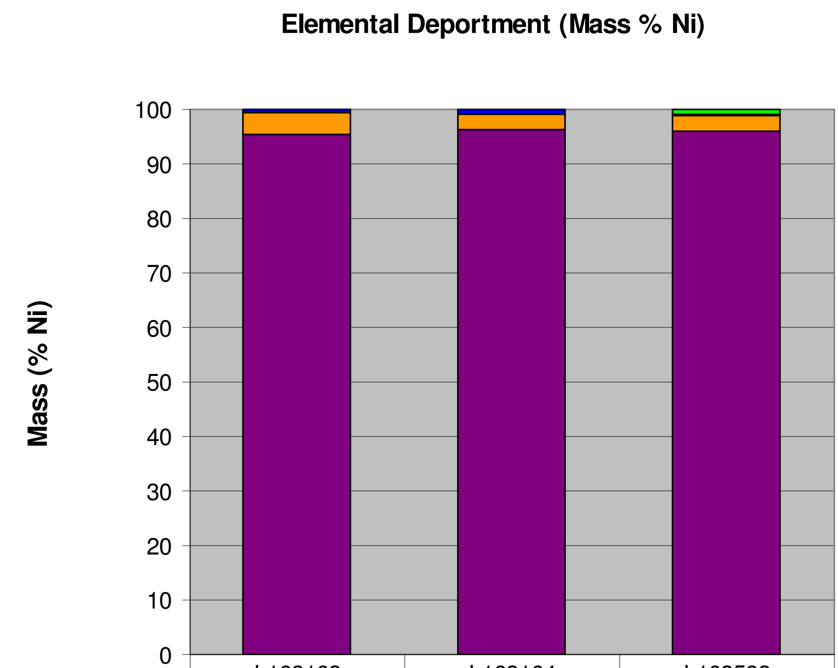
Mineral	Weight Percent										
	Na	Mg	K	Ni	Si	Al	Ca	Fe	Ti	Mn	Cr
Amphibole	0.59	10.6	0.32	0.07	23.4	3.34	8.53	7.07	0.33	0.13	0.26
Clinopyroxene	0.30	9.40	0.01	0.03	24.7	0.83	16.6	4.30	0.10	0.15	0.20
Biotite	0.09	12.1	8.30	0.09	17.6	8.10	0.00	5.48	2.10	0.01	0.84
Orthopyroxene	0.01	15.6	0.01	0.04	25.4	0.60	0.34	12.9	0.03	0.38	0.09

Mineral	Weight Percent						
	As	Fe	S	Ni	Zn	Co	Cu
Chalcopyrite	0.01	30.4	34.9	0.01	0.01	0.00	34.0
Pentlandite	0.01	30.1	33.1	35.8	0.01	0.76	0.03
Pyrite	0.00	46.0	53.1	0.05	0.00	0.73	0.00
Pyrrhotite	0.00	59.8	39.5	0.41	0.01	0.01	0.00

5. Nickel Elemental Deportment

The QEMSCAN elemental deportment of Ni is calculated using the mineral mass percent and the average chemistry from the electron microprobe analyses of the Ni-bearing minerals. Elemental Ni deportment is presented graphically in Figure 3.

Across the samples, pentlandite is the main contributor of nickel, hosting 95.5 to 96.3% of the overall Ni. Pyrrhotite hosts 2.7 to 4.0% of the overall nickel. Lesser contributors of Ni are orthopyroxene (0.03 to 0.78%), amphibole (0.07 to 0.73%), pyrite (0.02 to 0.17%), clinopyroxene (0.00 to 0.04%) and biotite/phlogopite (0.00 to 0.04%).



	L163163	L163164	L163593
Biotite/Phlogopite	0.00	0.01	0.04
Amphibole	0.47	0.73	0.07
Clinopyroxene	0.00	0.04	0.02
Orthopyroxene	0.03	0.03	0.78
Pyrite	0.02	0.17	0.12
Pyrrhotite	4.03	2.71	2.84
Pentlandite	95.5	96.3	96.1

Figure 3. Elemental Nickel Deportment

6. Cobalt Elemental Deportment

The QEMSCAN elemental deportment of Co is calculated using the mineral mass percent and the average chemistry from the electron microprobe analyses of the Co-bearing minerals. Elemental cobalt deportment is presented graphically in Figure 3.

Pentlandite and pyrite are the main hosts of cobalt in the samples. They contribute nearly equal proportions of Co in L163593 and L163164. Pentlandite is the main source of Co in L163163.

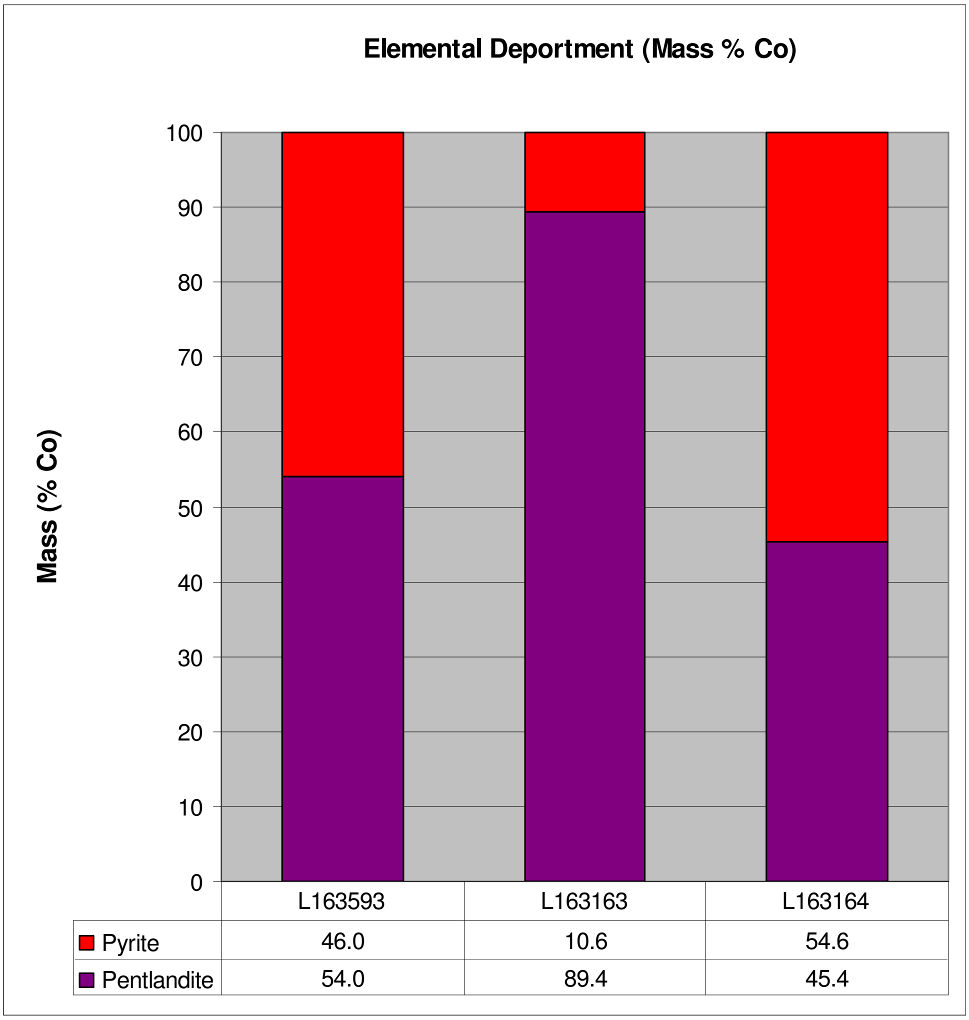


Figure 4. Elemental Cobalt Deportment

7. Copper Elemental Deportment

All copper is hosted by chalcopyrite.

8. Grain Size

The cumulative grain size distributions of the value mineral groups (pentlandite and chalcopyrite), Fe-sulphides, hard silicates, soft silicates, oxides and carbonates, along with the overall particle size distribution of the samples, are presented in Figure 5. Hard silicates (mainly pyroxenes and amphiboles) and Fe-sulphides (pyrrhotite and pyrite) tend to be the coarsest minerals, followed by pentlandite.

The P_{80}s (80% passing criteria, represents the particle or mineral grain size at which 80% is finer than this value) of targeted value minerals and overall particle are presented below in Table 5.

Table 5: P_{80}s of Minerals Calculated by QEMSCAN

Mineral	P_{80}		
	L163593	L163163	L163164
Pentlandite	53	65	62
Chalcopyrite	30	31	40
Fe-Sulphides	87	83	82
Hard Silicates	105	88	85
Soft Silicates	37	18	22
Oxides	22	16	57
Carbonates	22	30	30
Particle	104	88	94

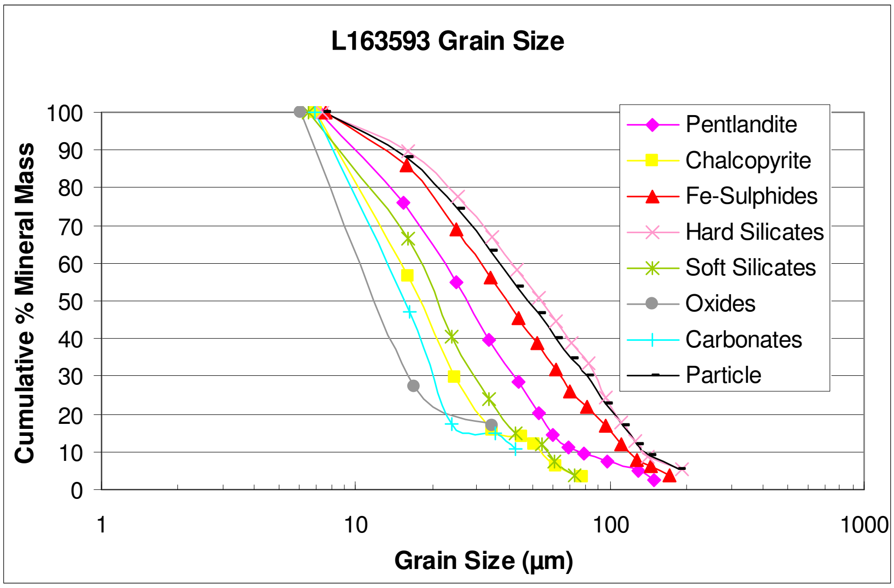


Figure 5: Grain Size for L163593

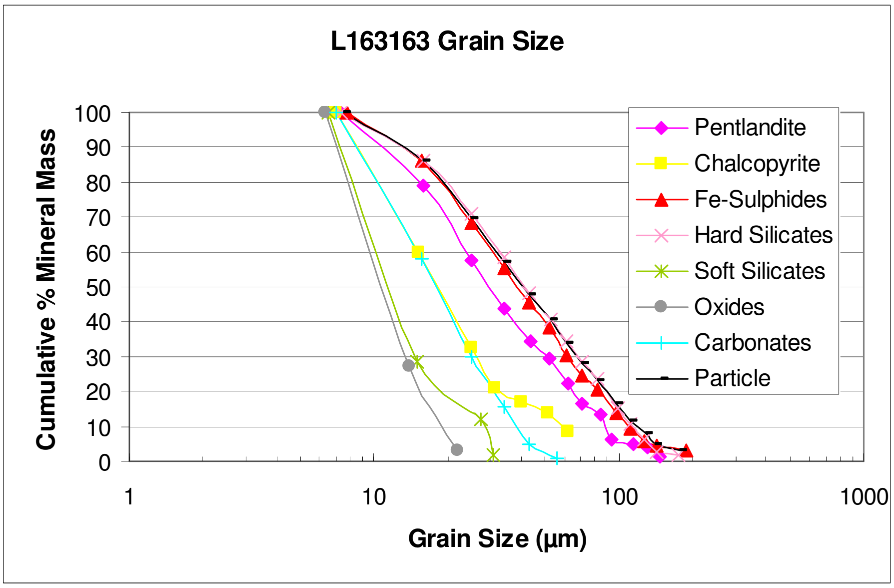


Figure 6: Grain Size for L163163

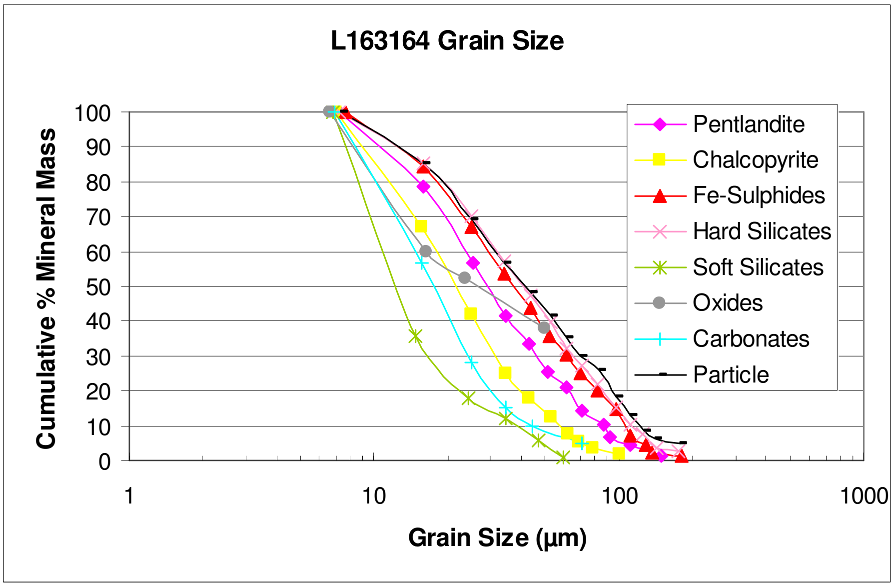


Figure 7: Grain Size for L163164

9. Liberation and Association

Liberation and association characteristics of the target value minerals, pentlandite and chalcopyrite, were examined. For the purposes of this analysis, particle liberation is defined based on 2D surface area percent. In liberation and association analysis, particles are classified in the following groups based on mineral-of-interest surface area percent:

Liberation and Association Classification Terminology

- Free = >95% surface area exposure of pentlandite (Pn) or chalcopyrite (Cpy)
- Liberated = >80% surface area exposure of Pn (or Cpy)
- Exp (Exposed) = Pn (or Cpy) with other mineral(s) combined show >95% surface area exposure, where Pn (or Cpy) shows >20% surface area exposure
- Pn (or Cpy) Inclusions = no surface area exposure of Pn (or Cpy)
- Exp Pn Complex = Pn with >20% surface area exposure combined with two or more other mineral groups
- <20% Pn (or Cpy) Complex = Particles in which Pn (or Cpy) surface exposure is <20%

To aid in the interpretation of the liberation and association data, the respective P_{80}s of L163593, L163163 and L163164 are 104 µm, 88 µm and 94 µm, respectively.

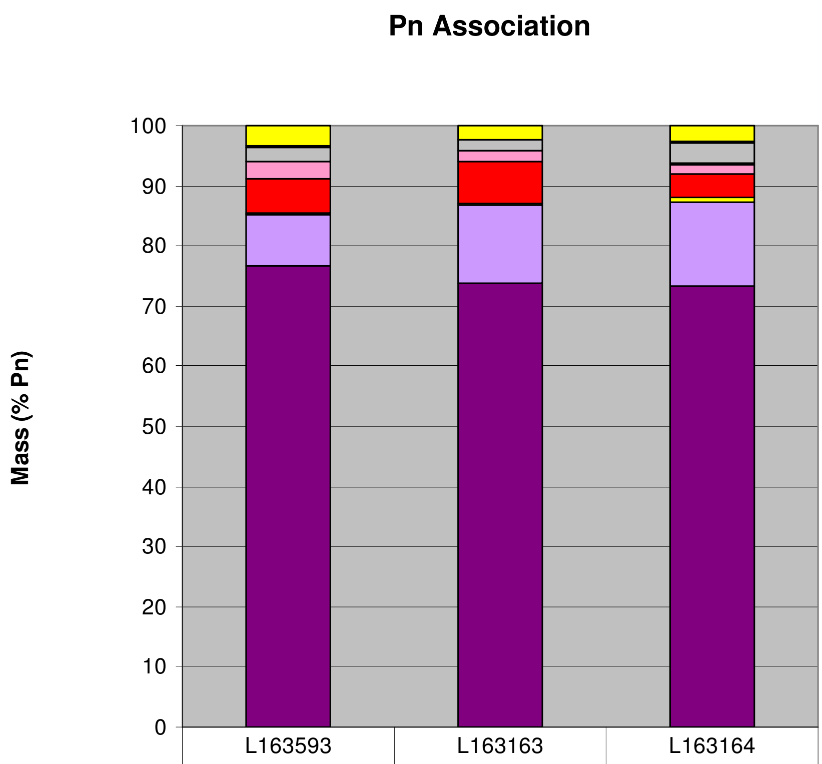
9.1. Pentlandite

Liberation and association characteristics of pentlandite are presented graphically in Figure 8 and are visually represented by pseudo-images sorted by association criteria in Figure 9.

Combined free and liberated pentlandite grains account for between 85.2 and 87.3% of the pentlandite across the samples. Non-liberated pentlandite which will likely float (surface area (SA) >20%) ranges from 9.8% to 11.1% (as summarized in Table 6). Non-liberated pentlandite which will likely not float (Complex Pn (Pn SA <20%)) ranges from 2.4% to 3.7%. Between 0.10% and 0.23% of the pentlandite occurs as inclusions and can not be floated. Pseudo-images of the complex grains are shown in Figure 10.

Table 6: Prediction of Flotation Characteristics of Pentlandite

Pentlandite	L163593	L163163	L163164
Free and Liberated	85.2	86.8	87.3
Non-Liberated but Floatable	11.1	10.8	9.83
Not Floatable	3.65	2.40	2.87



	L163593	L163163	L163164
<20% Pn Complex	3.42	2.27	2.68
Pn Inclusions	0.23	0.13	0.20
Exp Pn Complex	2.30	1.75	3.43
Exp Pn+Carbonates	0.00	0.02	0.02
Exp Pn+Oxides	0.05	0.01	0.02
Exp Pn+Phyllo/Clays	0.06	0.04	0.03
Exp Pn+Hard Sil	2.64	1.79	1.56
Exp Pn+FeS	5.92	7.02	4.09
Exp Pn+Cpy	0.17	0.18	0.68
Lib Pn	8.43	13.1	13.9
Free Pn	76.8	73.7	73.4

Figure 8: Pentlandite Liberation and Associations

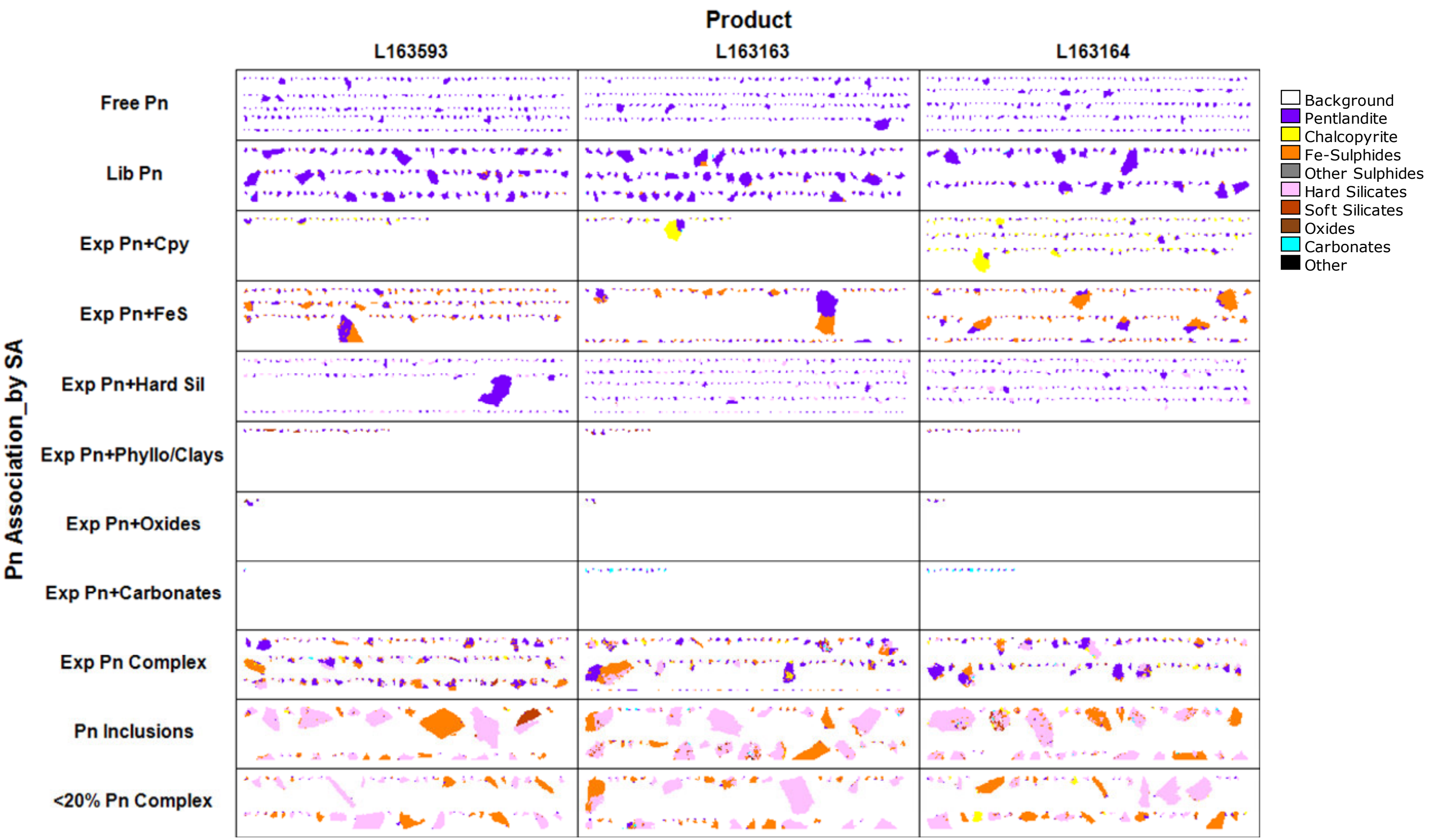


Figure 9: Image Grid of Pentlandite Associations

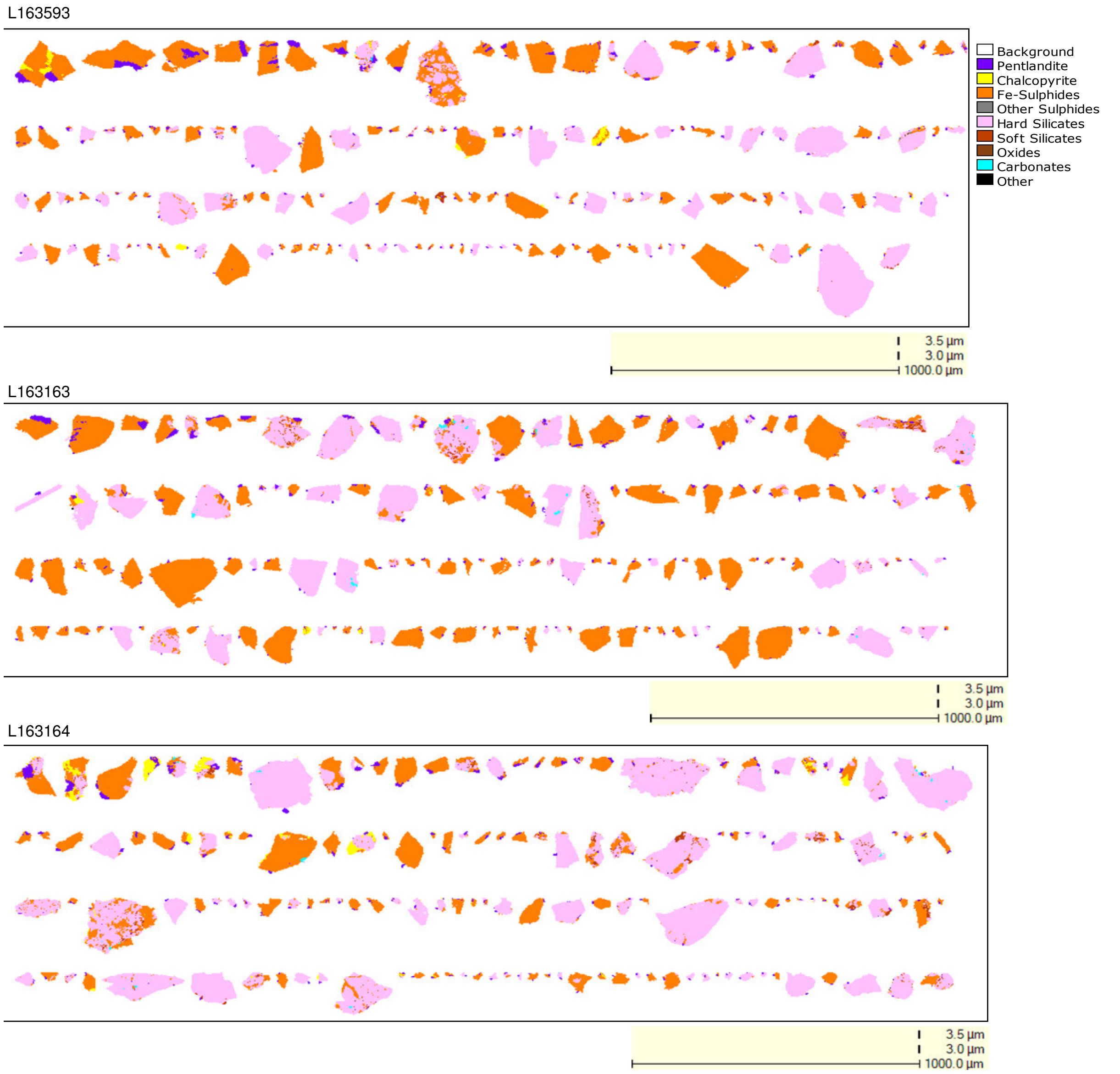


Figure 10: Particle Images of Complex Pentlandite Associations

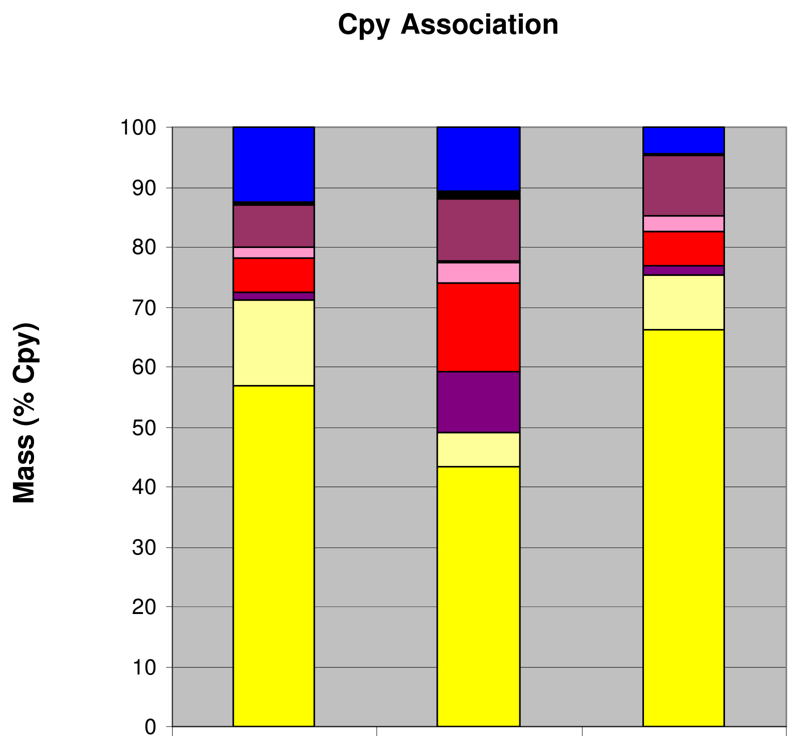
9.2. Chalcopyrite

Liberation and association characteristics of chalcopyrite are presented graphically in Figure 11 and are visually represented by pseudo-images sorted by association criteria in Figure 12.

Combined free and liberated chalcopyrite grains account for between 49.1% and 75.3% of the chalcopyrite across the samples. Sample L163164 has the highest chalcopyrite liberation and also has the highest amount of chalcopyrite (5.2% of sample). Non-liberated chalcopyrite which will likely float (surface area >20%) ranges from 15.9% to 39.0% (as summarized in Table 7). Non-liberated chalcopyrite which will likely not float (Complex Cpy (Cpy SA <20%)) ranges from 4.6% to 12.9%. Between 0.24% and 1.33% of the chalcopyrite across the samples occurs as inclusions and can not be floated. Pseudo-images of the complex grains are given in Figure 13.

Table 7: Prediction of Flotation Characteristics of Chalcopyrite

Chalcopyrite	L163593	L163163	L163164
Free and Liberated	71.2	49.1	75.3
Non-Liberated but Floatable	15.9	39.0	20.1
Not Floatable	12.9	11.9	4.56



	L163593	L163163	L163164
<20% Cpy Complex	12.6	10.6	4.32
Cpy Inclusions	0.37	1.33	0.24
Exp Cpy Complex	6.98	10.5	10.2
Exp Cpy+Carbonates	0.02	0.11	0.07
Exp Cpy+Oxides	0.00	0.02	0.00
Exp Cpy+Phyllo/Clays	0.07	0.00	0.01
Exp Cpy+Hard Sil	1.74	3.40	2.59
Exp Cpy+FeS	5.87	14.9	5.60
Exp Cpy+Pn	1.22	10.0	1.69
Lib Cpy	14.4	5.75	9.03
Free Cpy	56.8	43.3	66.3

Figure 11: Chalcopyrite Liberation and Associations

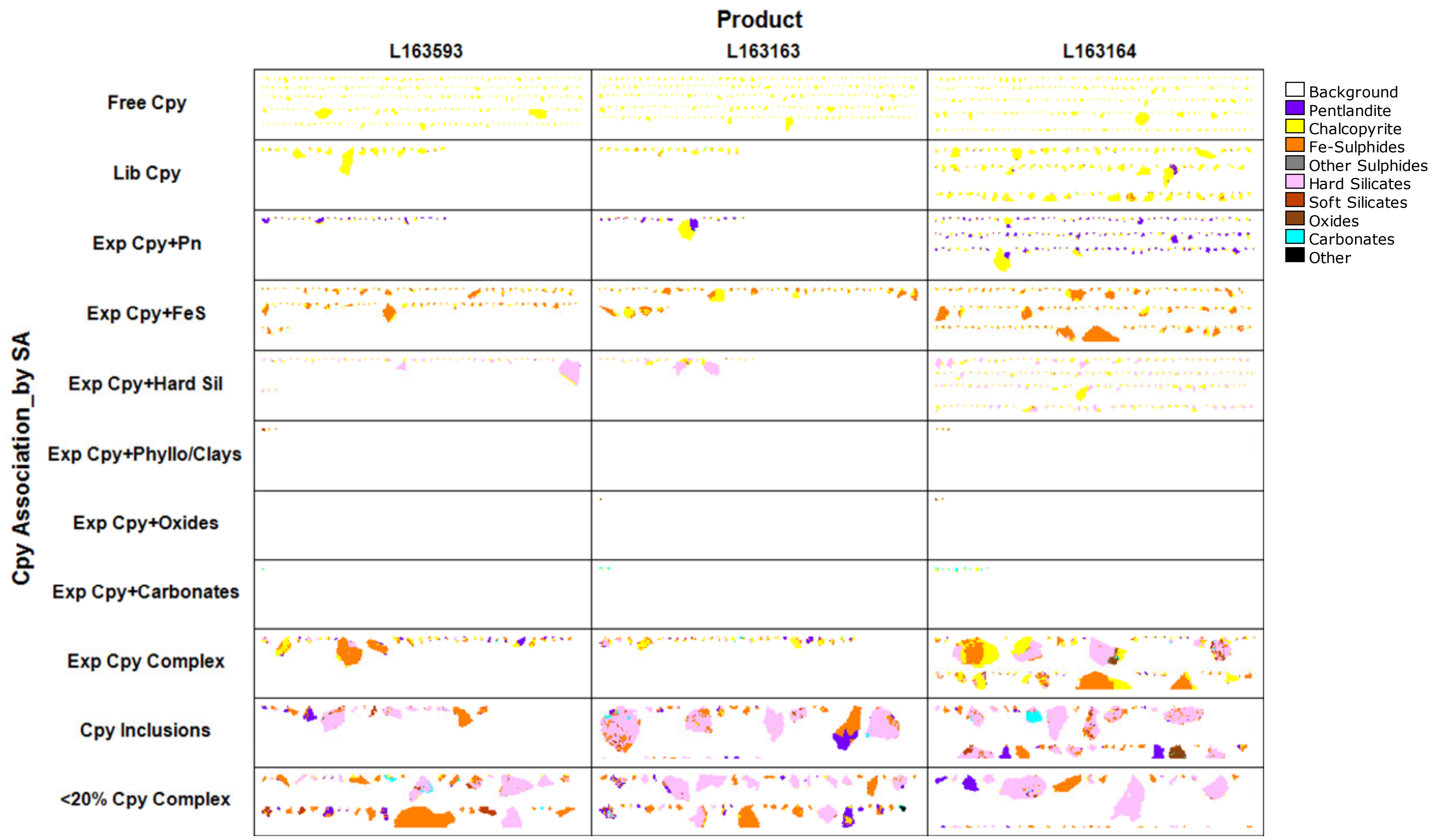
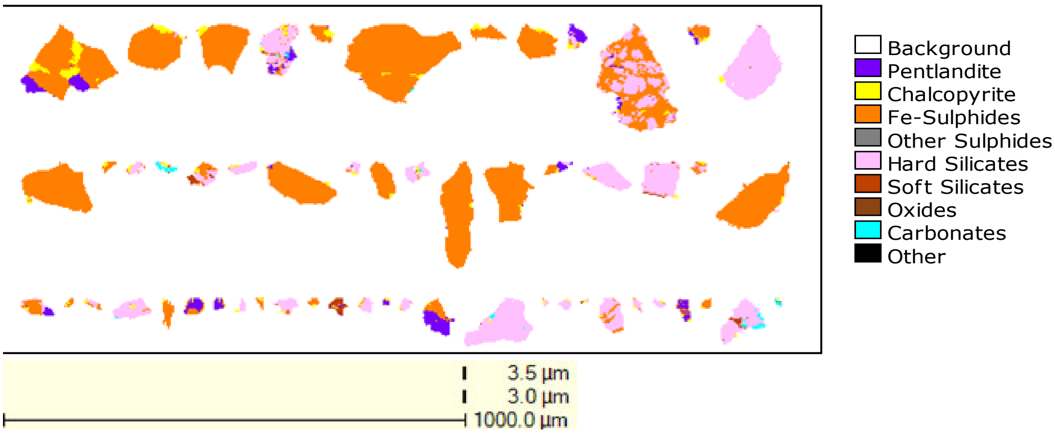
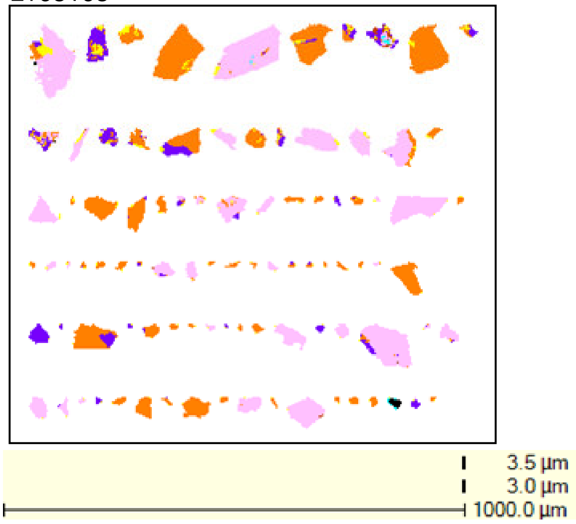


Figure 12: Image Grid of Chalcopyrite Associations

L163593



L163163



L163164

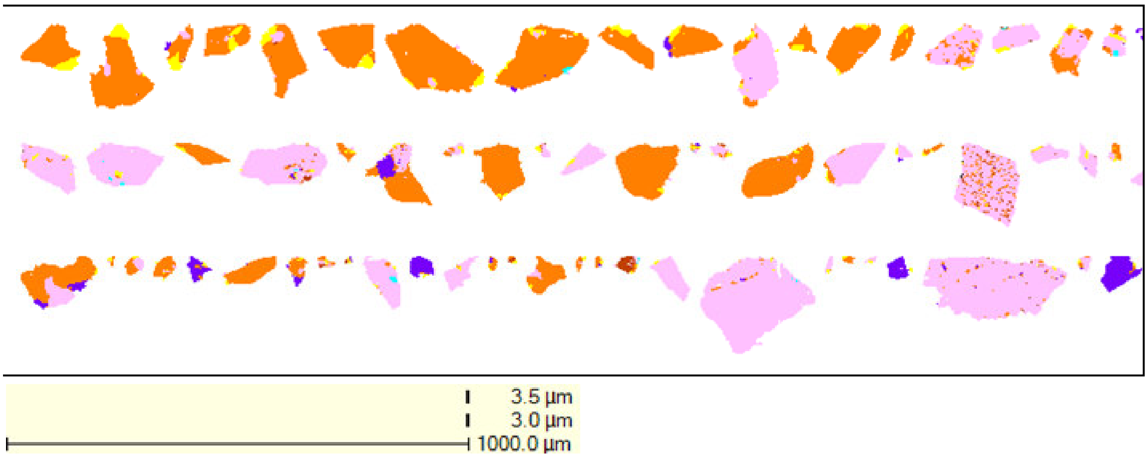


Figure 13: Particle Images of Complex Chalcopyrite Associations

10. Grade-Recovery Analyses

Mineralogically limiting grade-recovery analyses provide an indication of the theoretical maximum achievable elemental or mineral grade by recovery, based on the calculated mass of minerals and the total mass in each liberation category (individual particle liberation and grade). These results, of course, do not reflect any other physical factors (or flotation reagent kinetics) that could occur in the actual metallurgical process, such as possible fine-grained (<10 µm) sulphide and/or gangue entrainment (diluents) or very fine sulphide intergrowths on liberated grains (comprising <20% of the particle area) that would make selective sulphide flotation difficult. Therefore, predicted results show much higher grade-recovery relationships than actually achievable from the process. Mineralogically limiting grade-recovery curves for nickel and copper are summarized in Figure 14 and Figure 15.

10.1. Nickel

Based on the mineralogically limiting grade-recovery curves, for L163593, the maximum possible Ni grade is approximately 35% at a recovery of 84%. For L163163, the maximum possible Ni grade is approximately 35% at a recovery of 86%. For L163164, the maximum possible Ni grade is approximately 35% at a recovery of 87%. All three samples show high predicted recoveries for nickel.

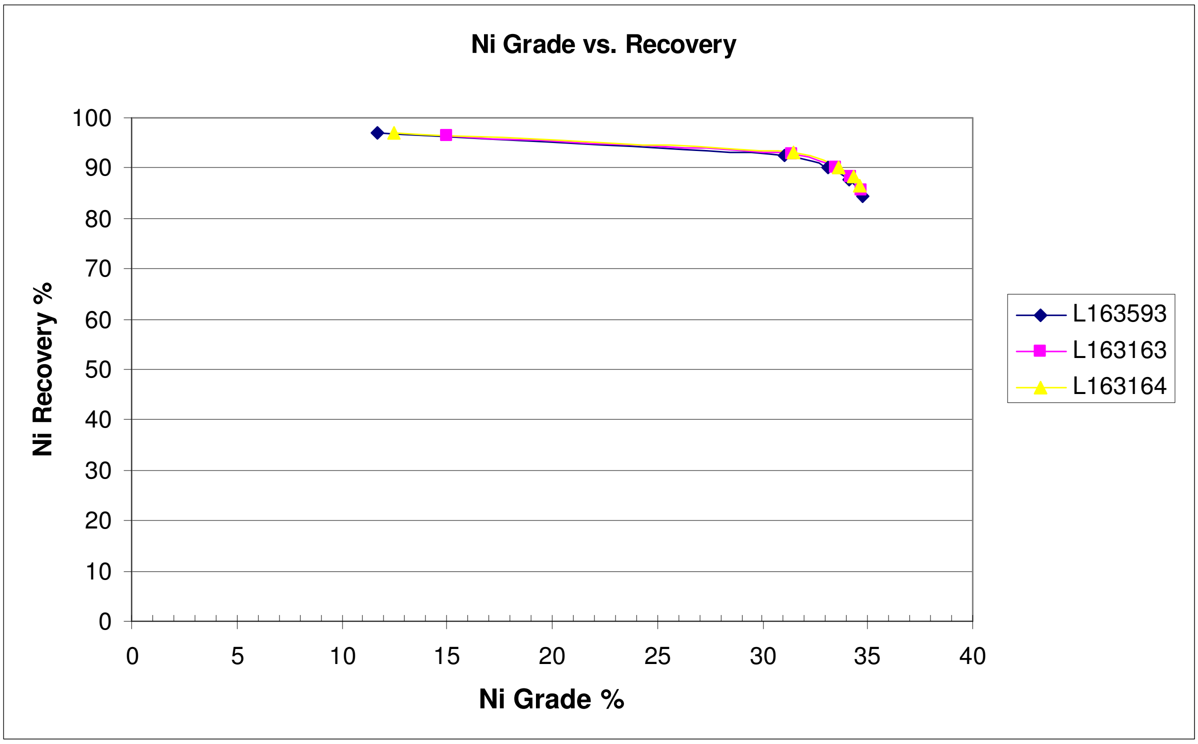


Figure 14. Predicted Nickel Grade vs. Recovery

10.2. Copper

For L163593, the maximum possible Cu grade is approximately 34% at a Cu recovery of 72%. For L163163, the maximum possible Cu grade is approximately 34% at a Cu recovery of 52%. For L163164, the maximum possible Cu grade is approximately 34% at a Cu recovery of 77%.

Sample L163163 shows relatively poor recovery (52%) compared with the other two samples (72 to 77%) at the highest grade of 34%. This sample has the lowest chalcopyrite grade and shows low chalcopyrite liberation values.

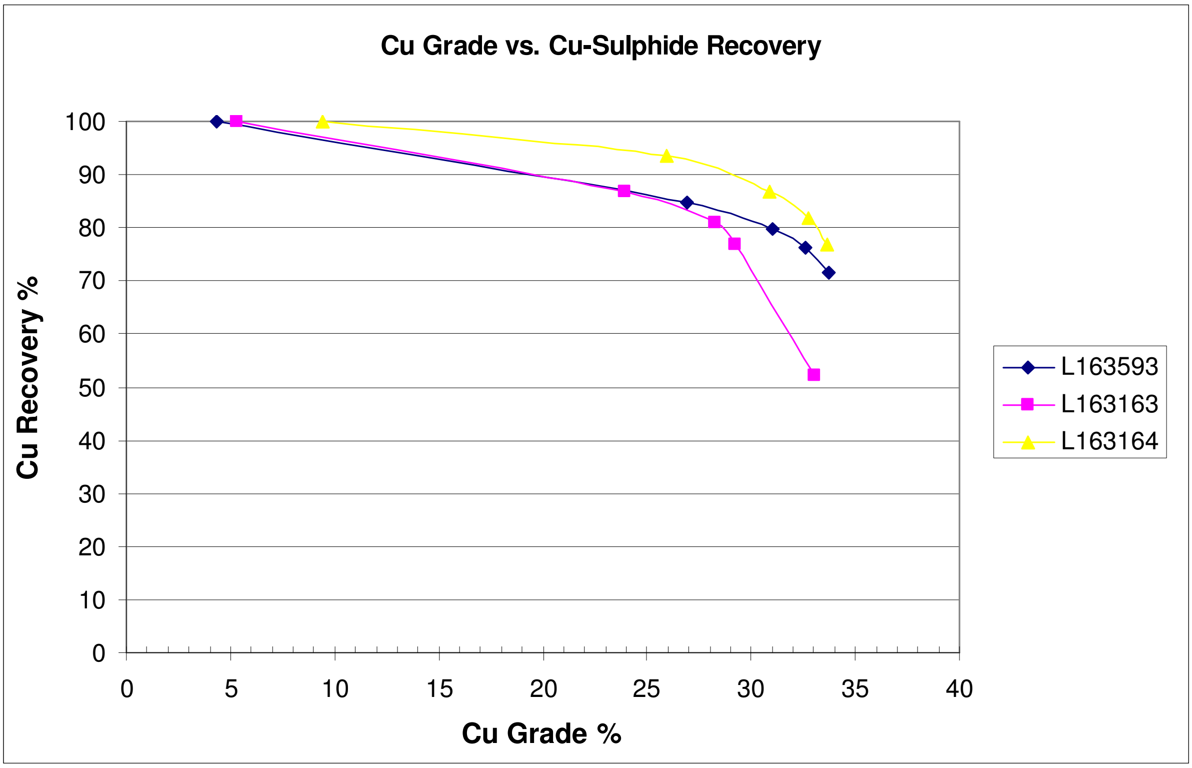


Figure 15. Predicted Copper Grade vs. Recovery

Conclusions

The high-definition mineralogical study of L163593, L163163 and L163164 identified the following sample characteristics:

QEMSCAN Modal Analysis

- Sample L163593 contains major orthopyroxene (52.0%); moderate pyrrhotite (20.9%); and minor pentlandite (8.2%), pyrite (7.1%), feldspars (4.8%), amphibole (2.8%) and clinopyroxene (2.1%). Trace amounts (<1%) of biotite/phlogopite, chalcopyrite, quartz and carbonates are also present.

- Sample L163163 contains major pyrrhotite (45.0%) and amphibole (29.5%); moderate amounts of pentlandite (12.4%); and minor amounts of feldspars (6.3%) and orthopyroxene (2.6%). Trace amounts (<2%) of pyrite, quartz, carbonates, chalcopyrite and biotite/phlogopite are also present.

- Sample L163164 contains major amphibole (35.3%); moderate pyrrhotite (23.1%) and pyrite (11.6%); and minor amounts of pentlandite (9.5%), feldspars (6.2%), chalcopyrite (5.2%) and clinopyroxene (4.0%). Trace amounts (<2%) of orthopyroxene, quartz, carbonates and biotite/phlogopite are also present.

Nickel Elemental Deportment

- Across the samples, pentlandite is the main contributor of nickel, hosting 95.5 to 96.3% of the overall Ni. Pyrrhotite hosts 2.7 to 4.0% of the overall nickel. Lesser contributors of Ni are orthopyroxene (0.03 to 0.78%), amphibole (0.07 to 0.73%), pyrite (0.02 to 0.17%), clinopyroxene (0.00 to 0.04%) and biotite/phlogopite (0.00 to 0.04%).

Cobalt Elemental Deportment

- Pentlandite and pyrite are the main hosts of cobalt in the samples. They contribute nearly equal proportions of Co in L163593 and L163164. Pentlandite is the main source of Co in L163163.

Chalcopyrite Elemental Deportment

- All Cu is hosted by chalcopyrite.

Grain Size

- Hard silicates (mainly pyroxenes and amphiboles) and Fe-sulphides (pyrrhotite and pyrite) tend to be the coarsest minerals, followed by pentlandite, chalcopyrite, carbonates, soft-silicates and oxides.

- Based on the QEMSCAN study, the respective P_{80}s of L163593, L163163 and L163164 are 104 µm, 88 µm and 94 µm, respectively.

Liberation of Pentlandite

- Combined free and liberated pentlandite grains account for between 85.2 and 87.3% of the pentlandite across the samples. Non-liberated pentlandite which will likely float (surface area >20%) ranges from 9.8% to 11.1%. Non-liberated pentlandite which will likely not float (Complex Pn (Pn SA <20%)) ranges from 2.4% to 3.7%. Between 0.10% and 0.23% of the pentlandite occurs as inclusions and can not be floated.

Liberation of Chalcopyrite

- Combined free and liberated chalcopyrite grains account for between 49.1% and 75.3% of the chalcopyrite across the samples. Sample L163164 has the highest chalcopyrite liberation and also has the highest abundance of chalcopyrite (5.2% of sample). Non-liberated chalcopyrite which will likely float (surface area >20%) ranges from 15.9% to 39.0%. Non-liberated chalcopyrite which will likely not float (Complex Cpy (Cpy SA <20%)) ranges from 4.6% to 12.9%. Between 0.24% and 1.33% of the chalcopyrite across the samples occurs as inclusions and can not be floated.

Mineralogically Limiting Grade Recovery

Irrespective of the actual metallurgical process, the mineralogically limiting grade-recovery curves indicate the best possible grade vs. recovery based solely on mineral liberation and grade.

- **Ni**: For L163593, the maximum possible Ni grade is approximately 35% at a recovery of 84%. For L163163, the maximum possible Ni grade is approximately 35% at a recovery of 86%. For L163164, the maximum possible Ni grade is approximately 35% at a recovery of 87%.

- **Cu**: For L163593, the maximum possible Cu grade is approximately 34% at a Cu recovery of 72%. For L163163, the maximum possible Cu grade is approximately 34% at a Cu recovery of 52%. For L163164, the maximum possible Cu grade is approximately 34% at a Cu recovery of 77%.

Appendix A – Certificate of Analysis

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

LR Internal Dept 14
Attn : Stephanie Downing

---, ---

Phone: ---
Fax:---

June 10, 2013

Date Rec. : 30 April 2013
LR Report : **CA03739-APR13**
Project : CALR-14021-001
Client Ref : MI5010-APR13

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Cu %	Ni %	Si %
1: L163593	0.23	3.36	14.8
2: L163163	0.17	4.52	9.06
3: L163164	1.75	3.30	11.8

Control Quality Assay
Not Suitable for Commercial Exchange

Tom Watt
Project Coordinator

OnLine LIMS

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

LR Internal Dept 14
Attn : Stephanie Downing

---, ---

Phone: ---
Fax:---

June 10, 2013

Date Rec. : 27 May 2013
LR Report : **CA03218-MAY13**
Project : CALR-14021-001
Client Ref : MI5010-APR13

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	S %
1: L163163	24.0

Control Quality Assay
Not Suitable for Commercial Exchange

Tom Watt
Project Coordinator

OnLine LIMS

Appendix B – EMPA Data

McGill

Electron Microprobe Laboratory, McGill University

Date 2013-May1, 3

Conditions

Name	JXA JEOL-8900L						
Acc. Voltage	20 kV						
Beam Current	30 nA						
Beam Size	3 um						
Correction Method	PRZ						
Counting Time (seconds)	As	Fe	S	Ni	Zn	Co	Cu
	20	20	20	20	20	20	20
Standards	CoNiAs	Po, Pn, Cpy, Py	Po, Pn, Cpy, Py	Pentlandite	Sphalerite	CoNiAs	Chalcopyrite
Detection Limits (wt%)							
Pyrite	0.0849	0.0303	0.0174	0.0245	0.0504	0.0276	0.0295
Pyrrhotite	0.0805	0.0304	0.0189	0.0257	0.0499	0.0282	0.0302
Chalcopyrite	0.0782	0.0308	0.0189	0.0276	0.0535	0.0291	0.0333
Pentlandite	0.0784	0.0286	0.0172	0.0273	0.0484	0.031	0.0323

Wt%

Name	As	Fe	S	Ni	Zn	Co	Cu	Total
L163593-Pentlandite	0.000	30.46	33.09	35.71	0.000	0.450	0.000	99.71
L163593-Pentlandite	0.000	30.11	33.09	35.66	0.011	0.650	0.037	99.56
L163593-Pentlandite	0.000	30.42	33.20	35.67	0.066	0.601	0.034	99.99
L163593-Pentlandite	0.000	30.03	33.00	35.79	0.000	0.638	0.026	99.48
L163593-Pentlandite	0.000	30.37	32.97	35.78	0.000	0.537	0.018	99.68
L163593-Pentlandite	0.011	30.25	33.16	36.17	0.000	0.640	0.039	100.27
L163593-Pentlandite	0.000	30.14	33.22	35.85	0.000	0.624	0.028	99.86
L163593-Pentlandite	0.000	30.19	33.12	35.79	0.000	0.688	0.027	99.82
L163593-Pentlandite	0.000	30.21	33.05	35.85	0.007	0.548	0.036	99.70
L163593-Pentlandite	0.000	30.15	33.18	35.62	0.011	0.623	0.032	99.62
L163593-Pentlandite	0.000	30.05	33.09	35.77	0.000	0.630	0.034	99.57
L163593-Pentlandite	0.000	30.61	33.13	35.76	0.000	0.489	0.005	99.99
L163593-Pentlandite	0.007	30.09	32.92	35.71	0.000	0.513	0.032	99.27
L163593-Pentlandite	0.000	30.01	33.17	35.82	0.000	0.615	0.015	99.63
L163593-Pentlandite	0.000	30.34	33.22	35.97	0.000	0.649	0.017	100.20
Average	**0.00**	**30.23**	**33.11**	**35.79**	**0.01**	**0.59**	**0.03**	**99.76**
Max	0.01	30.61	33.22	36.17	0.07	0.69	0.04	100.27
Min	0.00	30.01	32.92	35.62	0.00	0.45	0.00	99.27
Standard Deviation	0.00	0.18	0.09	0.14	0.02	0.07	0.01	0.27
L163593-Pyrite	0.009	46.35	53.07	0.100	0.000	0.484	0.000	100.01
L163593-Pyrite	0.000	46.44	53.37	0.073	0.041	0.440	0.000	100.36
L163593-Pyrite	0.000	46.18	53.32	0.124	0.000	0.567	0.000	100.19
L163593-Pyrite	0.000	46.12	53.15	0.028	0.000	0.558	0.000	99.86
L163593-Pyrite	0.000	45.80	53.17	0.055	0.000	0.938	0.005	99.97
L163593-Pyrite	0.000	46.10	53.00	0.010	0.010	0.516	0.000	99.64
L163593-Pyrite	0.000	46.23	53.09	0.059	0.000	0.377	0.000	99.76
L163593-Pyrite	0.000	46.24	52.87	0.027	0.000	0.614	0.007	99.76
L163593-Pyrite	0.000	45.87	53.06	0.044	0.000	0.752	0.000	99.73
Average	**0.00**	**46.15**	**53.12**	**0.06**	**0.01**	**0.58**	**0.00**	**99.92**
Max	0.01	46.44	53.37	0.12	0.04	0.94	0.01	100.36
Min	0.00	45.80	52.87	0.01	0.00	0.38	0.00	99.64
Standard Deviation	0.00	0.21	0.15	0.04	0.01	0.17	0.00	0.24
L163593-Pyrrhotite	0.000	59.55	39.66	0.450	0.000	0.021	0.000	99.68
L163593-Pyrrhotite	0.000	59.88	39.61	0.289	0.051	0.005	0.000	99.84
L163593-Pyrrhotite	0.000	59.81	39.61	0.259	0.000	0.000	0.010	99.69
L163593-Pyrrhotite	0.000	59.60	39.50	0.315	0.007	0.029	0.000	99.45
L163593-Pyrrhotite	0.000	60.09	39.61	0.334	0.000	0.015	0.008	100.06
L163593-Pyrrhotite	0.000	60.15	38.83	0.697	0.000	0.000	0.000	99.68
L163593-Pyrrhotite	0.000	60.07	39.18	0.757	0.000	0.000	0.000	100.01
L163593-Pyrrhotite	0.000	59.89	39.66	0.371	0.014	0.011	0.000	99.95
L163593-Pyrrhotite	0.000	59.74	39.57	0.329	0.000	0.006	0.000	99.65
L163593-Pyrrhotite	0.000	59.70	39.46	0.406	0.038	0.000	0.000	99.60
L163593-Pyrrhotite	0.000	59.58	39.53	0.346	0.000	0.000	0.000	99.46
L163593-Pyrrhotite	0.000	59.76	39.35	0.440	0.000	0.000	0.000	99.55
L163593-Pyrrhotite	0.000	59.33	39.47	0.509	0.000	0.014	0.000	99.32
L163593-Pyrrhotite	0.000	59.71	39.62	0.420	0.000	0.006	0.000	99.76
L163593-Pyrrhotite	0.008	59.71	39.42	0.385	0.000	0.040	0.019	99.58
Average	**0.00**	**59.77**	**39.47**	**0.42**	**0.01**	**0.01**	**0.00**	**99.68**
Max	0.01	60.15	39.66	0.76	0.05	0.04	0.02	100.06
Min	0.00	59.33	38.83	0.26	0.00	0.00	0.00	99.32
Standard Deviation	0.00	0.22	0.22	0.14	0.02	0.01	0.01	0.21
L163593-Chalcopyrite	0.000	30.01	35.04	0.037	0.000	0.000	33.94	99.03
L163593-Chalcopyrite	0.000	30.11	34.99	0.063	0.117	0.000	34.33	99.61
L163593-Chalcopyrite	0.000	30.20	34.79	0.009	0.000	0.000	34.16	99.16
L163593-Chalcopyrite	0.000	30.03	35.08	0.000	0.000	0.008	34.28	99.40
L163593-Chalcopyrite	0.000	30.30	34.90	0.008	0.000	0.000	34.25	99.46
Average	**0.00**	**30.13**	**34.96**	**0.02**	**0.02**	**0.00**	**34.19**	**99.33**
Max	0.00	30.30	35.08	0.06	0.12	0.01	34.33	99.61
Min	0.00	30.01	34.79	0.00	0.00	0.00	33.94	99.03
Standard Deviation	0.00	0.12	0.12	0.03	0.05	0.00	0.15	0.24

Wt%								
Name	**As**	**Fe**	**S**	**Ni**	**Zn**	**Co**	**Cu**	**Total**
L163163-Pentlandite	0.053	29.97	32.86	35.92	0.000	0.808	0.023	99.63
L163163-Pentlandite	0.051	30.26	32.91	35.80	0.000	0.735	0.022	99.78
L163163-Pentlandite	0.000	30.06	33.10	35.65	0.000	0.869	0.019	99.70
L163163-Pentlandite	0.000	30.01	32.91	35.86	0.000	0.923	0.051	99.75
L163163-Pentlandite	0.000	29.77	33.12	36.24	0.000	0.691	0.052	99.87
L163163-Pentlandite	0.000	30.28	33.12	35.75	0.000	0.834	0.050	100.03
L163163-Pentlandite	0.030	30.19	32.79	35.91	0.000	0.720	0.020	99.66
L163163-Pentlandite	0.000	30.08	32.78	36.07	0.000	0.748	0.044	99.72
L163163-Pentlandite	0.000	30.14	33.02	35.93	0.000	0.888	0.016	99.99
L163163-Pentlandite	0.009	29.81	32.97	36.11	0.027	0.773	0.020	99.72
L163163-Pentlandite	0.009	29.80	32.70	35.89	0.074	0.882	0.041	99.40
L163163-Pentlandite	0.000	30.10	32.97	35.90	0.000	0.891	0.032	99.89
L163163-Pentlandite	0.000	29.82	32.95	35.90	0.072	0.932	0.041	99.72
L163163-Pentlandite	0.000	30.12	32.99	36.18	0.007	0.688	0.019	100.01
L163163-Pentlandite	0.052	29.93	33.12	35.80	0.000	0.621	0.024	99.55
Average	**0.01**	**30.02**	**32.95**	**35.93**	**0.01**	**0.80**	**0.03**	**99.76**
Max	0.05	30.28	33.12	36.24	0.07	0.93	0.05	100.03
Min	0.00	29.77	32.70	35.65	0.00	0.62	0.02	99.40
Standard Deviation	0.02	0.17	0.13	0.16	0.03	0.10	0.01	0.18
L163163-Pyrite	0.000	44.15	53.04	0.161	0.000	2.740	0.000	100.09
L163163-Pyrite	0.000	46.06	53.02	0.000	0.000	0.926	0.000	100.01
L163163-Pyrite	0.000	46.15	53.07	0.019	0.000	0.616	0.000	99.86
L163163-Pyrite	0.000	46.04	53.01	0.069	0.000	0.476	0.000	99.60
L163163-Pyrite	0.000	46.41	53.17	0.021	0.000	0.556	0.000	100.16
L163163-Pyrite	0.036	45.88	52.93	0.032	0.000	0.535	0.000	99.41
L163163-Pyrite	0.000	45.01	52.81	0.041	0.000	1.610	0.000	99.47
L163163-Pyrite	0.025	45.18	53.24	0.059	0.028	1.780	0.008	100.32
L163163-Pyrite	0.000	46.44	52.91	0.011	0.000	0.375	0.016	99.75
L163163-Pyrite	0.000	45.86	53.11	0.034	0.000	0.750	0.000	99.75
Average	**0.01**	**45.72**	**53.03**	**0.04**	**0.00**	**1.04**	**0.00**	**99.84**
Max	0.04	46.44	53.24	0.16	0.03	2.74	0.02	100.32
Min	0.00	44.15	52.81	0.00	0.00	0.38	0.00	99.41
Standard Deviation	0.01	0.72	0.13	0.05	0.01	0.77	0.01	0.30
L163163-Pyrrhotite	0.000	59.93	39.40	0.434	0.000	0.022	0.000	99.79
L163163-Pyrrhotite	0.000	59.88	39.56	0.411	0.010	0.000	0.000	99.86
L163163-Pyrrhotite	0.000	59.62	39.66	0.489	0.000	0.006	0.009	99.78
L163163-Pyrrhotite	0.000	59.87	38.85	0.798	0.000	0.000	0.000	99.52
L163163-Pyrrhotite	0.000	59.70	39.47	0.348	0.043	0.007	0.000	99.57
L163163-Pyrrhotite	0.050	59.61	39.50	0.413	0.017	0.009	0.000	99.60
L163163-Pyrrhotite	0.000	59.96	39.42	0.278	0.000	0.005	0.000	99.66
L163163-Pyrrhotite	0.036	59.99	38.85	0.782	0.000	0.000	0.009	99.67
L163163-Pyrrhotite	0.047	59.75	39.22	0.592	0.000	0.000	0.000	99.61
L163163-Pyrrhotite	0.000	59.75	39.55	0.364	0.000	0.000	0.000	99.66
L163163-Pyrrhotite	0.000	59.70	39.57	0.366	0.000	0.014	0.000	99.65
L163163-Pyrrhotite	0.007	60.01	39.00	0.547	0.000	0.000	0.000	99.56
L163163-Pyrrhotite	0.000	59.77	39.77	0.369	0.000	0.000	0.018	99.93
L163163-Pyrrhotite	0.028	59.79	39.66	0.322	0.062	0.000	0.000	99.86
L163163-Pyrrhotite	0.000	59.97	39.55	0.335	0.000	0.013	0.000	99.87
Average	**0.01**	**59.82**	**39.40**	**0.46**	**0.01**	**0.01**	**0.00**	**99.71**
Max	0.05	60.01	39.77	0.80	0.06	0.02	0.02	99.93
Min	0.00	59.61	38.85	0.28	0.00	0.00	0.00	99.52
Standard Deviation	0.02	0.13	0.29	0.16	0.02	0.01	0.01	0.13
L163163-Chalcopyrite	0.000	30.42	35.11	0.094	0.000	0.005	34.01	99.64
L163163-Chalcopyrite	0.022	30.61	34.76	0.000	0.000	0.000	34.34	99.73
L163163-Chalcopyrite	0.000	30.80	34.90	0.000	0.000	0.000	33.81	99.51
L163163-Chalcopyrite	0.056	30.38	35.36	0.015	0.000	0.007	33.95	99.77
L163163-Chalcopyrite	0.000	30.19	35.00	0.000	0.000	0.000	29.41	94.60
L163163-Chalcopyrite	0.000	30.59	35.12	0.006	0.000	0.009	34.64	100.37
Average	**0.01**	**30.50**	**35.04**	**0.02**	**0.00**	**0.00**	**33.36**	**98.94**
Max	0.06	30.80	35.36	0.09	0.00	0.01	34.64	100.37
Min	0.00	30.19	34.76	0.00	0.00	0.00	29.41	94.60
Standard Deviation	0.02	0.21	0.21	0.04	0.00	0.00	1.96	2.14

Wt%								
Name	**As**	**Fe**	**S**	**Ni**	**Zn**	**Co**	**Cu**	**Total**
L163164-Pentlandite	0.000	29.84	33.38	35.77	0.035	0.947	0.034	100.01
L163164-Pentlandite	0.027	30.18	33.28	35.75	0.052	0.896	0.024	100.21
L163164-Pentlandite	0.000	30.32	33.25	35.75	0.000	0.831	0.038	100.19
L163164-Pentlandite	0.000	29.85	33.22	35.62	0.000	0.795	0.023	99.51
L163164-Pentlandite	0.000	29.59	33.22	36.09	0.000	0.810	0.034	99.74
L163164-Pentlandite	0.066	30.10	33.26	35.68	0.000	0.892	0.025	100.02
L163164-Pentlandite	0.015	29.93	32.93	35.62	0.000	0.928	0.016	99.44
L163164-Pentlandite	0.025	29.83	33.12	35.69	0.084	0.891	0.000	99.64
L163164-Pentlandite	0.000	29.94	33.08	35.63	0.000	0.914	0.035	99.60
L163164-Pentlandite	0.000	29.98	33.03	35.67	0.000	0.920	0.045	99.64
L163164-Pentlandite	0.000	30.18	33.42	35.58	0.000	0.909	0.031	100.12
L163164-Pentlandite	0.000	29.97	33.22	35.70	0.057	0.792	0.047	99.79
L163164-Pentlandite	0.000	29.67	32.97	35.84	0.000	0.979	0.031	99.49
L163164-Pentlandite	0.000	29.62	33.14	36.14	0.000	0.770	0.039	99.71
Average	**0.01**	**29.93**	**33.18**	**35.75**	**0.02**	**0.88**	**0.03**	**99.79**
Max	0.07	30.32	33.42	36.14	0.08	0.98	0.05	100.21
Min	0.00	29.59	32.93	35.58	0.00	0.77	0.00	99.44
Standard Deviation	0.02	0.22	0.14	0.17	0.03	0.07	0.01	0.27
L163164-Pyrite	0.000	46.29	52.94	0.024	0.011	0.710	0.006	99.98
L163164-Pyrite	0.000	46.05	52.95	0.045	0.000	0.421	0.023	99.49
L163164-Pyrite	0.000	46.27	52.88	0.061	0.000	0.596	0.000	99.81
L163164-Pyrite	0.012	46.09	53.02	0.034	0.036	0.432	0.014	99.64
L163164-Pyrite	0.000	46.43	53.08	0.046	0.000	0.479	0.000	100.04
L163164-Pyrite	0.005	46.35	53.06	0.049	0.000	0.534	0.000	100.00
L163164-Pyrite	0.017	46.33	53.19	0.096	0.000	0.442	0.000	100.08
L163164-Pyrite	0.000	46.21	52.99	0.059	0.000	0.592	0.000	99.85
L163164-Pyrite	0.000	46.35	53.04	0.072	0.000	0.571	0.011	100.04
L163164-Pyrite	0.000	46.16	53.17	0.005	0.000	0.824	0.010	100.17
Average	**0.00**	**46.25**	**53.03**	**0.05**	**0.00**	**0.56**	**0.01**	**99.91**
Max	0.02	46.43	53.19	0.10	0.04	0.82	0.02	100.17
Min	0.00	46.05	52.88	0.01	0.00	0.42	0.00	99.49
Standard Deviation	0.01	0.12	0.10	0.03	0.01	0.13	0.01	0.21
L163164-Pyrrhotite	0.007	59.77	39.48	0.361	0.000	0.005	0.000	99.62
L163164-Pyrrhotite	0.000	59.90	39.48	0.360	0.000	0.000	0.000	99.74
L163164-Pyrrhotite	0.000	60.03	39.42	0.287	0.072	0.007	0.000	99.82
L163164-Pyrrhotite	0.000	59.74	39.47	0.285	0.043	0.017	0.006	99.56
L163164-Pyrrhotite	0.000	59.67	39.44	0.302	0.000	0.000	0.005	99.42
L163164-Pyrrhotite	0.000	59.90	39.90	0.259	0.014	0.021	0.000	100.09
L163164-Pyrrhotite	0.000	59.61	39.55	0.392	0.009	0.010	0.000	99.57
L163164-Pyrrhotite	0.010	59.94	39.62	0.276	0.000	0.000	0.000	99.85
L163164-Pyrrhotite	0.000	59.88	39.02	0.617	0.000	0.000	0.000	99.52
L163164-Pyrrhotite	0.000	59.91	39.44	0.290	0.000	0.000	0.000	99.64
L163164-Pyrrhotite	0.000	59.68	39.42	0.419	0.052	0.000	0.000	99.57
L163164-Pyrrhotite	0.000	60.21	39.55	0.249	0.000	0.000	0.027	100.04
L163164-Pyrrhotite	0.000	59.90	39.55	0.262	0.000	0.015	0.006	99.73
L163164-Pyrrhotite	0.000	60.01	39.51	0.365	0.007	0.015	0.000	99.91
L163164-Pyrrhotite	0.000	59.61	39.58	0.387	0.000	0.006	0.000	99.58
Average	**0.00**	**59.85**	**39.50**	**0.34**	**0.01**	**0.01**	**0.00**	**99.71**
Max	0.01	60.21	39.90	0.62	0.07	0.02	0.03	100.09
Min	0.00	59.61	39.02	0.25	0.00	0.00	0.00	99.42
Standard Deviation	0.00	0.17	0.18	0.09	0.02	0.01	0.01	0.20
L163164-Chalcopyrite	0.000	30.31	34.51	0.000	0.000	0.000	34.57	99.39
L163164-Chalcopyrite	0.000	30.57	34.69	0.000	0.000	0.000	34.63	99.89
L163164-Chalcopyrite	0.000	30.58	34.83	0.000	0.000	0.000	34.44	99.85
L163164-Chalcopyrite	0.000	30.25	35.07	0.000	0.000	0.000	34.50	99.82
L163164-Chalcopyrite	0.000	30.23	34.62	0.017	0.000	0.000	34.39	99.26
L163164-Chalcopyrite	0.000	30.55	34.59	0.000	0.000	0.014	34.60	99.75
L163164-Chalcopyrite	0.000	30.35	34.76	0.009	0.000	0.000	34.61	99.73
L163164-Chalcopyrite	0.000	30.45	34.75	0.000	0.000	0.000	34.57	99.77
L163164-Chalcopyrite	0.050	30.32	34.94	0.000	0.000	0.000	34.49	99.80
L163164-Chalcopyrite	0.008	30.56	34.62	0.000	0.000	0.000	34.60	99.79
L163164-Chalcopyrite	0.000	30.48	34.73	0.005	0.000	0.000	34.44	99.66
L163164-Chalcopyrite	0.039	30.56	34.72	0.000	0.000	0.000	34.61	99.93
L163164-Chalcopyrite	0.000	30.43	34.76	0.000	0.009	0.011	34.54	99.75
L163164-Chalcopyrite	0.000	30.60	35.20	0.000	0.000	0.000	34.41	100.21
L163164-Chalcopyrite	0.006	30.59	35.26	0.000	0.000	0.000	34.58	100.44
Average	**0.01**	**30.46**	**34.80**	**0.00**	**0.00**	**0.00**	**34.53**	**99.80**
Max	0.05	30.60	35.26	0.02	0.01	0.01	34.63	100.44
Min	0.00	30.23	34.51	0.00	0.00	0.00	34.39	99.26
Standard Deviation	0.02	0.13	0.22	0.00	0.00	0.00	0.08	0.28

McGill

Electron Microprobe Laboratory, McGill University

Date 2013-May-13-14

Conditions

Name JXA JEOL-8900L

Acc. Voltage 20 kV
Beam Current 30 nA
Beam Size 3-10 um
Correction Method ZAF

	Na_2O	MgO	K_2O	NiO	SiO_2	Al_2O_3	CaO	FeO	TiO_2	MnO	Cr_2O_3
Counting Time (seco	20	20	20	30	20	20	20	20	20	20	20
Standards	Albite	Diopside	Orthoclase	NiO	Diopside	Orthoclase	Diopside	Hematite	Rutile	Spessartine	Chromite
Detecion Limits (wt%)											
Amphibole	0.0234	0.0220	0.0144	0.0179	0.0263	0.0191	0.0186	0.0912	0.0277	0.0194	0.0424
Mica	0.0236	0.0214	0.0140	0.0182	0.0256	0.0190	0.0178	0.0197	0.0288	0.0200	0.0421

Wt%

Name	Na	Mg	K	Ni	Si	Al	Ca	Fe	Ti	Mn	Cr
L163593-Amphibole	1.072	9.774	0.978	0.066	20.553	5.832	8.451	5.569	1.035	0.054	1.037
L163593-Amphibole	1.141	10.006	0.881	0.057	20.746	5.924	8.622	5.818	0.761	0.058	0.999
L163593-Amphibole	1.084	9.932	0.878	0.049	20.710	5.927	8.546	5.746	0.738	0.049	1.002
L163593-Amphibole	0.415	12.175	0.238	0.070	24.294	2.720	8.748	4.545	0.174	0.060	0.501
L163593-Amphibole	1.157	10.126	0.885	0.064	21.143	5.539	8.651	5.136	0.970	0.054	0.923
Average	**0.974**	**10.40**	**0.772**	**0.061**	**21.49**	**5.188**	**8.604**	**5.363**	**0.736**	**0.055**	**0.892**
Max	1.157	12.17	0.978	0.070	24.29	5.927	8.748	5.818	1.035	0.060	1.037
Min	0.415	9.77	0.238	0.049	20.55	2.720	8.451	4.545	0.174	0.049	0.501
Standard Deviation	0.315	0.999	0.301	0.008	1.58	1.389	0.112	0.529	0.339	0.004	0.223
L163163-Amphibole	0.482	11.017	0.241	0.055	24.105	2.733	8.400	7.126	0.079	0.215	0.037
L163163-Amphibole	0.614	10.062	0.198	0.070	22.952	3.770	8.696	7.482	0.542	0.126	0.313
L163163-Amphibole	0.338	11.686	0.081	0.057	24.796	2.086	8.786	5.495	0.284	0.160	0.233
L163163-Amphibole	0.194	11.649	0.061	0.053	25.368	1.341	8.942	6.129	0.094	0.129	0.063
L163163-Amphibole	0.594	10.788	0.165	0.068	23.461	3.537	8.539	6.464	0.354	0.143	0.239
L163163-Amphibole	0.473	11.706	0.115	0.068	24.457	2.587	8.346	5.870	0.151	0.148	0.109
L163163-Amphibole	0.260	12.058	0.061	0.081	25.242	1.696	8.758	5.461	0.134	0.129	0.039
L163163-Amphibole	0.362	11.738	0.068	0.067	24.804	2.030	8.714	5.852	0.142	0.140	0.064
L163163-Amphibole	0.562	10.313	0.296	0.074	23.311	3.382	8.585	7.887	0.259	0.158	0.158
L163163-Amphibole	0.450	11.537	0.108	0.067	24.241	2.842	8.287	6.214	0.176	0.095	0.055
L163163-Amphibole	0.448	10.680	0.192	0.075	23.961	2.813	8.454	7.336	0.156	0.171	0.093
L163163-Amphibole	0.310	11.414	0.094	0.087	24.664	2.060	8.892	6.131	0.245	0.137	0.118
L163163-Amphibole	0.711	9.746	0.447	0.074	22.478	3.820	8.553	8.051	0.635	0.150	0.255
L163163-Amphibole	0.482	10.884	0.083	0.056	24.086	2.663	8.631	7.068	0.336	0.138	0.131
L163163-Amphibole	0.663	10.144	0.237	0.073	22.827	3.731	8.572	7.348	0.714	0.094	0.311
Average	**0.463**	**11.03**	**0.163**	**0.068**	**24.05**	**2.739**	**8.610**	**6.661**	**0.287**	**0.142**	**0.148**
Max	0.711	12.06	0.447	0.087	25.37	3.820	8.942	8.051	0.714	0.215	0.313
Min	0.194	9.75	0.061	0.053	22.48	1.341	8.287	5.461	0.079	0.094	0.037
Standard Deviation	0.150	0.723	0.108	0.010	0.88	0.790	0.191	0.858	0.199	0.029	0.098
L163164-Amphibole	0.734	8.821	0.540	0.083	22.234	4.186	8.391	9.796	0.291	0.138	0.196
L163164-Amphibole	0.329	11.543	0.076	0.075	24.706	2.241	8.697	5.796	0.192	0.146	0.094
L163164-Amphibole	0.357	11.224	0.097	0.075	24.675	2.094	8.402	7.102	0.140	0.191	0.035
L163164-Amphibole	0.523	10.989	0.189	0.075	23.928	2.798	8.246	7.000	0.116	0.187	0.068
L163164-Amphibole	0.407	10.771	0.226	0.096	24.371	2.021	8.462	7.943	0.188	0.171	0.125
L163164-Amphibole	0.706	9.327	0.473	0.083	22.519	3.994	8.383	9.445	0.158	0.156	0.086
L163164-Amphibole	0.734	9.400	0.474	0.095	22.455	3.950	8.345	9.503	0.158	0.142	0.081
L163164-Amphibole	0.620	10.124	0.340	0.065	23.240	3.357	8.197	8.357	0.157	0.193	0.092
L163164-Amphibole	0.831	9.673	0.393	0.072	22.310	4.390	8.356	8.373	0.332	0.152	0.213
L163164-Amphibole	0.576	9.534	0.383	0.083	23.047	3.386	8.495	8.986	0.219	0.139	0.205
L163164-Amphibole	0.562	9.663	0.393	0.087	23.052	3.223	8.489	8.975	0.266	0.144	0.185
L163164-Amphibole	0.668	9.612	0.373	0.072	22.599	4.197	8.434	8.260	0.343	0.146	0.107
L163164-Amphibole	0.000	14.401	0.016	0.056	26.498	0.098	0.425	12.617	0.007	0.632	0.002
L163164-Amphibole	0.013	14.115	0.007	0.044	26.347	0.234	0.264	13.203	0.000	0.707	0.006
L163164-Amphibole	0.001	14.449	0.007	0.069	26.271	0.112	0.481	12.577	0.000	0.601	0.012
L163164-Amphibole	0.059	14.770	0.004	0.043	25.987	0.668	0.217	11.821	0.008	0.380	0.032
L163164-Amphibole	0.050	12.932	0.017	0.055	25.733	0.376	0.923	14.003	0.019	0.762	0.016
L163164-Amphibole	0.033	12.913	0.020	0.066	25.679	0.309	0.821	13.998	0.011	0.756	0.028
L163164-Amphibole	0.028	14.990	0.004	0.046	26.339	0.267	0.192	12.066	0.023	0.510	0.016
L163164-Amphibole	0.062	14.000	0.005	0.055	25.833	0.440	0.339	13.109	0.008	0.496	0.043
Average	**0.365**	**11.66**	**0.202**	**0.070**	**24.39**	**2.117**	**5.228**	**10.147**	**0.132**	**0.337**	**0.082**
Max	0.831	14.99	0.540	0.096	26.50	4.390	8.697	14.003	0.343	0.762	0.213
Min	0.000	8.82	0.004	0.043	22.23	0.098	0.192	5.796	0.000	0.138	0.002
Standard Deviation	0.305	2.174	0.197	0.016	1.60	1.651	4.001	2.544	0.118	0.240	0.070
L163593-Mica	0.083	11.740	8.150	0.080	17.559	8.218	0.000	5.451	2.301	0.007	0.893
L163593-Mica	0.044	12.611	8.346	0.083	17.777	8.206	0.007	4.902	1.817	0.016	0.856
L163593-Mica	0.122	11.431	8.363	0.155	17.470	7.738	0.001	6.207	2.455	0.013	0.907
L163593-Mica	0.062	11.898	8.359	0.065	17.503	8.182	0.000	5.761	2.094	0.023	0.778
L163593-Mica	0.147	12.790	8.289	0.075	17.796	8.140	0.000	5.064	1.815	0.009	0.744
Average	**0.091**	**12.09**	**8.301**	**0.092**	**17.62**	**8.097**	**0.002**	**5.477**	**2.096**	**0.014**	**0.836**
Max	0.147	12.79	8.363	0.155	17.80	8.218	0.007	6.207	2.455	0.023	0.907
Min	0.044	11.43	8.150	0.065	17.47	7.738	0.000	4.902	1.815	0.007	0.744
Standard Deviation	0.042	0.582	0.090	0.036	0.15	0.203	0.003	0.528	0.286	0.006	0.072

McGill — Electron Microprobe Laboratory, McGill University

Date 2013-May-13-14

Conditions

Name	JXA JEOL-8900L										
Acc. Voltage	20 kV										
Beam Current	30 nA										
Beam Size	3-10 um										
Correction Method	ZAF										
Counting Time (seco	Na2O	MgO	K2O	NiO	SiO2	Al2O3	CaO	FeO	TiO2	MnO	Cr2O3
	20	20	20	30	20	20	20	20	20	20	20
Standards	Albite	Diopside	Orthoclase	NiO	Diopside	Orthoclase	Diopside	Hematite	Rutile	Spessartine	Chromite
Detecion Limits (wt%)											
Opx	0.0235	0.0234	0.0139	0.0178	0.0278	0.0186	0.0174	0.0215	0.0283	0.0194	0.4180
Cpx	0.0228	0.0232	0.0149	0.0181	0.0279	0.0189	0.0180	0.0201	0.0284	0.0202	0.0416

Wt%

Name	Na	Mg	K	Ni	Si	Al	Ca	Fe	Ti	Mn	Cr
L163593-Opx	0.000	17.205	0.007	0.068	25.279	0.848	0.256	11.112	0.056	0.222	0.124
L163593-Opx	0.010	17.212	0.014	0.035	25.343	0.799	0.223	11.075	0.027	0.222	0.182
L163593-Opx	0.000	17.246	0.020	0.039	25.263	0.922	0.463	10.781	0.037	0.209	0.191
L163593-Opx	0.000	17.336	0.000	0.042	25.225	0.873	0.255	10.991	0.028	0.213	0.180
L163593-Opx	0.000	17.114	0.009	0.049	25.384	0.831	0.678	10.660	0.036	0.211	0.194
L163593-Opx	0.007	17.196	0.007	0.035	25.261	0.826	0.254	11.098	0.044	0.215	0.184
L163593-Opx	0.000	17.281	0.007	0.038	25.286	0.926	0.220	10.931	0.034	0.227	0.186
L163593-Opx	0.000	17.288	0.012	0.039	25.333	0.839	0.220	10.943	0.029	0.211	0.205
L163593-Opx	0.000	17.375	0.012	0.039	25.183	0.867	0.227	10.999	0.043	0.219	0.193
L163593-Opx	0.000	17.295	0.009	0.052	25.289	0.917	0.242	10.774	0.036	0.226	0.183
Average	**0.002**	**17.25**	**0.010**	**0.044**	**25.28**	**0.865**	**0.304**	**10.94**	**0.037**	**0.218**	**0.182**
Max	0.010	17.37	0.020	0.068	25.38	0.926	0.678	11.11	0.056	0.227	0.205
Min	0.000	17.11	0.000	0.035	25.18	0.799	0.220	10.66	0.027	0.209	0.124
Standard Deviation	0.004	0.08	0.005	0.010	0.06	0.044	0.150	0.15	0.009	0.007	0.022
L163163-Opx	0.005	15.192	0.000	0.039	24.898	0.527	0.265	14.798	0.031	0.345	0.049
L163163-Opx	0.000	14.887	0.009	0.045	24.859	0.402	0.286	15.399	0.026	0.448	0.049
L163163-Opx	0.007	16.066	0.015	0.042	24.929	0.731	0.283	12.994	0.056	0.430	0.061
L163163-Opx	0.000	14.913	0.004	0.035	24.679	0.610	0.299	15.234	0.040	0.330	0.057
L163163-Opx	0.007	15.348	0.004	0.023	24.924	0.558	0.246	14.661	0.029	0.398	0.055
L163163-Opx	0.000	15.162	0.009	0.027	24.822	0.509	0.239	14.990	0.043	0.349	0.043
L163163-Opx	0.001	15.006	0.010	0.035	24.936	0.479	0.253	15.271	0.030	0.368	0.043
L163163-Opx	0.000	15.108	0.003	0.036	24.790	0.642	0.261	14.931	0.034	0.379	0.080
L163163-Opx	0.012	15.188	0.008	0.042	24.831	0.639	0.292	14.658	0.050	0.298	0.041
L163163-Opx	0.000	15.069	0.005	0.041	24.865	0.584	0.261	15.014	0.031	0.348	0.042
Average	**0.003**	**15.19**	**0.007**	**0.036**	**24.85**	**0.568**	**0.269**	**14.79**	**0.037**	**0.369**	**0.052**
Max	0.012	16.07	0.015	0.045	24.94	0.731	0.299	15.40	0.056	0.448	0.080
Min	0.000	14.89	0.000	0.023	24.68	0.402	0.239	12.99	0.026	0.298	0.041
Standard Deviation	0.004	0.34	0.004	0.007	0.08	0.094	0.020	0.68	0.010	0.046	0.012
L163593-Cpx	0.477	9.449	0.004	0.036	24.713	0.883	16.096	4.196	0.107	0.116	0.351
L163593-Cpx	0.376	9.530	0.001	0.038	24.346	1.294	16.426	3.788	0.125	0.101	0.311
L163593-Cpx	0.382	9.612	0.003	0.035	24.581	1.130	16.244	3.885	0.107	0.105	0.365
L163593-Cpx	0.339	9.691	0.004	0.042	24.587	1.105	16.636	3.382	0.126	0.082	0.311
L163593-Cpx	0.342	9.788	0.009	0.035	24.634	1.093	16.620	3.430	0.110	0.100	0.295
L163593-Cpx	0.399	9.514	0.001	0.042	24.467	1.187	16.273	3.811	0.131	0.094	0.413
L163593-Cpx	0.410	9.566	0.002	0.036	24.418	1.347	16.156	3.820	0.141	0.101	0.430
L163593-Cpx	0.315	9.849	0.015	0.028	24.648	1.002	16.552	3.277	0.098	0.077	0.355
L163593-Cpx	0.334	9.789	0.018	0.031	24.475	1.193	16.628	3.390	0.156	0.093	0.369
L163593-Cpx	0.363	9.687	0.014	0.020	24.575	1.118	16.429	3.591	0.115	0.105	0.364
Average	**0.374**	**9.65**	**0.007**	**0.034**	**24.54**	**1.135**	**16.406**	**3.66**	**0.122**	**0.098**	**0.356**
Max	0.477	9.85	0.018	0.042	24.71	1.347	16.636	4.20	0.156	0.116	0.430
Min	0.315	9.45	0.001	0.020	24.35	0.883	16.096	3.28	0.098	0.077	0.295
Standard Deviation	0.047	0.13	0.006	0.006	0.11	0.134	0.203	0.29	0.018	0.011	0.043
L163163-Cpx	0.315	9.193	0.009	0.053	24.400	1.141	16.205	4.976	0.182	0.157	0.135
L163163-Cpx	0.254	9.380	0.017	0.034	24.578	0.822	16.461	4.822	0.126	0.157	0.144
L163163-Cpx	0.293	9.200	0.009	0.038	24.423	1.167	16.584	4.665	0.155	0.128	0.125
L163163-Cpx	0.219	9.524	0.008	0.032	24.799	0.540	17.086	4.159	0.074	0.167	0.062
L163163-Cpx	0.257	9.327	0.008	0.028	24.822	0.707	16.784	4.684	0.086	0.177	0.148
L163163-Cpx	0.231	9.527	0.010	0.025	24.938	0.749	16.872	3.842	0.104	0.183	0.122
L163163-Cpx	0.286	9.150	0.012	0.014	24.768	0.838	16.803	4.523	0.101	0.213	0.148
L163163-Cpx	0.295	9.248	0.005	0.034	24.762	1.030	16.334	4.697	0.139	0.181	0.091
L163163-Cpx	0.254	9.530	0.009	0.031	24.822	0.862	16.838	3.890	0.107	0.181	0.144
L163163-Cpx	0.171	9.455	0.004	0.032	25.248	0.251	17.501	4.173	0.005	0.195	0.073
Average	**0.257**	**9.35**	**0.009**	**0.032**	**24.76**	**0.811**	**16.747**	**4.44**	**0.108**	**0.174**	**0.119**
Max	0.315	9.53	0.017	0.053	25.25	1.167	17.501	4.98	0.182	0.213	0.148
Min	0.171	9.15	0.004	0.014	24.40	0.251	16.205	3.84	0.005	0.128	0.062
Standard Deviation	0.043	0.15	0.004	0.010	0.25	0.276	0.378	0.40	0.049	0.023	0.032
L163164-Cpx	0.338	8.898	0.065	0.026	24.423	1.098	15.787	5.458	0.164	0.189	0.192
L163164-Cpx	0.242	9.230	0.005	0.010	25.026	0.210	17.146	4.461	0.014	0.183	0.089
L163164-Cpx	0.203	9.354	0.015	0.023	24.959	0.306	17.071	4.403	0.028	0.177	0.073
L163164-Cpx	0.305	9.065	0.004	0.037	24.688	0.510	16.481	5.121	0.055	0.198	0.138
L163164-Cpx	0.222	9.198	0.012	0.035	24.739	0.311	16.859	4.813	0.025	0.184	0.060
L163164-Cpx	0.237	9.424	0.008	0.028	24.735	0.484	16.487	4.627	0.050	0.190	0.078
L163164-Cpx	0.320	8.925	0.053	0.030	24.402	0.980	16.051	5.305	0.171	0.179	0.161
L163164-Cpx	0.194	9.460	0.009	0.075	25.040	0.288	17.080	4.538	0.031	0.180	0.067
L163164-Cpx	0.220	9.224	0.013	0.027	24.725	0.508	17.058	4.481	0.050	0.174	0.110
L163164-Cpx	0.280	9.197	0.007	0.021	24.601	0.718	16.265	4.840	0.122	0.167	0.131
Average	**0.256**	**9.20**	**0.019**	**0.031**	**24.73**	**0.541**	**16.629**	**4.80**	**0.071**	**0.182**	**0.110**
Max	0.338	9.46	0.065	0.075	25.04	1.098	17.146	5.46	0.171	0.198	0.192
Min	0.194	8.90	0.004	0.010	24.40	0.210	15.787	4.40	0.014	0.167	0.060
Standard Deviation	0.051	0.19	0.021	0.017	0.23	0.302	0.485	0.38	0.059	0.009	0.044

Appendix C – QEMSCAN Modes of Operation

QEMSCAN Modes of Operation

QEMSCAN is an acronym for Quantitative Evaluation of Materials by Scanning Electron Microscopy, a system which differs from image analysis systems in that it is configured to measure mineralogical variability based on chemistry at the micrometer-scale. QEMSCAN utilizes both the back-scattered electron (BSE) signal intensity as well as an Energy Dispersive X-ray Signal (EDS) at each measurement point. It thus makes no simplifications or assumptions of homogeneity based on the BSE intensity, as many mineral phases show BSE overlap. EDS signals are used to assign mineral identities to each measurement point by comparing the EDS spectrum against a mineral species identification program (SIP) or database.

There are two general types of measurement: those using the linear intercept and those based on particle mapping. Bulk mineral analysis (BMA) is performed using the linear intercept method, and is used to provide statistically abundant data for speciation and mineral distribution. Particle mapping modes, including Particle Mineral Analysis (PMA), Specific Mineral Search (SMS) analysis and Trace Mineral Search (TMS) analysis provide information on spatial relationships of minerals, including liberation and association data and provide a visual representation of mineral textures. The particle mapping modes of measurement also allow for advanced analysis of the minerals of interest, including grade vs. recovery relationships and mineral release curves. Specific details of the measurement modes are presented below, while visual examples of these two measurement classes are presented in Figures A and B.

Bulk Mineral Analysis, or BMA, is performed by the linear intercept method, in which the electron beam is rastered at a pre-defined point spacing (nominally 3 micrometers, but variable with particle size) along several lines per field, and covering the entire polished section at any given magnification. An example of a BMA measurement image is shown in Figure A. This measurement provides a robust data set for determination of the bulk mineralogy, with mineral identities and proportions, along with grain size measurements.

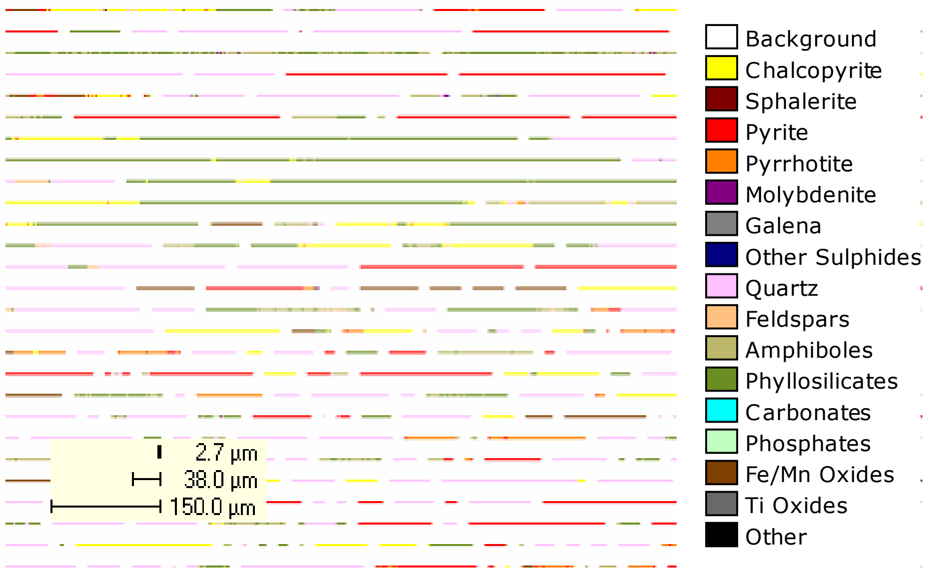


Figure A. BMA Measurement Mode

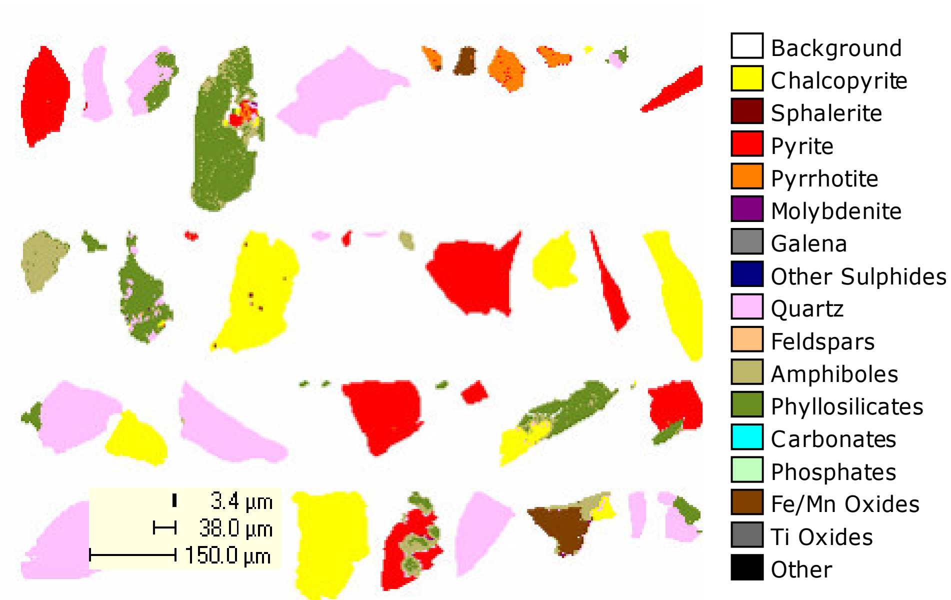


Figure B. Particle Mapping (PMA, SMS or TMS) Measurement Mode

Particle Mineral Analysis (PMA) is a two-dimensional mapping analysis aimed at resolving liberation and locking characteristics of a generic set of particles. A pre-defined number of particles are mapped at a point spacing selected in order to spatially resolve and describe mineral textures and associations. This mode is often selected to characterize concentrate products, as both gangue and value minerals report in statistically abundant quantities to be resolved.

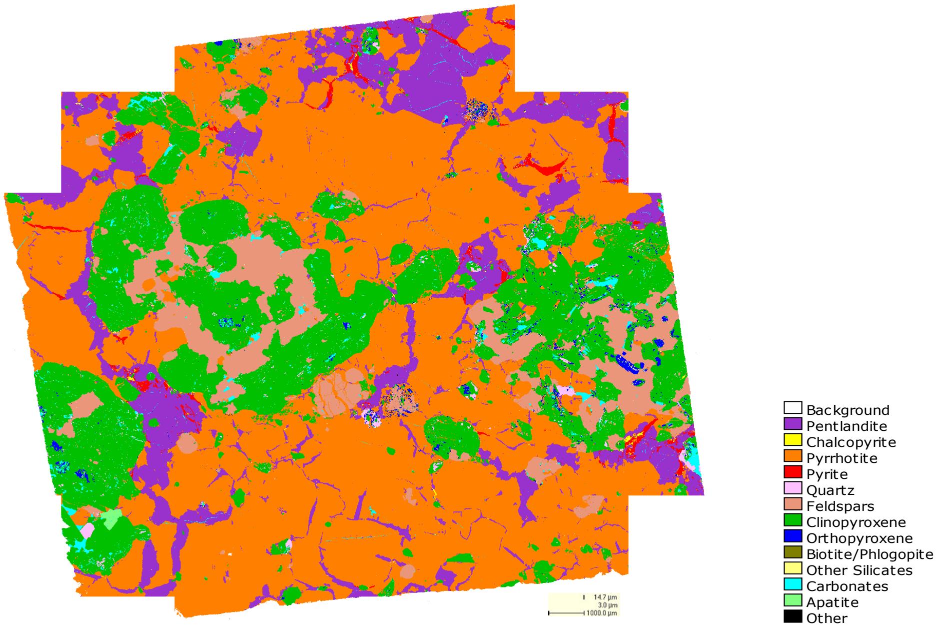
Specific Mineral Search, or SMS, is a modified Particle Mineral Analysis (PMA) routine. However, in an SMS routine, a phase reports as a low-grade constituent and can be located by thresholding of the back-scattered electron intensity. Any accompanying phases of similar and higher brightness are also mapped. For example, this mode of measurement would be selected in ores of low sulphide grade, searching specifically for particles containing sulphide minerals.

Trace Mineral Search (TMS) is an additional mapping routine, where a phase reports as a trace constituent and can be located by thresholding of the back-scattered electron intensity. The objective of this routine is to reject barren fields and increase analysis efficiency. The outputs are otherwise identical to the SMS routine. This mode of measurement is often used for advanced studies of PGE ore types, or trace minerals of interest such as molybdenite.

It is important to note that with regards to SMS and TMS modes, results pertain only to the target minerals. PMA must be selected if quantitative gangue characterization is required. For example, in some sulphide ores, it may be more efficient to reject barren pyrites in favour of copper-bearing minerals. However, it must be noted that data captured in this manner will not reflect the true characteristics of pyrite, as only the pyrite associated with the copper-bearing minerals will be represented.

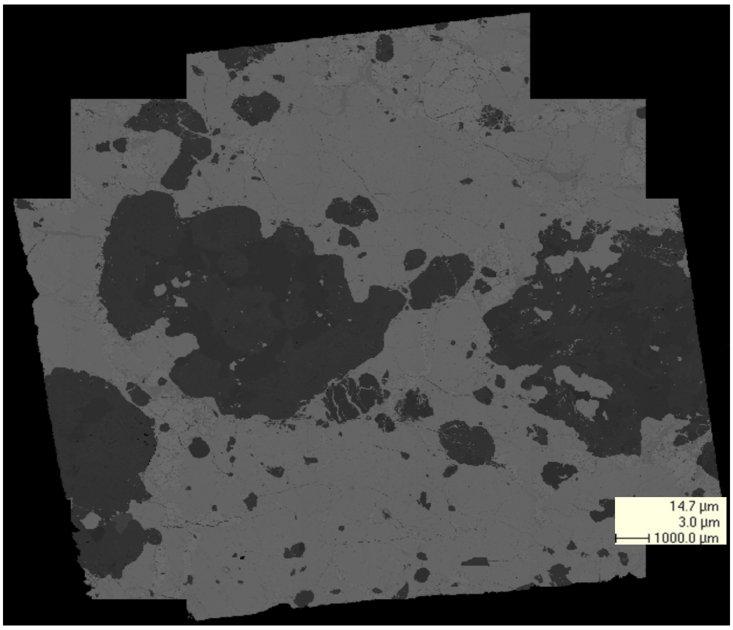
Appendix D – QEMSCAN Field Images

QEMSCAN Field Image for L163163

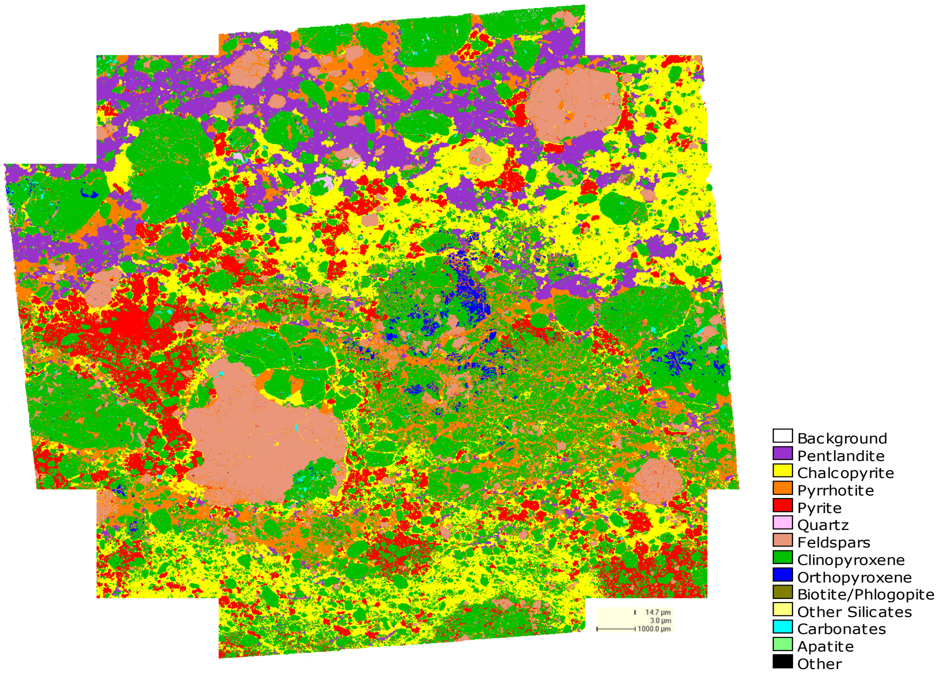


Mineral	Mass %
Pentlandite	14.7
Chalcopyrite	0.09
Pyrrhotite	57.7
Pyrite	1.15
Quartz	0.37
Feldspars	5.40
Clinopyroxene	19.2
Orthopyroxene	0.63
Biotite/Phlogopite	0.01
Other Silicates	0.05
Carbonates	0.72
Apatite	0.06
Other	0.01

QEMSCAN BSE Image for L163163

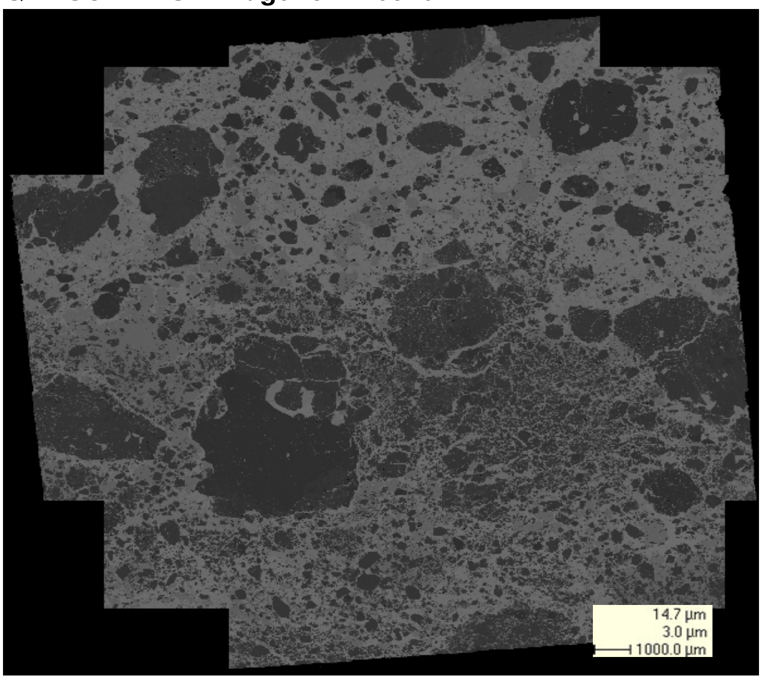


QEMSCAN Field Image for L163164

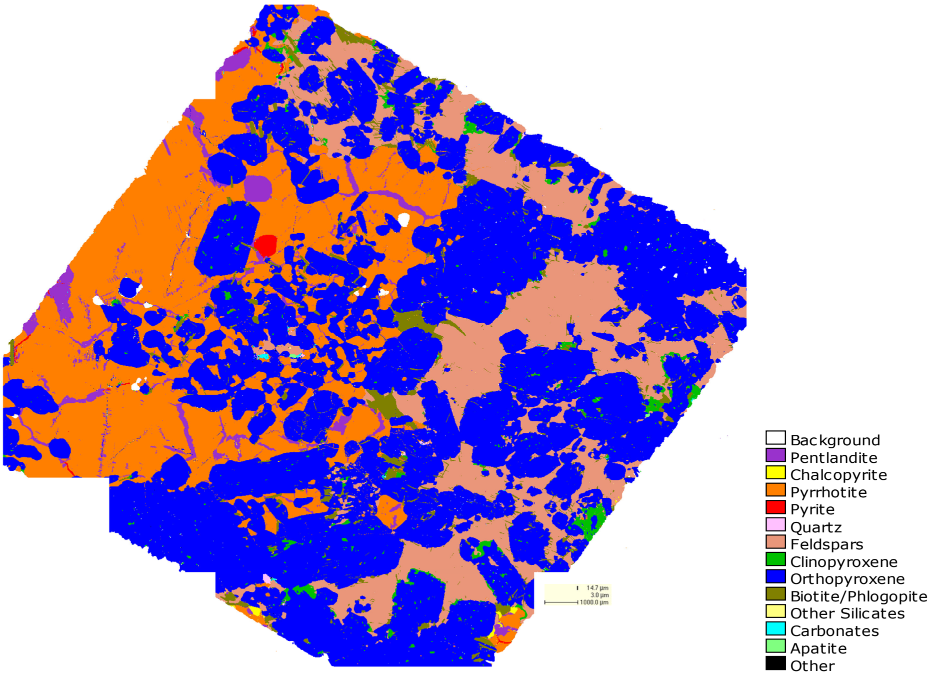


Mineral	Mass %
Pentlandite	12.9
Chalcopyrite	21.7
Pyrrhotite	13.5
Pyrite	12.9
Quartz	0.13
Feldspars	6.68
Clinopyroxene	30.6
Orthopyroxene	1.00
Biotite/Phlogopite	0.28
Other Silicates	0.07
Carbonates	0.27
Apatite	0.01
Other	0.00

QEMSCAN BSE Image for L163164



QEMSCAN Field Image for L163593



Mineral	Mass %
Pentlandite	3.02
Chalcopyrite	0.12
Pyrrhotite	28.4
Pyrite	0.27
Quartz	0.04
Feldspars	10.7
Clinopyroxene	1.11
Orthopyroxene	53.9
Biotite/Phlogopite	2.32
Other Silicates	0.05
Carbonates	0.05
Apatite	0.01
Other	0.01

QEMSCAN BSE Image for L163593