Kinetic Testing of Waste Rock and Ore from the Doris Deposits, Hope Bay – Supporting Data

Prepared for

TMAC Resources Inc.

Prepared by

SRK Consulting (Canada) Inc.
1CT022.002
June 2015

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1 Introduction

TMAC Resources Inc. (TMAC) is advancing plans for underground mining of the Doris deposits at Hope Bay. SRK was asked to compile and evaluate all of the relevant kinetic testing results used to evaluate the metal leaching and acid rock drainage (ML/ARD) potential of waste rock and ore that would be produced as part of the proposed underground mining activities at Doris. The findings were reported in SRK 2015.

This document provides a series of appendices with supporting data for the ML/ARD assessment. It should be read in conjunction with SRK 2015.

2 References

SRK 2015. Kinetic Testing of Waste Rock and Ore from the Doris Deposits, Hope Bay. Report prepared for Hope Bay Mining Ltd. by SRK Consulting (Canada) Inc., June 2015.

Appendix A – Humidity Cell and Barrel Test Sample Intervals

HCT ID	Rock Type	Drillhole	From (m)	To (m)	Length (m)
DOP #12	1	TDD275	54.6	54.88	0.28
DUMV #5	1	TDD390A	169.88	170.66	0.78
DUG #6	10a	TDD383	199.32	199.69	0.37
DUQ #1	12q	TDD375	202	203	1
HC-7	1	08TDD632	61.05	135.89	74.84
HC-42	1	02TDD506	39	64	25
HC-43	1	02TDD545	6.36	32	25.64
HC-49	1	TDD370	253.21	255.12	1.91
HC-50	1	TDD387	151.2	153.5	2.3
HC-44	1 w. 12q	02TDD545	82	100.73	18.73
HC-45	1 w. 12q	TDD380	245	254.5	9.5
HC-6	7a mixed	08TDD626	83.8	96.59	12.79
		08TDD626	219.68	257.81	38.13
HC-46	10a	TDD380	272	294	22
HC-51	10a	97TDD131	169.13	171.61	2.48
HC-65	10a	06TDD614	64	65	1
HC-47	11c	TDD374	61	67.6	6.6
HC-48	11c	TDD374	11.63	36	24.37
HC-53	12q	TDD368	175	178	3
HC-36	12q	08TDD631	33.5	37.3	1.47
HC-54	12q	TDD363	153.85	155.96	2.11
HC-52	12q	TDD392	214.58	216.68	2.1

Barrel ID	Rock Type	Drillhole	From (m)	To (m)	Length (m)	Mass (kg)
W1	1a	08TDD632	61.05	135.89	74.84	297.9
W5	7a	08TDD626	83.80	96.59	50.92	239.3
			219.68	257.81		
W13	10a	96TDD067	79.76	90	10.24	96.7
		97TDD131	169.13	193.1	23.97	94.3
		TDD383	18.53	22.91	4.38	
		TDD383	27.44	31.76	4.32	
W10	11cm	08TDD623	117.81	161	43.19	247.3
W9	12q w. 1a	08TDD628	27.97	102.22	74.25	209.9

Appendix B – SRK Humidity Cell and Barrel Test Mineralogy

Appendix B1 – SRK Humidity Cell and Barrel Test Carbonate and Sulphide Mineralogy by XRD, SEM, and MLA

HCT ID	Rock Type[1]	Total Sulphur	Preliminary Economic Classification	Carbonates								Sulphides											
				Ferroan Dolomite $Ca(Fe,Mg)CO_3$			Siderite $FeCO_3$			Calcite $CaCO_3$		Pyrite FeS_2		Chalcopyrite $CuFeS_2$	Gersdorffite (Fe,Co,Ni)AsS	Pyrrhotite Fe(1-x)S	Galena PbS	Cobaltite CoAsS	Sphalerite ZnS	Tetrahedrite Cu_3SbS	Total Sulphur %S		
		% Rank		XRD	MLA	SEM*	XRD	MLA	SEM*	XRD	MLA	XRD	MLA	MLA	MLA	MLA	MLA	MLA	MLA	MLA	XRD	MLA	ABA
HC-7	1	26%	waste	22	19.01	Ca(Mg0.56Fe0.44)CO3	1	1.83	(Mg0.23Fe0.77)CO3	bd	0.21	bd	0.27	<0.01	bd	<0.01	bd	bd	bd	bd	bd	0.15	0.11
	1	59%	waste	25	--	--	bd	--	--	bd	--	bd	--	--	--	--	--	--	--	--	bd	0.00	0.17
HC-42	1	21%	waste	3	5.02	Ca(Mg0.57Fe0.43)CO3	bd	0.21	*	9	8.50	bd	0.24	<0.01	bd	<0.01	bd	bd	bd	bd	bd	0.13	0.10
HC-43	1	85%	waste	21	17.39	Ca(Mg0.49Fe0.51)CO3	1	1.61	(Fe0.75Mg0.25)CO3	1	1.28	<1	1.12	<0.01	bd	<0.001	bd	bd	bd	bd	0.5	0.60	0.52
HC-49	1	60%	waste	23	21.99	Ca(Mg0.44Fe0.56)CO3	7	5.20	(Fe0.78Mg0.22)CO3	bd	0.04	bd	0.07	<0.01	bd	<0.01	bd	<0.001	<0.001	bd	bd	0.05	0.17
HC-50	1	95%	waste	31	28.48	Ca(Mg0.45Fe0.55)CO3	4	2.57	(Fe0.77Mg0.23)CO3	bd	0.08	3	1.91	<0.01	bd	<0.01	<0.001	<0.001	<0.001	bd	1.6	1.03	1.78
HC-44	1 w. 12q	29%	waste	12	14.03	Ca(Mg0.62Fe0.38)CO3	bd	0.10	*	9	9.74	bd	0.95	0.03	<0.001	0.01	bd	<0.01	<0.01	bd	bd	0.53	0.31
HC-45	1 w. 12q	86%	ore	30	20.74	Ca(Mg0.56Fe0.44)CO3	2	1.21	(Fe0.75Mg0.25)CO3	bd	0.19	2	4.66	0.01	<0.01	0.02	bd	<0.01	<0.01	bd	1.1	2.51	2.37
HC-6	7a mixed	--	mixed	8	14.20	Ca(Mg0.54Fe0.46)CO3	tr	0.18	(Mg0.19Fe0.81)CO3	7	5.83	bd	0.12	<0.01	<0.01	<0.01	bd	<0.01	<0.01	bd	bd	0.08	0.13
HC-46	10a	92%	waste	13	13.51	Ca(Mg0.48Fe0.52)CO3	bd	0.61	*	4	3.38	bd	0.24	<0.01	bd	<0.001	bd	bd	<0.001	bd	bd	0.13	0.29
HC-51	10a	98%	waste	34	36.96	Ca(Mg0.67Fe0.33)CO3	1	1.53	(Fe0.53Mg0.47)CO3	bd	0.30	1	1.74	0.03	<0.01	<0.001	<0.001	<0.01	<0.001	<0.001	0.5	0.94	1.19
HC-65	10a	58%	decline	bd	bd	--	bd	bd	*	bd	bd	bd	0.21	<0.01	bd	<0.01	bd	bd	bd	bd	bd	0.12	0.10
HC-47	11c	95%	waste	bd	0.48	*	bd	0.11	*	3	0.78	<1	0.03	0.02	bd	<0.01	bd	bd	bd	bd	0.5	0.02	0.10
HC-48	11c	98%	waste	bd	1.43	*	bd	0.12	*	1	1.03	<1	0.08	0.01	<0.01	<0.01	bd	bd	<0.001	<0.001	0.5	0.05	0.12
HC-53	12q	50%	waste	1	0.65	Ca(Mg0.64Fe0.36)CO3	bd	<0.01	*	bd	-0.01	bd	0.28	<0.001	bd	<0.01	bd	bd	bd	bd	bd	0.15	0.09
HC-54	12q	49%	ore	3	4.12	Ca(Mg0.62Fe0.38)CO3	bd	<0.01	*	bd	-0.01	1	1.94	<0.01	bd	<0.01	bd	bd	bd	bd	0.5	1.04	0.61
HC-52	12q	76%	ore	8	5.35	Ca(Mg0.57Fe0.43)CO3	bd	0.16	*	bd	0.03	3	3.97	<0.001	bd	<0.01	<0.001	<0.001	<0.01	<0.001	1.6	2.12	1.69
HC-36	12q	100%	ore	27	11.95	Ca(Mg0.55Fe0.45)CO3	bd	0.72	*	1	0.06	2	6.17	<0.01	bd	<0.01	bd	bd	<0.001	bd	1.1	3.30	6.03

[1]Rock codes as follows: **1** = mafic volcanic; **7a** = early gabbro; **10a** = late gabbro; **11c** = diabase; **12q** = quartz dominated

*SEM analyses not conducted because mineral level below detection, as indicated by XRD

n/a: sample not available for characterization.

-- indicates analysis performed on alternate static sample

bd: below detection

Barrel ID	Rock Type[1]	Carbonates					Sulphides		
		Ferroan Dolomite $Ca(Fe,Mg)CO_3$		Siderite $FeCO_3$		Calcite $CaCO_3$	Pyrite FeS_2	Sulphide %S	
		XRD	SEM*	XRD	SEM*	XRD	XRD	XRD	ABA
W1	1	22	Ca(Mg0.56Fe0.44)CO3	1	(Mg0.23Fe0.77)CO3	bd	bd	bd	0.11
	1	25	n/a	bd	n/a	bd	bd	bd	0.16
W5	7a mixed	8	Ca(Mg0.54Fe0.46)CO3	tr	(Mg0.19Fe0.81)CO3	7	bd	bd	0.13
W13	10a	4	n/a	bd	n/a	3	bd	bd	0.06
W10	11c	bd	n/a	bd	n/a	bd	bd	bd	0.03
W9	12q with 1	22	n/a	9	n/a	bd	2	1.07	2.05

[1]Rock codes as follows: **1** = mafic volcanic; **7a** = early gabbro; **10a** = late gabbro; **11c** = diabase; **12q** = quartz dominated

*SEM analyses not conducted because mineral level below detection, as indicated by XRD

n/a: sample not available for characterization.

bd: below detection

Appendix B2 – SRK Humidity Cell and Barrel Test XRD Dataset

Kinetic Test ID	Sample ID	Albite	Amphibole	Ferroan Dolomite	Biotite	Calcite	Chlorite	Chloritoid	Diopside	Epidote	Ilmenite	K-feldspar
		NaAlSi3O8(Ca,Na)(Al,Si)4O8	Ca2(Mg,Fe,Al)5(Al,Si)8O22(OH)2	Ca(Fe,Mg)(CO3)2	K(Mg,Fe)3(AlSi3O10)(OH)2	CaCO3	(Mg,Fe,Al)6(Al,Si)4O10(OH)8	(Fe,Mg,Mn)2Al4Si2O10(OH)4	Ca(Mg,Fe)Si2O6	Ca2(Al, Fe)3(SiO4)3(OH)	FeTiO3	KAlSi3O8
HC-36	08TDD631-SRK-WR-435	--	bd	27	bd	1	bd	bd	--	bd	bd	bd
HC-42	208828	--	5	3	bd	9	56	bd	--	bd	bd	bd
HC-43	208885	--	<1	21	bd	1	36	bd	--	<1	bd	bd
HC-44	208888	--	bd	12	bd	9	33	bd	--	2	bd	bd
HC-45	202734	--	bd	30	bd	bd	5	bd	--	2	bd	bd
HC-46	202736	--	bd	13	bd	4	34	bd	--	3	bd	bd
HC-47	202713	--	9	bd	bd	3	40	bd	--	10	bd	bd
HC-48	202708	--	12	bd	bd	1	34	bd	--	9	bd	bd
HC-49	178784	--	bd	23	bd	bd	5	bd	--	bd	bd	bd
HC-50	178823	--	bd	31	bd	bd	bd	bd	--	bd	bd	bd
HC-51	178814	--	bd	34	bd	bd	14	bd	--	bd	bd	bd
HC-52	178769	--	bd	8	bd	bd	bd	bd	--	bd	bd	bd
HC-53	178719	--	bd	1	bd	bd	bd	bd	--	bd	bd	bd
HC-54	178726	--	bd	3	bd	bd	bd	bd	--	bd	bd	bd
HC-65	HB-214522	--	42	bd	2	bd	13	--	--	--	--	--
HC-6 / Barrel W5	08-DOR-WR-05	--	11	8	bd	7	39	bd	--	bd	bd	bd
HC-7 / Barrel W1	08-DOR-WR-02	--	bd	22	bd	bd	37	bd	--	bd	bd	bd
	Wt. Av. Composite	--	bd	25	bd	bd	33	bd	--	bd	bd	bd
Barrel W9	HB DCEN 08TDD628	--	--	22	--	--	1	--	--	--	--	--
Barrel W10	HB DCEN 08TDD623	48.5	2	--	--	--	8	--	29	--	--	--
Barrel W13	HB DCEN/DCONN TDD067, 131, 383 Comp	18.3	17	4	--	3	24	--	--	17	--	--

'bd' indicates below detection
'--' indicates not reported

Kinetic Test ID	Sample ID	Gypsum	Magnesite	Magnetite	Muscovite	Muscovite/Sericite	Paragonite	Plagioclase	Pyrite	Pyrophyllite	Pyroxene	Quartz	Rutile	Sepiolite	Siderite
		CaSO4·2(H2O)	MgCO3	Fe3O4	KAl2(AlSi3O10)(OH)2		NaAl3Si3O10 (OH) 2	(Ca,Na)(Al,Si)AlSi2O8	FeS2	AlSi2O5(OH)	(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)2O6	SiO2	TiO2	Mg4Si6O15(OH)2×6(H2O)	FeCO3
HC-36	08TDD631-SRK-WR-435	bd	bd	bd	bd	12	3	bd	2	bd	bd	52	2	bd	bd
HC-42	208828	bd	bd	bd	5	bd	bd	8	bd	bd	bd	14	tr	bd	bd
HC-43	208885	bd	bd	bd	7	bd	8	6	<1	bd	bd	18	1	bd	1
HC-44	208888	bd	bd	bd	5	bd	16	4	bd	bd	bd	21	<1	bd	bd
HC-45	202734	bd	bd	bd	3	bd	18	5	2	bd	3	31	1	bd	2
HC-46	202736	bd	bd	bd	2	bd	8	15	bd	bd	bd	22	<1	bd	bd
HC-47	202713	bd	bd	bd	bd	bd	bd	27	<1	bd	bd	11	bd	bd	bd
HC-48	202708	bd	bd	bd	bd	bd	16	16	<1	bd	2	7	bd	bd	bd
HC-49	178784	bd	bd	bd	10	bd	21	bd	bd	bd	bd	33	1	bd	7
HC-50	178823	bd	bd	bd	14	bd	10	bd	3	bd	bd	36	1	bd	4
HC-51	178814	bd	bd	bd	13	bd	14	bd	1	bd	bd	21	1	bd	1
HC-52	178769	bd	bd	bd	5	bd	2	bd	3	bd	bd	81	1	bd	bd
HC-53	178719	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd	99	bd	bd	bd
HC-54	178726	bd	bd	bd	bd	4	bd	bd	1	bd	bd	92	bd	bd	bd
HC-65	HB-214522	--	--	--	--	--	--	40	bd	--	--	4	--	--	bd
HC-6 / Barrel W5	08-DOR-WR-05	bd	bd	bd	bd	bd	bd	16	bd	bd	bd	18	bd	bd	tr
HC-7 / Barrel W1	08-DOR-WR-02	bd	bd	bd	bd	9	bd	9	bd	bd	bd	21	1	bd	1
	Wt. Av. Composite	bd	bd	bd	bd	6	bd	13	bd	bd	bd	22	1	bd	bd
Barrel W9	HB DCEN 08TDD628	--	--	--	10	--	17	--	2	--	--	38	1	--	9
Barrel W10	HB DCEN 08TDD623	--	--	--	5	--	--	--	--	--	--	6	--	--	--
Barrel W13	HB DCEN/DCONN TDD067, 131, 383 Comp	--	--	--	--	--	--	--	--	--	--	18	--	--	--

'bd' indicates below detection
'--' indicates not reported

Kinetic Test ID	Sample ID	Siderite/Magnesite	Stilpnomelane	Talc	Titanite	Tourmaline	Sum
			K(Fe,Mg)8(Si,Al)12(O,OH)27·n(H2O)	Mg3Si4O10(OH)2	CaTiSiO5	Na(Fe,Mg)3Al6Si6O18(BO3)3(OH)4	
HC-36	08TDD631-SRK-WR-435	bd	bd	bd	bd	bd	99
HC-42	208828	bd	bd	bd	bd	bd	100
HC-43	208885	bd	bd	bd	bd	bd	99
HC-44	208888	bd	bd	bd	bd	bd	102
HC-45	202734	bd	bd	bd	bd	bd	102
HC-46	202736	bd	bd	bd	bd	bd	101
HC-47	202713	bd	Tr	bd	bd	bd	100
HC-48	202708	bd	4	bd	bd	bd	101
HC-49	178784	bd	bd	bd	bd	bd	100
HC-50	178823	bd	bd	bd	bd	bd	99
HC-51	178814	bd	bd	bd	bd	bd	99
HC-52	178769	bd	bd	bd	bd	bd	100
HC-53	178719	bd	bd	bd	bd	bd	100
HC-54	178726	bd	bd	bd	bd	bd	100
HC-65	HB-214522	--	--	--	--	--	101
HC-6 / Barrel W5	08-DOR-WR-05	bd	bd	bd	1	bd	100
HC-7 / Barrel W1	08-DOR-WR-02	bd	bd	bd	bd	bd	100
	Wt. Av. Composite	bd	bd	bd	bd	bd	100
Barrel W9	HB DCEN 08TDD628	--	--	--	--	--	100
Barrel W10	HB DCEN 08TDD623	--	--	2	--	--	100
Barrel W13	HB DCEN/DCONN TDD067, 131, 383 Comp	--	--	--	--	--	100

'bd' indicates below detection
'--' indicates not reported

Appendix B3 – SRK Humidity Cell Test MLA Dataset

Kinetic Test ID	Sample ID	Albite	Albite/Andesine	Amphibole	Andesine	Anhydrite	Anhydrite/Gypsum	Ankerite	Apatite	Arsenopyrite		Barite	Biotite
		%	%	%	%	%	%	%	%	%	As % eq.	%	%
HC-36	08TDD631-SRK-WR-435	2.9	--	0.27	bd	bd	bd	12	0.52	bd	0.019	bd	bd
HC-42	208828	7.5	--	1	bd	bd	bd	5	0.16	bd	0.00037	<0.001	0.11
HC-43	208885	5.6	--	0.38	bd	bd	bd	17	0.38	bd	0.0045	<0.001	0.26
HC-44	208888	7.2	--	0.9	bd	bd	bd	14	0.14	bd	0.0027	bd	0.067
HC-45	202734	3.3	--	0.2	bd	<0.001	bd	21	0.62	bd	0.011	<0.001	<0.001
HC-46	202736	17	--	1.2	bd	bd	bd	14	0.17	bd	0.0017	bd	0.013
HC-47	202713	27	--	13	bd	bd	bd	0.48	0.051	bd	0.0003	bd	0.032
HC-48	202708	29	--	29	bd	bd	bd	1.4	0.025	bd	0.00074	bd	0.3
HC-49	178784	7.4	--	0.74	bd	bd	bd	22	0.19	bd	0.00048	bd	<0.001
HC-50	178823	4.9	--	0.17	bd	bd	bd	28	0.34	bd	0.014	bd	<0.01
HC-51	178814	0.61	--	0.15	bd	bd	bd	37	0.14	bd	0.01	bd	<0.01
HC-52	178769	0.027	--	<0.01	bd	<0.001	bd	5.4	0.017	bd	0.0091	bd	<0.01
HC-53	178719	0.015	--	<0.01	bd	bd	bd	0.65	<0.01	bd	0.00057	<0.001	<0.01
HC-54	178726	0.075	--	<0.001	bd	bd	bd	4.1	<0.001	bd	0.0017	bd	<0.001
HC-65	HB-214522	--	12	51	--	bd	bd	bd	0.1	bd	0.00026	bd	3.4
HC-6 / Barrel W5	08-DOR-WR-05	--	--	3.1	--	bd	bd	14	0.17	bd	0.0007	bd	0.026
HC-7 / Barrel W1	08-DOR-WR-02	--	--	bd	--	bd	bd	19	0.26	bd	0.00037	bd	0.031

'bd' indicates below detection

'--' indicates not reported

Kinetic Test ID	Sample ID	Calcite	Chalcopyrite		Chlorite	Chloritoid	Chromite	Cobaltite		Diopside	Electrum	Enstatite	Epidote	FeClay	Galena
		%	%	Cu % eq.	%	%	%	%	Co % eq.	%	%	%	%	%	%
HC-36	08TDD631-SRK-WR-435	0.057	<0.01	0.011	0.12	--	bd	bd	0.0074	bd	bd	bd	0.01	<0.001	bd
HC-42	208828	8.5	<0.01	0.0092	37	--	bd	bd	0.0084	bd	bd	<0.001	0.34	<0.001	bd
HC-43	208885	1.3	<0.01	0.0077	25	--	bd	bd	0.0079	bd	bd	bd	0.1	<0.01	bd
HC-44	208888	9.7	0.026	0.02	21	--	bd	<0.01	0.009	bd	bd	bd	1.1	<0.01	bd
HC-45	202734	0.19	0.013	0.024	5.7	--	bd	<0.01	0.0092	bd	bd	bd	0.62	<0.01	bd
HC-46	202736	3.4	<0.01	0.012	30	--	bd	bd	0.01	0.27	bd	bd	1.3	<0.001	bd
HC-47	202713	0.78	0.016	0.021	38	--	bd	bd	0.013	0.41	bd	<0.001	3.5	bd	bd
HC-48	202708	1	0.014	0.028	22	--	bd	bd	0.011	bd	bd	bd	4.7	<0.001	bd
HC-49	178784	0.035	<0.01	0.011	10	--	bd	<0.001	0.0084	bd	bd	bd	0.22	<0.01	bd
HC-50	178823	0.078	<0.01	0.0086	1.1	--	<0.001	<0.001	0.0077	bd	bd	<0.001	0.11	<0.01	<0.001
HC-51	178814	0.3	0.03	0.026	9.4	--	bd	<0.01	0.013	bd	bd	<0.001	0.039	<0.001	<0.001
HC-52	178769	0.032	<0.001	0.0048	0.21	--	<0.001	<0.001	0.0034	bd	bd	bd	0.025	<0.001	<0.001
HC-53	178719	<0.01	<0.001	0.00076	0.029	--	<0.001	bd	0.00031	bd	bd	<0.001	<0.001	<0.001	bd
HC-54	178726	<0.01	<0.01	0.0044	0.087	--	<0.001	bd	0.0018	bd	bd	bd	<0.001	<0.001	bd
HC-65	HB-214522	bd	<0.01	0.013	5.4	bd	bd	bd	0.0093	--	--	--	6.8	bd	bd
HC-6 / Barrel W5	08-DOR-WR-05	5.8	<0.01	0.026	22	--	<0.01	<0.01	0.0094	--	--	--	4	<0.01	bd
HC-7 / Barrel W1	08-DOR-WR-02	0.21	<0.01	0.0091	30	--	bd	bd	0.0083	--	--	--	bd	<0.01	bd

'bd' indicates below detection

'--' indicates not reported

Kinetic Test ID	Sample ID		Gersdorffite	Gold	Hematite	Ilmenite	Iron	Kspar	Magnetite	Millerite		Monazite	Muscovite	Olivine
		Pb % eq.	%	%	%	%	%	%	%	%	Ni % eq.	%	%	%
HC-36	08TDD631-SRK-WR-435	0.00035	bd	bd	bd	0.3	<0.001	<0.01	0.072	bd	0.00065	<0.01	12	bd
HC-42	208828	0.000069	bd	<0.001	bd	0.42	<0.001	0.74	<0.001	bd	0.00049	<0.01	2.1	bd
HC-43	208885	0.0001	bd	<0.001	bd	0.62	<0.01	1.4	0.14	bd	0.00035	0.014	12	bd
HC-44	208888	0.00027	<0.001	<0.001	bd	0.21	<0.01	0.11	<0.001	bd	0.0051	<0.01	6.3	bd
HC-45	202734	0.00028	<0.01	<0.001	bd	0.4	<0.01	<0.01	0.25	bd	0.0028	<0.01	13	bd
HC-46	202736	0.000081	bd	<0.001	1.5	0.23	<0.01	0.15	0.037	bd	0.00039	<0.01	2.4	bd
HC-47	202713	0.000058	bd	bd	1.2	<0.01	bd	0.02	bd	bd	0.0053	<0.001	0.034	bd
HC-48	202708	0.00025	<0.01	<0.001	0.76	0.047	<0.001	0.063	<0.01	bd	0.0034	<0.001	0.13	bd
HC-49	178784	0.0002	bd	bd	bd	0.34	<0.01	<0.01	1.7	bd	0.00028	<0.01	8	bd
HC-50	178823	0.0012	bd	bd	bd	1	<0.001	<0.01	0.53	bd	0.00048	0.013	29	bd
HC-51	178814	0.00052	<0.01	<0.001	bd	0.14	<0.001	0.038	<0.01	bd	0.0097	<0.01	24	bd
HC-52	178769	0.00049	bd	<0.001	bd	0.036	<0.01	<0.01	0.019	bd	0.0023	<0.01	3.5	bd
HC-53	178719	0.00014	bd	<0.001	bd	0.02	<0.01	<0.01	<0.001	bd	0.00045	<0.001	0.92	bd
HC-54	178726	0.000057	bd	<0.001	bd	0.014	bd	<0.001	<0.01	bd	0.00059	<0.01	1.7	bd
HC-65	HB-214522	0.00032	bd	bd	0.77	0.76	bd	--	bd	bd	0.0061	bd	12	--
HC-6 / Barrel W5	08-DOR-WR-05	0.00031	<0.01	bd	0.56	0.28	bd	--	0.032	bd	0.0054	<0.01	4.7	--
HC-7 / Barrel W1	08-DOR-WR-02	0.0001	bd	bd	bd	0.34	<0.01	--	0.7	bd	0.00065	<0.01	7.3	--

'bd' indicates below detection

'--' indicates not reported

Kinetic Test ID	Sample ID	Paragonite	Platinum	Pyrite	Pyrophyllite	Pyrrhotite	Quartz	Rutile	Scheelite	Sepiolite*	Siderite	Sphalerite		Sphene
		%	%	%	%	%	%	%	%	%	%	%	Zn % eq.	%
HC-36	08TDD631-SRK-WR-435	3.7	bd	6.2	<0.001	<0.01	61	0.18	bd	bd	0.72	<0.001	0.004	<0.001
HC-42	208828	0.033	bd	0.24	<0.001	<0.01	37	0.27	bd	bd	0.21	bd	0.021	0.02
HC-43	208885	1.6	bd	1.1	<0.001	<0.001	30	0.38	bd	bd	1.6	bd	0.014	<0.01
HC-44	208888	2.5	bd	0.95	<0.001	0.013	35	0.15	bd	bd	0.1	<0.01	0.032	0.011
HC-45	202734	16	bd	4.7	0.014	0.021	32	0.38	bd	bd	1.2	<0.01	0.012	<0.001
HC-46	202736	0.6	bd	0.24	<0.001	<0.001	27	0.35	bd	bd	0.61	<0.001	0.019	0.69
HC-47	202713	0.029	bd	0.025	bd	<0.01	12	<0.01	bd	bd	0.11	bd	0.017	2.6
HC-48	202708	0.03	bd	0.076	<0.001	<0.01	10	<0.01	bd	bd	0.12	<0.001	0.012	2.2
HC-49	178784	5	bd	0.073	<0.01	<0.01	38	0.39	bd	bd	5.2	<0.001	0.029	<0.001
HC-50	178823	1.7	bd	1.9	<0.01	<0.01	27	0.56	bd	bd	2.6	<0.001	0.0092	<0.001
HC-51	178814	2.5	bd	1.7	<0.001	<0.001	22	0.47	bd	bd	1.5	<0.001	0.011	<0.01
HC-52	178769	0.79	bd	4	bd	<0.01	86	0.047	bd	bd	0.16	<0.01	0.0022	<0.001
HC-53	178719	0.12	<0.01	0.28	<0.001	<0.01	97	0.012	bd	bd	<0.01	bd	0.00084	bd
HC-54	178726	0.21	bd	1.9	<0.001	<0.01	92	0.017	bd	bd	<0.01	bd	0.00079	bd
HC-65	HB-214522	<0.01	--	0.21	bd	<0.01	3.9	<0.01	bd	bd	bd	bd	0.0063	1.5
HC-6 / Barrel W5	08-DOR-WR-05	3.7	--	0.12	<0.01	<0.01	28	0.24	bd	bd	0.18	<0.01	--	0.31
HC-7 / Barrel W1	08-DOR-WR-02	0.041	--	0.27	<0.01	<0.01	30	0.34	bd	bd	1.8	bd	--	<0.01

'bd' indicates below detection

'--' indicates not reported

Kinetic Test ID	Sample ID	Stilpnomelane	Talc	Tetradymite	Tetrahedrite	Titanomagnetite	Tourmaline	Xenotime	Zircon
		%	%	%	%	%	%	%	%
HC-36	08TDD631-SRK-WR-435	--	--	bd	bd	bd	0.031	<0.01	bd
HC-42	208828	--	--	bd	bd	bd	0.055	<0.001	bd
HC-43	208885	--	--	bd	bd	bd	0.38	<0.01	bd
HC-44	208888	--	--	bd	bd	bd	0.94	<0.001	bd
HC-45	202734	--	--	bd	bd	bd	1.1	<0.01	bd
HC-46	202736	--	--	bd	bd	bd	0.07	<0.01	<0.001
HC-47	202713	--	--	bd	bd	bd	0.025	bd	<0.001
HC-48	202708	--	--	bd	<0.001	bd	<0.0001	bd	<0.001
HC-49	178784	--	--	bd	bd	bd	0.61	<0.01	bd
HC-50	178823	--	--	bd	bd	bd	0.091	<0.01	bd
HC-51	178814	--	--	bd	<0.001	bd	0.17	<0.01	<0.001
HC-52	178769	--	--	bd	<0.001	bd	0.25	<0.01	bd
HC-53	178719	--	--	bd	bd	bd	0.8	<0.01	<0.001
HC-54	178726	--	--	bd	bd	bd	<0.01	<0.001	bd
HC-65	HB-214522	bd	<0.01	--	bd	0.022	0.042	bd	<0.01
HC-6 / Barrel W5	08-DOR-WR-05	--	--	--	bd	<0.01	0.4	<0.01	<0.01
HC-7 / Barrel W1	08-DOR-WR-02	--	--	--	bd	bd	0.06	<0.01	bd

'bd' indicates below detection

'--' indicates not reported

Appendix B4 – Newmont Metallurgical Services Mineralogy Report

NEWMONT MINING CORPORATION

Semiquantitative Mineralogy by XRD and Sulfide Characterization by MLA for Forty-three Ore and Waste Composites from Various Sites in Hope Bay undergoing Humidity Cell Testing

Plato Malozemoff Technical Facility

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May 9, 2011

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Memorandum

TO: C. Bucknam/Inverness

File 11486
MI 207561, 209144, 210052, 210117,210172, 210173

FROM: D. Lopez/Inverness

DATE: February 10, 2011

COPY: D. Brosnahan/Inverness
D. Doerr/Inverness
K. M. Le Vier/Inverness
D. Snyder/Inverness
L. Barazzuol/SRK

SUBJECT: Semiquantitative Mineralogy by XRD and Sulfide Characterization by MLA for Forty-three Ore and Waste Composites from Various Sites in Hope Bay undergoing Humidity Cell Testing

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SUMMARY

XRD (X-ray diffraction) and MLA (Mineral Liberation Analyzer) were used to characterize forty-four environmental composites from various sites in Hope Bay undergoing humidity cell testing. Samples were analyzed by XRD for bulk semiquantitative mineralogy and analyzed by MLA for characterization of any sulfides detected. MLA was able to detect trace amounts of sulfide, commonly unaccounted for by XRD due to detection limits, and supply mineral associations and free surface amounts from detected sulfides. MLA used the Extended Back-Scattered Electron (XBSE) method; an extended liberation analysis where back-scattered electron (BSE) images are collected and segmented based on a range of gray levels. A copper standard was used in establishing a gray scale due to the similar gray levels of the complex mixed gangue found in the samples. This elevated the contrast between gray levels optimizing the segmentation of gangue, which is necessary for a more accurate account of mineral association. Pyrite's (the predominate sulfide detected in most samples) particle size was given by percent passing values P_{50} (50% passing) and P_{80} (80% passing) in microns, ranging from 25-905µm; <1%-40% is the range of encapsulated pyrite. Pyrite's crystal morphology was classed as anhedral, subhedral, and euhedral; in addition pyrite particles were described as either coarse and/or fine-grained, whether there was dissemination in gangue, and whether particles had sieve texture.

INTRODUCTION

Forty-three ore and waste composites from different sites in Hope Bay undergoing humidity cell testing were submitted by C. Bucknam for identification of mineral content by XRD and sulfide characterization by MLA. Mineral weight percents, sulfide mineral associations, sulfide encapsulation, size and morphology of pyrite (the predominate sulfide detected in most of the

samples), calculated and measured assays, and back scattered electron images from MLA, are given for each composite.

DISCUSSION

Experimental

Analytic pulps of the samples were initially analyzed by XRD for semiquantitative mineralogy. Table I shows major and minor phases identified by XRD, with quantities determined by Rietveld refinement, whole pattern fitting, and based on chemical analyses. Table III shows measured chemical analyses used to aid XRD identifications, and to check XRD quantity estimates.

The samples were then analyzed by MLA (Mineral Liberation Analyzer), which uses a SEM (scanning electron microscope) with EDS (energy dispersive X-ray spectrometers) and automated quantitative mineralogy software, to detect trace minerals with a focus in characterizing sulfides. Five grams from each sample were mounted and slurried in epoxy, polished, and carbon-coated for MLA analysis. Most samples were analyzed at a ¼" mesh size (four samples were analytic pulps, -500 mesh) using the Extended Back-Scattered Electron (XBSE) measurement. MLA/XBSE is an extended liberation analysis where back-scattered electron (BSE) images are collected and segmented based on gray levels. An EDS spectrum is then collected for each segmented gray level image or "phase" and matched to a standards (mineral) list by pattern fitting.

Gold is commonly used as a standard to establish a gray level scale because of its brightness. Due to the similar gray levels of the complex mixed gangue found in the samples, copper was used to establish the gray scale. This elevated the contrast between gray levels which optimized the segmentation of gangue.

Data Analysis

Each sample is detailed with a brief description which includes the following:

-Major and minor minerals detected by XRD and MLA.
-Mineral weight percentages for any sulfide detected by MLA.
-Mineral associations of sulfides (≥0.01 wt%) detected by MLA.
-Encapsulation of sulfide quantities (≥0.01 wt%) determined by MLA.
-Particle size of pyrite, given by percent passing values P_{50} (50% passing) and P_{80} (80% passing), in microns.
-Pyrite's crystal morphology.

Mineral Content

XRD and MLA mineral weight percentages are given in a table for each sample (Table II contains MLA mineral weight % for all samples, Table V contains mineral key). The minerals are listed based on highest to lowest weight % by MLA, which were in accordance with XRD quantities for most samples. Sulfides detected by MLA are in bold. Calculated assays from MLA weight % for each sample are included in Table IV.

XRD and MLA shows the predominate gangue in these samples are silicates (quartz, albite, chlorite, muscovite/sericite, K-feldspar, and paragonite) and carbonates (ankerite, siderite, and calcite). XRD quantities of major and minor phases should be regarded when comparing with MLA's quantities for gangue; similar gray levels were still not fully segmented by MLA even though a Cu standard was used to optimize segmentation. XRD only detected pyrite when it was ~1% or higher, whereas trace amounts were detected by MLA.

There were eleven sulfide phases detected in this suite of samples: pyrite (FeS_2), chalcopyrite ($CuFeS_2$), gersdorffite ((Fe,Co,Ni)AsS), pyrrhotite ($Fe_{(1-x)}S$) , arsenopyrite (FeAsS), galena (PbS), cobaltite (CoAsS), millerite (NiS), sphalerite (ZnS), tetradymite (Bi_2Te_2S), and tetrahedrite (Cu_3SbS_3). Pyrite was the predominate sulfide followed by chalcopyrite.

Sulfide Mineral Associations

A table showing mineral associations was created for each sample, for any sulfides detected by MLA. The values represent the percentage of the periphery length in which a sulfide is associated (touching) with another phase. There is a "free surface" column which represents the percent of the sulfide that is exposed (touching epoxy). The last column in the table is "OTHER", this percentage represents the sum of phases which had <1% association with each sulfide detected in the sample.

Sulfide Encapsulation

A table showing sulfide encapsulation was created for each sample, for any sulfides detected by MLA. The values represent the percentage of sulfide that occurred in grains that were present in the following three categories:

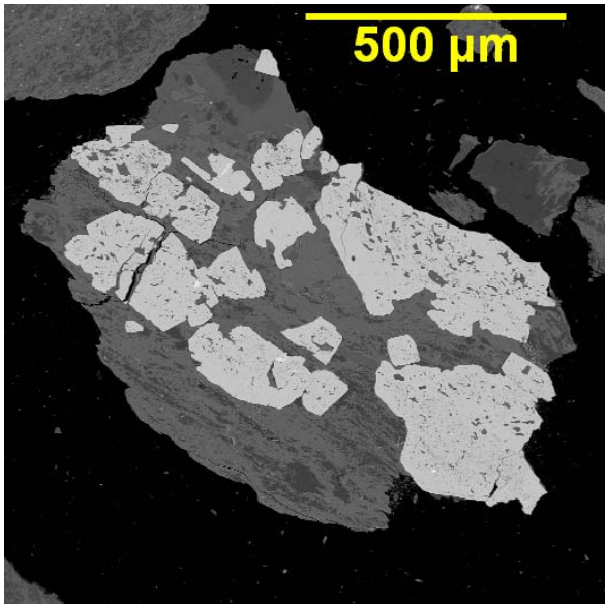
1) encapsulated (0% exposed)
2) liberated (100% exposed)
3) intermediate exposure (0%<x<100%)

This can be useful for determining potential oxidation of sulfides. For example, it may be assumed that sulfide that was completely encapsulated will not oxidize, which could help explain disagreements between humidity cell test results and anticipated results based on sulfur chemical analyses. Encapsulation was based on two-dimensional images, which could be exaggerated due to possible exposure in the third dimension.

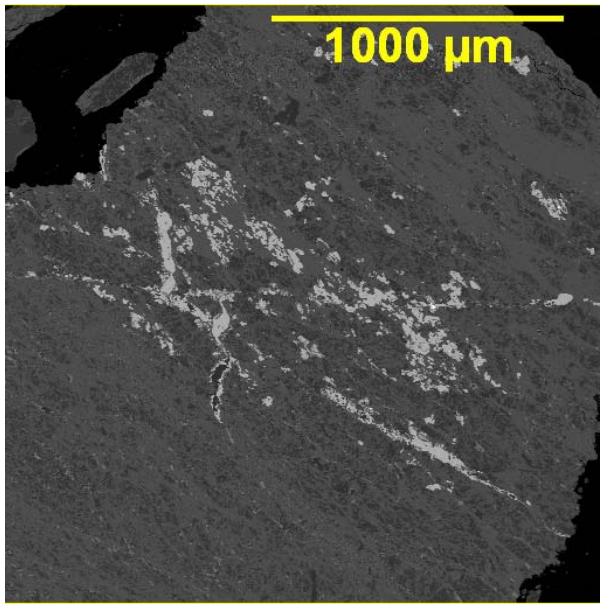
08PMD650, 33-36.4m (HC-17) **-** Predominately composed of chlorite, ankerite, and quartz. Lesser amounts of muscovite/sericite, calcite, and rutile were also detected. MLA detected 2.13% pyrite which was manually confirmed, while XRD did not detect any sulfide. Chemical analyses show total sulfur of 0.46%, which is equivalent to ~1% pyrite. MLA also detected trace amounts of chalcopyrite (0.03%) and <0.01% cobaltite. Pyrite was mainly associated with chlorite (44%) and quartz (12%); 13% of pyrite had a free surface. One percent of pyrite was encapsulated, 1% was liberated, and 98% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 342µm and 905µm respectively. Pyrite's crystal morphology, displayed in images below, is mostly anhedral to subhedral, coarse-grained with sieve texture (left image). There is some fine-grained disseminated anhedral pyrite detected in gangue (right image)**.** Chalcopyrite was also mainly associated with chlorite (50%) and quartz (17%); 7% of chalcopyrite had a free surface. Eighty-eight percent of chalcopyrite was encapsulated, 4% was liberated, and 8% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Chlorite	37.95	41
Ankerite	25.36	23
Quartz	19.69	22
Muscovite	5.19	6
Amphibole	3.78	
Calcite	3.05	6
Pyrite	2.13	
Albite	0.96	
Rutile	0.49	1
Ilmenite	0.47	
Epidote	0.33	
Sphene	0.30	
Kspar	0.12	
Apatite	0.05	
Chalcopyrite	0.03	
Iron	0.03	
Paragonite	0.03	
Siderite	0.02	
Tourmaline	0.02	
Biotite	0.01	
Chromite	<0.01%	
Cobaltite	<0.01%	
Monazite	<0.01%	
Anhydrite	<0.001%	
Enstatite	<0.001%	
FeClay	<0.001%	



BSE image of bright subhedral pyrite with sieve texture in a chlorite (light gray) and quartz (dark gray) particle.



BSE image of bright disseminated pyrite in a chlorite (light gray) and quartz (dark gray) particle.

Sulfide Mineral Associations

MINERAL	Albite	Amphibole	Ankerite	Calcite	Chalcopyrite	Chlorite	Ilmenite	Muscovite	Pyrite	Quartz	Rutile	Free Surface	OTHER
Chalcopyrite	0.00	3.43	9.59	1.36	0.00	49.82	0.42	0.13	9.72	16.89	0.40	7.34	0.89
Cobaltite	2.81	0.00	3.99	0.00	12.53	21.21	2.10	15.13	0.00	37.27	4.96	0.00	0.00
Pyrite	0.61	5.68	8.63	2.72	0.41	43.51	1.55	8.52	0.00	12.44	1.62	13.10	1.20

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	87.87	8.44	3.69
Cobaltite	100.00	0.00	0.00
Pyrite	1.04	97.92	1.03

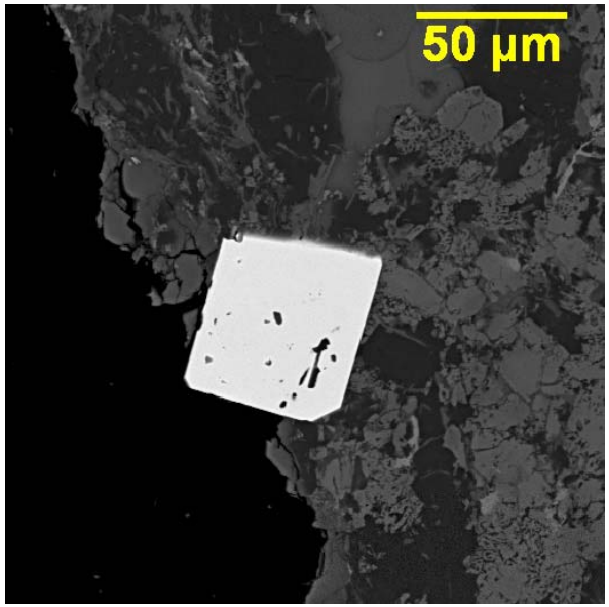
Pyrite Particle Size by Percent Passing

P-value	µm
P50	342.23
P80	905.12

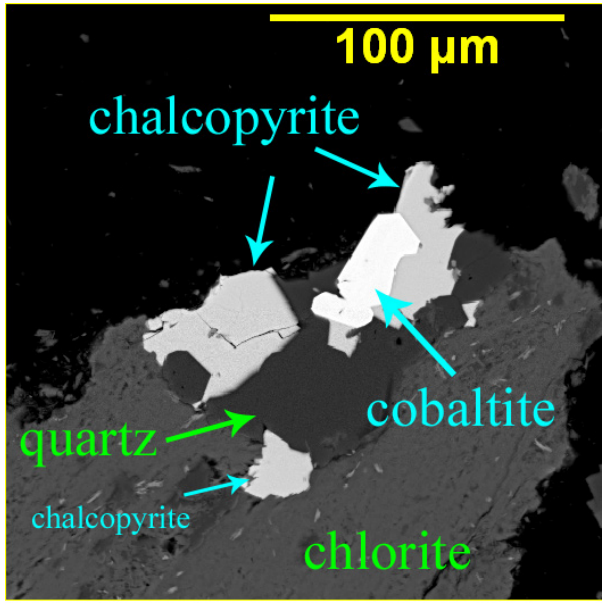
07PMD552, 134-144.5m (HC-18) **-** Predominately composed of chlorite, albite, muscovite/sericite, and quartz. Lesser amounts of epidote, calcite, ankerite, and sphene were also detected. MLA measured trace amounts of pyrite (0.13%), chalcopyrite (0.05%), cobaltite (< 0.01%), and millerite (<0.001%). Pyrite was mainly associated with albite (22%), chlorite (13%), and muscovite/sericite (9%); 30% of pyrite had a free surface. Twenty-six percent of pyrite was encapsulated, 13% was liberated, and 61% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 106µm and 124µm respectively. Pyrite's crystal morphology, displayed in left image below, is mostly subhedral to euhedral, coarse-grained with some sieve texture. Chalcopyrite was mainly associated with albite (26%), chlorite (20%), and muscovite/sericite (12%); 12% of chalcopyrite had a free surface. Thirty-eight percent of chalcopyrite was encapsulated, <1% was liberated, and 61% had intermediate exposure. An image of chalcopyrite locked with cobaltite in a quartz and chlorite particle is displayed in right image below.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Albite	34.16	21
Chlorite	24.55	27
Ankerite	11.55	5
Muscovite	9.11	18
Quartz	7.65	15
Epidote	4.64	6
Calcite	3.06	6
Tourmaline	1.75	
Paragonite	1.58	
Kspar	0.99	
Biotite	0.56	
Pyrite	0.13	
Sphene	0.11	2
Chalcopyrite	0.05	
Amphibole	0.03	
Ilmenite	0.03	
Rutile	0.02	
Siderite	0.01	
Apatite	<0.01	
Chromite	<0.01	
Cobaltite	<0.01	
Enstatite	<0.001	
FeClay	<0.001	
Magnetite	<0.001	
Millerite	<0.001	
Monazite	<0.001	
Pyrophyllite	<0.001	



BSE image of a bright euhedral pyrite with sieve texture in an epidote (light gray) and albite (dark gray) particle.



BSE image of very bright cobaltite and bright chalcopyrite grains in quartz (dark gray) found in chlorite (light gray).

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Biotite	Calcite	Chalcopyrite	Chlorite	Cobaltite	Epidote	Kspar	Muscovite	Paragonite	Pyrite	Quartz	Free Surface	OTHER
Chalcopyrite	25.52	4.85	0.13	1.65	0.00	20.03	1.05	4.94	2.96	12.11	0.00	1.40	12.14	12.42	0.79
Cobaltite	19.93	2.30	3.01	0.00	8.98	22.60	0.00	0.00	0.00	10.77	1.28	2.89	19.12	8.54	0.57
Millerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.75	0.00	0.00	0.00	0.00	26.81	54.44	0.00
Pyrite	21.76	3.89	1.88	2.22	0.73	13.09	0.18	4.61	3.88	8.87	1.06	0.00	7.02	29.63	1.19

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	38.29	61.04	0.67
Cobaltite	57.39	41.34	1.28
Millerite	30.77	0.00	69.23
Pyrite	26.04	60.88	13.08

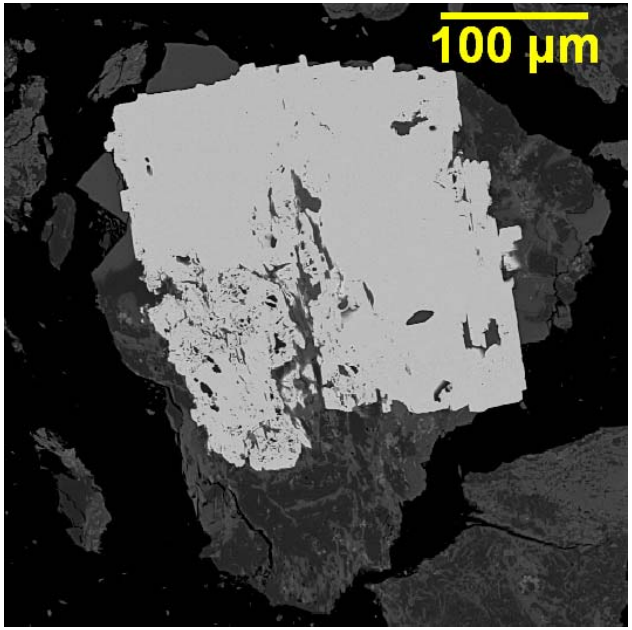
Pyrite Particle Size by Percent Passing

P-value	µm
P50	106.07
P80	124.16

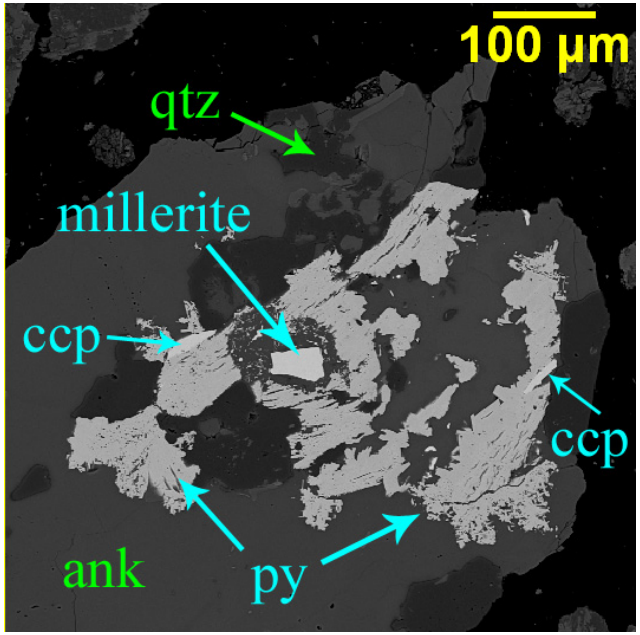
08PSD142, 245.5-254.5m (HC-19) **-** Predominately composed of albite, chlorite, quartz, and epidote. Lesser amounts of calcite, muscovite/sericite, amphibole, and sphene were also detected. MLA measured trace amounts of pyrite (0.58%), pyrrhotite (0.18%), chalcopyrite (0.04%), sphalerite (0.02%), millerite (<0.01%), and <0.001% cobaltite and tetrahedrite. Pyrite was mainly associated with albite (18%), epidote (14%), and ankerite (11%); 24% of pyrite had a free surface. Five percent of pyrite was encapsulated, 6% was liberated, and 89% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 170µm and 289µm respectively. Pyrite's crystal morphology, displayed in images below, is mostly anhedral to euhedral, coarse-grained with sieve texture. Pyrrhotite and chalcopyrite were mainly associated with albite (18-21%) and epidote (21-29%); 30% of pyrrhotite and 15% of chalcopyrite had a free surface. Twenty percent of pyrrhotite was encapsulated, 14% was liberated, and 66% had intermediate exposure. Thirty-one percent of chalcopyrite was encapsulated, 10% was liberated, and 59% had intermediate exposure. Sphalerite was mainly associated with muscovite/sericite (25%) and epidote (17%); 21% of sphalerite had a free surface. Twenty-five percent of sphalerite was encapsulated, <1% was liberated, and 74% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Albite	38.42	24
Epidote	20.33	17
Chlorite	16.18	24
Quartz	10.43	18
Calcite	6.44	7
Muscovite	3.36	6
Tourmaline	1.22	
Ankerite	1.15	
Amphibole	0.64	2
Pyrite	0.58	
Kspar	0.48	
Sphene	0.24	2
Paragonite	0.19	
Pyrrhotite	0.18	
Biotite	0.07	
Chalcopyrite	0.04	
Sphalerite	0.02	
Apatite	<0.01	
Ilmenite	<0.01	
Iron	<0.01	
Millerite	<0.01	
Rutile	<0.01	
Siderite	<0.01	
Cobaltite	<0.001	
FeClay	<0.001	
Pyrophyllite	<0.001	
Tetrahedrite	<0.001	



BSE image of a bright euhedral pyrite with sieve texture in a calcite (light gray) and albite (dark gray) particle.



BSE image of very bright millerite and chalcopyrite, light gray anhedral/subhedral pyrite in ankerite (medium gray).

Sulfide Mineral Associations

MINERAL	Albite	Amphibole	Ankerite	Calcite	Chalcopyrite	Chlorite	Epidote	Kspar	Muscovite	Pyrite	Pyrrhotite	Quartz	Sphalerite	Sphene	Tourmaline	Free Surface	OTHER
Chalcopyrite	20.87	2.69	1.72	2.86	0.00	8.38	29.35	2.13	0.25	3.51	3.67	7.05	1.78	0.07	1.05	14.56	0.07
Cobaltite	22.75	0.00	25.99	2.56	1.92	4.85	22.59	0.00	13.32	6.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Millerite	6.75	0.00	63.02	0.00	0.00	0.00	18.19	0.00	0.00	0.00	0.00	0.00	0.00	1.34	0.00	10.70	0.00
Pyrite	17.55	0.69	10.72	6.18	0.67	7.31	14.31	2.81	4.10	0.00	1.33	9.25	0.24	0.32	0.21	23.59	0.71
Pyrrhotite	17.98	2.53	0.47	3.54	1.16	10.37	21.22	0.69	0.28	2.18	0.00	9.32	0.21	0.51	0.00	29.50	0.03
Sphalerite	0.27	0.00	0.89	9.17	9.70	0.00	16.66	2.41	24.51	6.81	3.55	4.57	0.00	0.00	0.00	21.47	0.00
Tetrahedrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	30.71	59.57	9.72
Cobaltite	100.00	0.00	0.00
Millerite	3.15	96.85	0.00
Pyrite	5.31	88.56	6.13
Pyrrhotite	19.80	65.68	14.52
Sphalerite	25.49	74.19	0.33
Tetrahedrite	0.00	0.00	100.00

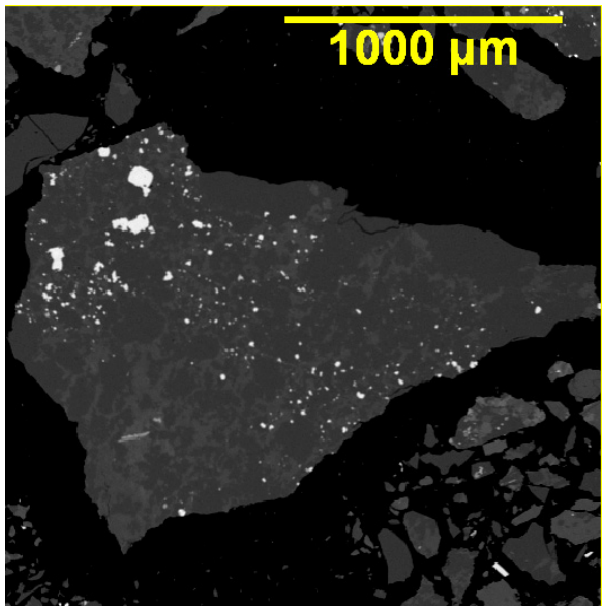
Pyrite Particle Size by Percent Passing

P-value	µm
P50	170.11
P80	288.58

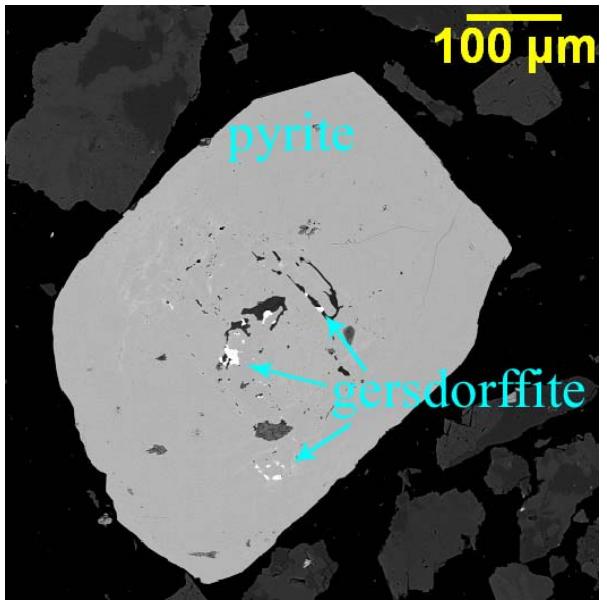
06PMD470, 217.03-218.7m (HC-20) **-** Predominately composed of ankerite, quartz, and albite. Lesser amounts of pyrite, muscovite/sericite, chlorite, and rutile were also detected. MLA measured a relatively high amount of pyrite (6.05%) along with trace amounts of gersdorffite (0.09%), chalcopyrite (<0.01%), and <0.001% cobaltite and pyrrhotite. Pyrite was mainly associated with ankerite (23%) and quartz (17%); 48% of pyrite had a free surface. Three percent of pyrite was encapsulated, 25% was liberated, and 72% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 132µm and 247µm respectively. Pyrite's crystal morphology, displayed in images below, is mostly subhedral to euhedral, coarse to fine-grained with slight sieve texture. Gersdorffite was mainly associated with ankerite (37%), quartz (20%), and pyrite (16%); 12% of gersdorffite had a free surface. Forty-seven percent of gersdorffite was encapsulated, 6% was liberated, and 47% had intermediate exposure. An image of subhedral pyrite with gersdorffite inclusions is displayed in right image below.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Ankerite	43.57	45
Quartz	38.49	38
Albite	8.26	11
Pyrite	6.05	4
Chlorite	1.97	<1
Muscovite	0.40	2
Rutile	0.36	<1
Amphibole	0.23	
Ilmenite	0.19	
Gersdorffite	0.09	
Kspar	0.09	
Chromite	0.08	
Apatite	0.06	
Biotite	0.04	
Siderite	0.04	
Paragonite	0.03	
Epidote	0.01	
Calcite	<0.01	
Chalcopyrite	<0.01	
Monazite	<0.01	
Sphene	<0.01	
Tourmaline	<0.01	
Anhydrite	<0.001	
Cobaltite	<0.001	
Gold	<0.001	
Iron	<0.001	
Pyrophyllite	<0.001	
Pyrrhotite	<0.001	



BSE image of bright coarse and fine-grained pyrite in an ankerite (light gray) and quartz (dark gray) particle.



BSE image of very bright gersdorffite inclusions in light gray subhedral pyrite with sieve texture.

Sulfide Mineral Associations

MINERAL	Albite	Amphibole	Ankerite	Chlorite	Gersdorffite	Muscovite	Pyrite	Quartz	Free Surface	OTHER
Chalcopyrite	4.04	2.97	24.41	9.31	1.18	3.60	32.31	8.99	12.44	0.76
Cobaltite	0.00	0.00	27.91	0.00	0.00	0.00	0.00	20.65	51.44	0.00
Gersdorffite	6.76	0.31	37.05	3.26	0.00	2.53	16.29	19.87	11.79	2.16
Pyrite	7.63	0.03	22.60	1.08	1.12	0.98	0.00	17.10	48.12	1.35
Pyrrhotite	1.09	0.00	3.75	0.00	0.00	0.00	16.57	18.80	59.79	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	32.37	65.67	1.96
Cobaltite	25.93	0.00	74.07
Gersdorffite	46.91	46.83	6.26
Pyrite	3.18	71.93	24.90
Pyrrhotite	3.09	62.65	34.26

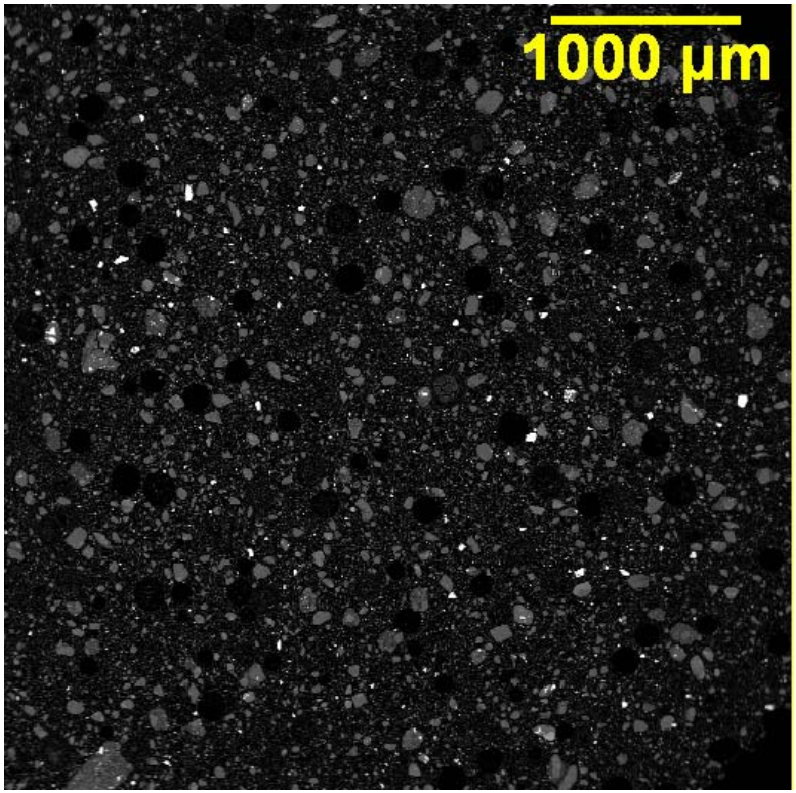
Pyrite Particle Size by Percent Passing

P-value	µm
P50	132.34
P80	247.34

07PMD542, 104.15-105.29m (HC-21) **-** Predominately composed of albite, muscovite/sericite, quartz, and ankerite. Lesser amounts of pyrite, chlorite, and rutile were also detected. MLA measured a relatively high amount of pyrite (9.35%), almost double of what XRD detected; based on total sulfur amount (3.54%) from chemical analyses pyrite weight percent should be ~7%. Sulfide mineral associations and sulfide exposure parameters were not included for this sample because most particles have been liberated due to pulverization. The image below shows pulverized sample with liberated grains of gangue and sulfides.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Muscovite	26.35	24
Quartz	22.93	20
Albite	22.26	27
Ankerite	14.20	20
Pyrite	9.35	5
Chlorite	1.89	3
Kspar	0.75	
Paragonite	0.65	
Apatite	0.52	
Ilmenite	0.34	
Rutile	0.23	1
Epidote	0.16	
Tourmaline	0.08	
Amphibole	0.07	
Calcite	0.05	
Pyrrhotite	0.04	
Pyrophyllite	0.03	
Biotite	0.02	
Chalcopyrite	0.02	
Iron	0.02	
Monazite	0.02	
Barite	<0.01	
Chromite	<0.01	
FeClay	<0.01	
Siderite	<0.01	
Sphalerite	<0.01	
Sphene	<0.01	
Cobaltite	<0.001	
Xenotime	<0.001	



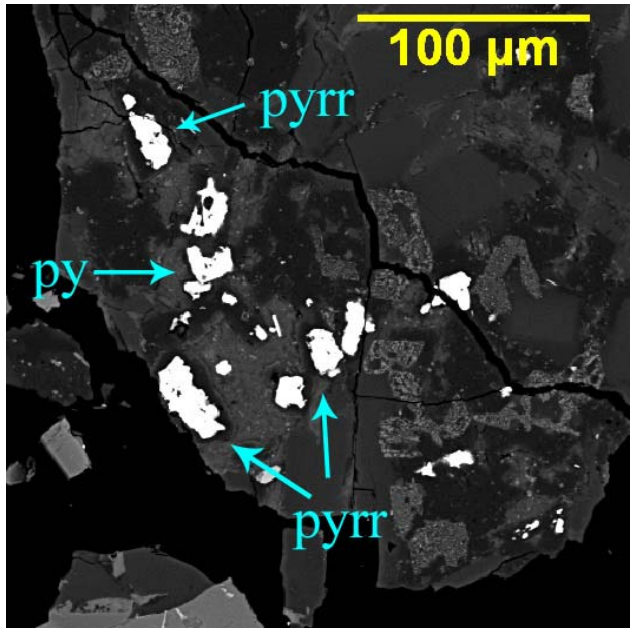
Low magnification BSE image of pulverized sample. Bright gray particles are sulfides and darker gray particles are gangue. Black spheres are holes in the epoxy formed by air bubbles during sample mounting.

06PMD470, 371.05-376.28m (HC-22) **-** Predominately composed of diopside and plagioclase (albite, andesine). Lesser amounts of chlorite, quartz, titanomagnetite, and ankerite were also detected. MLA measured trace amounts of chalcopyrite (0.06%), pyrrhotite (0.03%), pyrite (0.02%), and <0.001% tetrahedrite. Pyrite was mainly associated with albite (22%%) and chlorite (18%); 17% of pyrite had a free surface. Thirty-four percent of pyrite was encapsulated, 21% was liberated, and 45% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 10µm and 16µm respectively. Pyrite's crystal morphology, displayed in left image below, is mostly anhedral and fine-grained. Chalcopyrite was mainly associated with diopside (30%) and albite (20%); 11% of chalcopyrite had a free surface. Sixty-seven percent of chalcopyrite was encapsulated, 5% was liberated, and 28% had intermediate exposure. Pyrrhotite (also displayed in left image below) was mainly associated with chlorite (30%) and albite (14%); 23% of pyrrhotite had a free surface. Three of pyrrhotite was encapsulated, 6% was liberated, and 91% had intermediate exposure. MLA detected titanium-rich magnetite (titanomagnetite), shown in the right image below.

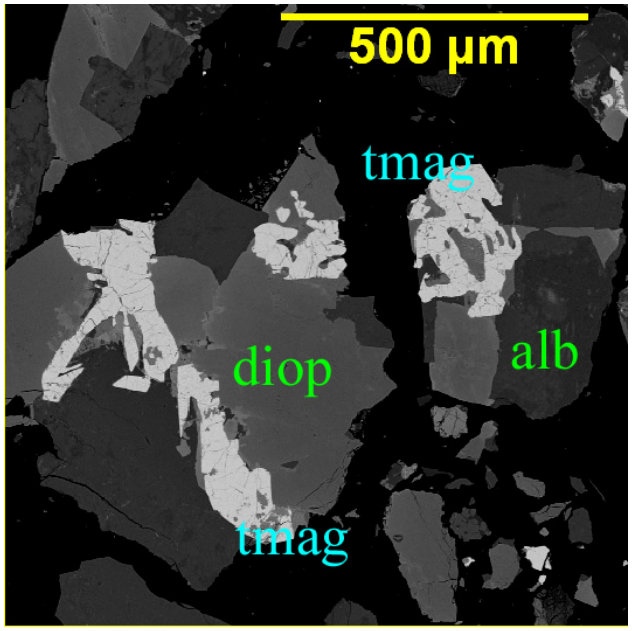
Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Diopside	40.18	40
Albite	25.92	45
Andesine	12.64	
Titanomagnetite	5.34	2*
Chlorite	4.69	8
Epidote	3.51	
Quartz	3.03	3
Calcite	0.89	
Ankerite	0.86	1
Kspar	0.86	
Amphibole	0.64	
Biotite	0.55	
Sphene	0.32	
Ilmenite	0.29	
Apatite	0.08	
Chalcopyrite	0.06	
Paragonite	0.04	
Pyrrhotite	0.03	
Tourmaline	0.03	
Pyrite	0.02	
Hematite	<0.01	
Iron	<0.01	
Olivine	<0.01	
Rutile	<0.01	
Siderite	<0.01	
Gold	<0.001	
Monazite	<0.001	
Tetrahedrite	<0.001	
Zircon	<0.001	

*Titanomagnetite was quantified as magnetite by XRD



BSE image of bright anhedral pyrite (py) and pyrrhotite (pyrr) in mixed gangue of epidote, quartz, chlorite, and albite.



BSE image of bright titanomagnetite (tmag) in light gray diopside (diop) and dark gray albite (alb) mixed particles.

Sulfide Mineral Associations

MINERAL	Albite	Andesine	Ankerite	Biotite	Calcite	Chalcopyrite	Chlorite	Diopside	Epidote	Kspar	Pyrite	Pyrrhotite	Quartz	Titanomagnetite	Free Surface	OTHER
Chalcopyrite	19.89	11.78	1.24	2.24	1.14	0.00	8.15	30.09	1.33	1.19	0.51	0.10	5.99	3.57	10.97	1.81
Pyrite	21.72	5.77	1.27	0.43	0.87	1.05	17.63	19.42	2.47	0.26	0.00	2.85	6.38	1.68	17.06	1.14
Pyrrhotite	14.25	5.49	0.11	0.42	1.64	0.28	29.64	4.88	1.03	0.24	3.78	0.00	14.18	1.25	22.75	0.04
Tetrahedrite	22.80	0.00	0.00	0.00	0.00	32.16	0.00	37.21	0.00	0.00	0.00	0.00	0.00	0.00	7.83	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	67.28	28.17	4.55
Pyrite	33.99	45.21	20.80
Pyrrhotite	3.33	90.60	6.07
Tetrahedrite	94.12	2.75	3.14

Pyrite Particle Size by Percent Passing

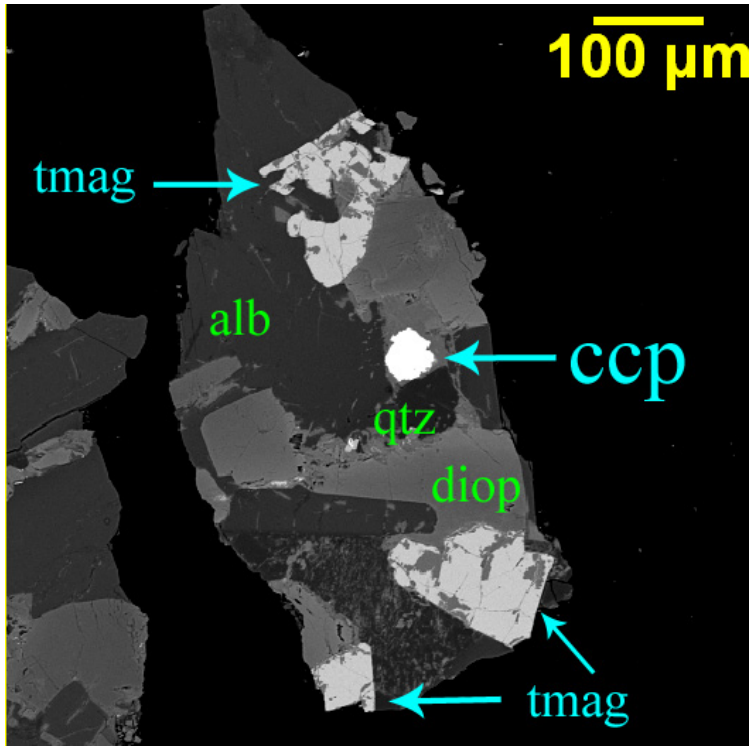
P-value	µm
P50	9.88
P80	16.03

07PMD542, 73.28-77m (HC-23) **-** Predominately composed of plagioclase (albite, andesine) and diopside. Lesser amounts of chlorite, quartz, titanomagnetite, and ankerite were also detected. MLA detected major amounts of diopside (38.08%) compared to XRD (18%) due to difficulties segmenting similar gray level phases, which is most likely the reason for lower MLA quantities of plagioclase compared to XRD. MLA measured trace amounts of chalcopyrite (0.06%), <0.01% pyrite and pyrrhotite, and <0.001% tetrahedrite. Chalcopyrite was mainly associated with diopside (30%) and albite (19%); 9% of chalcopyrite had a free surface. Sixty-seven percent of chalcopyrite was encapsulated, 3% was liberated, and 30% had intermediate exposure. Pyrite was mainly associated with diopside (18%) and chlorite (15%); 31% of pyrite had a free surface. Forty percent of pyrite was encapsulated, 37% was liberated, and 22% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 9µm and 16µm respectively. MLA detected titanium-rich magnetite (titanomagnetite), shown in the image below.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Diopside	38.08	18
Albite	24.30	63
Andesine	13.11	
Chlorite	9.78	8
Titanomagnetite	5.73	5*
Quartz	3.29	2
Epidote	3.14	
Ankerite	0.64	4
Biotite	0.62	
Calcite	0.47	
Ilmenite	0.28	
Sphene	0.22	
Apatite	0.09	
Chalcopyrite	0.06	
Hematite	0.06	
Siderite	0.05	
Tourmaline	0.03	
Chromite	0.02	
Kspar	0.02	
Olivine	<0.01	
Pyrite	<0.01	
Pyrrhotite	<0.01	
Enstatite	<0.001	
FeClay	<0.001	
Monazite	<0.001	
Paragonite	<0.001	
Rutile	<0.001	
Tetrahedrite	<0.001	
Zircon	<0.001	

*Titanomagnetite was quantified as magnetite by XRD



BSE image of bright chalcopyrite grain (ccp) and light grey titanomagnetite (tmag) in a diopside (diop) and albite (alb) mixed particle.

Sulfide Mineral Associations

MINERAL	Albite	Andesine	Ankerite	Biotite	Calcite	Chalcopyrite	Chlorite	Diopside	Pyrite	Pyrrhotite	Quartz	Titanomagnetite	Free Surface	OTHER
Chalcopyrite	18.92	9.45	0.96	2.31	0.39	0.00	11.26	29.76	0.15	0.24	11.49	5.00	8.84	1.23
Pyrite	9.28	5.97	1.23	3.38	2.23	1.14	15.12	17.92	0.00	4.00	5.30	1.29	31.19	1.96
Pyrrhotite	11.65	1.10	24.38	0.00	18.73	2.31	14.07	7.62	5.17	0.00	4.87	0.00	10.10	0.00
Tetrahedrite	14.54	31.29	0.00	6.92	0.00	7.13	0.00	23.61	0.00	0.00	16.52	0.00	0.00	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	66.68	30.25	3.07
Pyrite	40.40	22.22	37.39
Pyrrhotite	73.60	22.13	4.27
Tetrahedrite	100.00	0.00	0.00

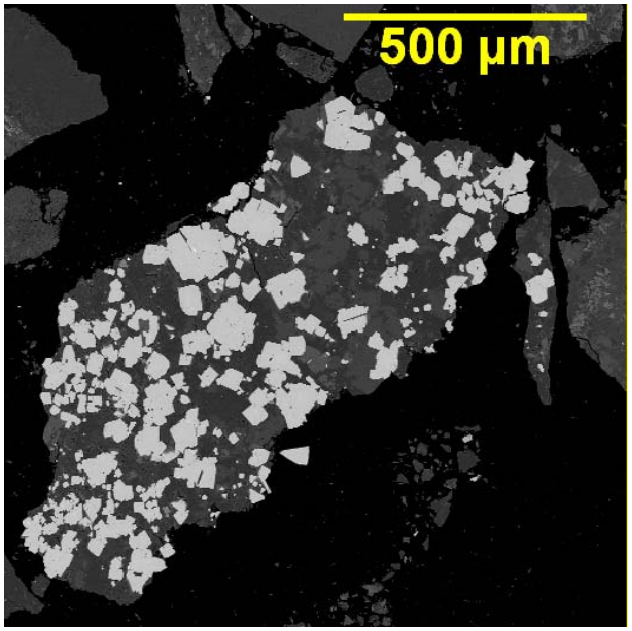
Pyrite Particle Size by Percent Passing

P-value	µm
P50	8.67
P80	16.21

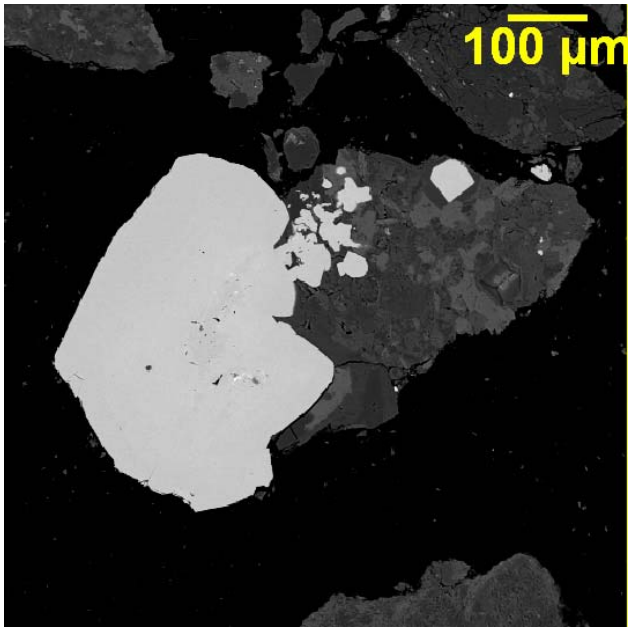
06PMD484, 224.5-226.5m (HC-24) **-** Predominately composed of ankerite, albite, quartz, and chlorite. MLA detected 17% muscovite/sericite which is in close agreement with the K values (1.4-2.0%) from chemical analyses. Lesser amounts of pyrite, and rutile were also detected. MLA measured minor amounts of pyrite (3.69%) along with trace amounts of chalcopyrite (0.03%), gersdorffite (0.03%), and <0.001% cobaltite, pyrrhotite and sphalerite. Pyrite was mainly associated with ankerite (18%), muscovite/sericite (17%), chlorite (11%), and quartz (10%); 28% of pyrite had a free surface. Three percent of pyrite was encapsulated, 14% was liberated, and 83% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 125µm and 301µm respectively. Pyrite's crystal morphology, displayed in images below, is mostly subhedral to euhedral, coarse to fine-grained with sieve texture. Chalcopyrite was mainly associated with ankerite (26%) and chlorite (17%); 18% of chalcopyrite had a free surface. Forty-five percent of chalcopyrite was encapsulated, 6% was liberated, and 49% had intermediate exposure. Gersdorffite was mainly associated with muscovite/sericite (23%), chlorite (22%) and ankerite (17%); 10% of gersdorffite had a free surface. Seventy percent of gersdorffite was encapsulated, 3% was liberated, and 28% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Ankerite	41.14	45
Muscovite	16.68	9
Quartz	12.06	15
Albite	11.52	15
Chlorite	10.62	12
Pyrite	3.69	3
Kspar	2.53	
Amphibole	0.39	
Rutile	0.38	1
Ilmenite	0.26	
Epidote	0.22	
Biotite	0.16	
Paragonite	0.10	
Calcite	0.08	
Apatite	0.05	
Chalcopyrite	0.03	
Chromite	0.03	
Gersdorffite	0.03	
Tourmaline	0.02	
Monazite	<0.01	
Siderite	<0.01	
Sphene	<0.01	
Xenotime	<0.01	
Cobaltite	<0.001	
FeClay	<0.001	
Gold	<0.001	
Pyrophyllite	<0.001	
Pyrrhotite	<0.001	
Sphalerite	<0.001	



BSE image of bright coarse and fine-grained euhedral pyrite in an ankerite (light gray) and muscovite/sericite (dark gray) particle.



BSE image of bright subhedral/euhedral pyrite in a chlorite (light gray) and muscovite/sericite (dark gray) particle.

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Chalcopyrite	Chlorite	Gersdorffite	Kspar	Muscovite	Pyrite	Quartz	Free Surface	OTHER
Chalcopyrite	2.60	26.46	0.00	16.64	5.65	0.42	7.31	10.36	10.64	18.08	1.83
Cobaltite	0.00	20.29	2.10	35.78	0.00	0.00	0.00	0.00	41.82	0.00	0.00
Gersdorffite	5.72	16.75	5.98	22.17	0.00	1.63	23.48	5.97	7.03	10.19	1.08
Pyrite	10.73	18.01	0.21	10.99	0.12	3.26	16.91	0.00	9.94	28.20	1.63
Pyrrhotite	9.06	0.00	0.00	7.58	0.00	0.00	4.88	35.04	2.29	41.15	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	45.42	48.69	5.89
Cobaltite	100.00	0.00	0.00
Gersdorffite	69.38	27.70	2.92
Pyrite	2.98	83.13	13.89
Pyrrhotite	23.99	70.95	5.07
Sphalerite	100.00	0.00	0.00

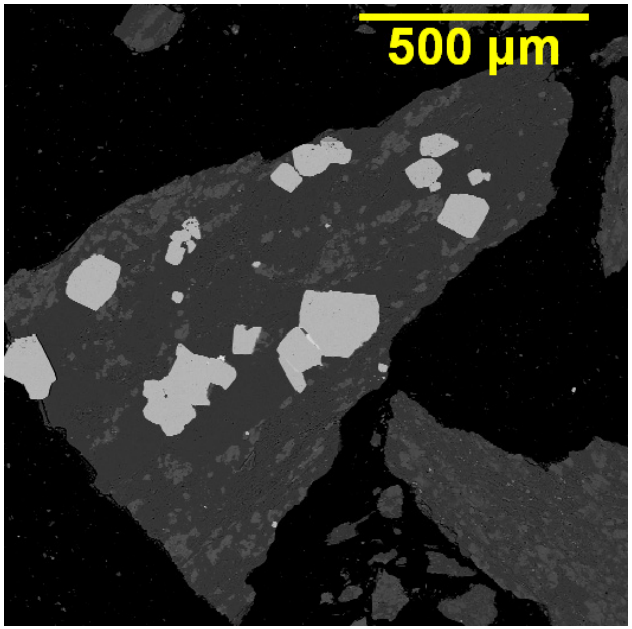
Pyrite Particle Size by Percent Passing

P-value	µm
P50	125.15
P80	300.75

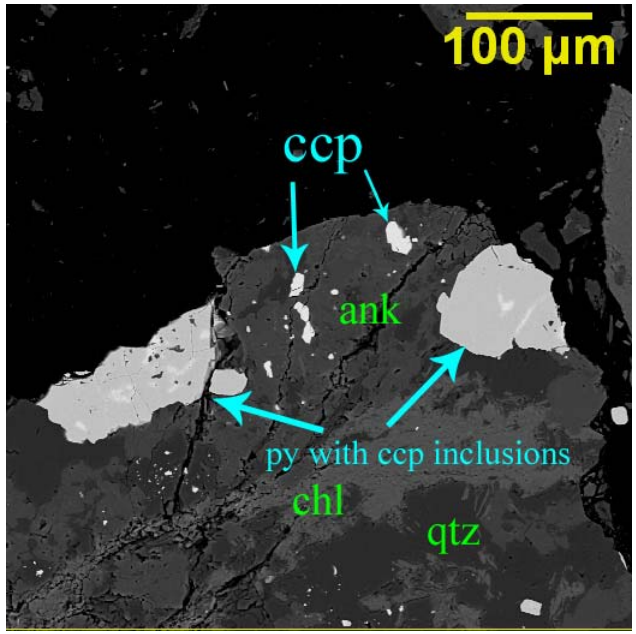
07PMD552, 58.5-72m (HC-25) **-** Predominately composed of ankerite, quartz, and muscovite/sericite. Lesser amounts of paragonite, chlorite, albite, and rutile were also detected. MLA measured trace amounts of pyrite (0.97%), chalcopyrite (0.03%), 0.01% cobaltite and gersdorffite, <0.01% millerite, and <0.001% pyrrhotite and sphalerite. Pyrite was mainly associated with muscovite/sericite (25%) and quartz (16%); 19% of pyrite had a free surface. Seven percent of pyrite was encapsulated, 9% was liberated, and 84% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 91µm and 169µm respectively. Pyrite's crystal morphology, displayed in images below, is mostly anhedral to subhedral, coarse grained with sieve texture. Chalcopyrite was mainly associated with pyrite (24%) and quartz (21%); 12% of chalcopyrite had a free surface. Fifty-two percent of chalcopyrite was encapsulated, 4% was liberated, and 44% had intermediate exposure. Gersdorffite and cobaltite were mainly associated with muscovite/sericite (21-27%); 12% of gersdorffite and 5% of cobaltite had a free surface. Thirty-seven percent of gersdorffite was encapsulated, 3% was liberated, and 60% had intermediate exposure. Eighty-three percent of cobaltite was encapsulated, 1% was liberated, and 15% had intermediate exposure .

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Ankerite	24.18	31
Muscovite	21.26	16
Albite	19.31	10
Quartz	13.72	19
Paragonite	11.52	11
Chlorite	6.31	11
Kspar	1.47	
Pyrite	0.97	
Epidote	0.53	
Tourmaline	0.28	
Amphibole	0.13	
Calcite	0.08	
Rutile	0.07	1
Ilmenite	0.05	
Apatite	0.04	
Chalcopyrite	0.03	
Biotite	0.02	
Cobaltite	0.01	
Gersdorffite	0.01	
Millerite	<0.01	
Monazite	<0.01	
Pyrophyllite	<0.01	
Siderite	<0.01	
Chromite	<0.001	
Enstatite	<0.001	
FeClay	<0.001	
Iron	<0.001	
Magnetite	<0.001	
Pyrrhotite	<0.001	
Sphalerite	<0.001	
Sphene	<0.001	
Xenotime	<0.001	



BSE image of bright subhedral/euhedral pyrite grains in an ankerite (light gray) and albite (dark gray) particle.



BSE image of very bright chalcopyrite grains encapsulated in bright gray pyrite found in mixed gangue (ankerite-ank, chlorite-chl, and quartz-qtz).

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Chalcopyrite	Chlorite	Cobaltite	Gersdorffite	Kspar	Millerite	Muscovite	Paragonite	Pyrite	Quartz	Siderite	Free Surface	OTHER
Chalcopyrite	6.13	15.33	0.00	6.48	0.26	0.15	0.66	0.85	8.34	3.58	24.25	20.81	0.49	12.10	0.57
Cobaltite	10.44	16.67	0.98	4.45	0.00	7.29	1.19	1.12	20.70	12.43	12.16	7.20	0.00	4.77	0.60
Gersdorffite	11.35	7.87	0.36	5.31	4.80	0.00	5.04	1.96	26.77	9.56	8.58	5.67	0.00	12.32	0.41
Millerite	10.12	17.35	6.11	1.80	2.15	5.73	0.00	0.00	19.75	0.84	18.79	14.73	0.00	2.62	0.00
Pyrite	11.33	11.00	1.94	1.84	0.26	0.28	1.29	0.21	24.90	10.92	0.00	15.87	0.02	19.26	0.88
Pyrrhotite	0.00	13.97	0.00	3.09	0.00	0.00	0.00	0.00	0.00	3.33	54.15	9.96	1.55	13.94	0.00
Sphalerite	24.62	43.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.44	0.00	0.00	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	52.36	43.89	3.75
Cobaltite	83.32	15.40	1.28
Gersdorffite	36.64	60.03	3.33
Millerite	84.67	14.83	0.50
Pyrite	7.32	83.77	8.90
Pyrrhotite	6.59	73.08	20.33
Sphalerite	100.00	0.00	0.00

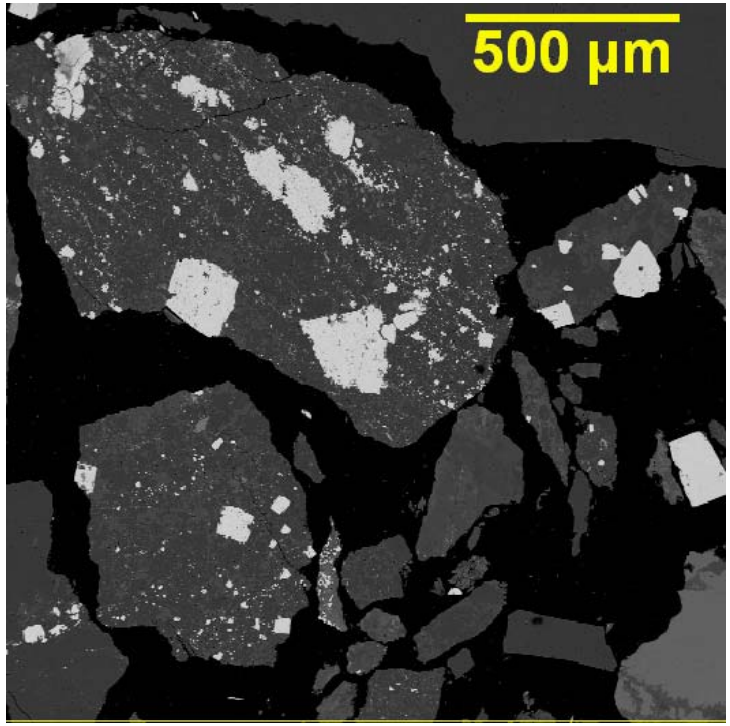
Pyrite Particle Size by Percent Passing

P-value	µm
P50	90.70
P80	169.39

07PMD522, 27-38m (HC-26) **-** Predominately composed of ankerite, quartz, and albite. Lesser amounts of chlorite, pyrite, and rutile were also detected. MLA measured relatively high amounts of pyrite (6.61%), which is in agreement with XRD and chemical analyses. Also detected were trace amounts of gersdorffite (0.02%), chalcopyrite (0.01%), and <0.001% galena and pyrrhotite. Pyrite was mainly associated with albite (30%) and ankerite (28%); 20% of pyrite had a free surface. One percent of pyrite was encapsulated, 8% was liberated, and 91% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 102µm and 192µm respectively. Pyrite's crystal morphology, displayed in image below, is anhedral to euhedral, coarse to fine-grained with sieve texture. Disseminated pyrite is common in gangue. Gersdorffite was mainly associated with ankerite (39%) and chlorite (31%); 9% of gersdorffite had a free surface. Thirty-four percent of gersdorffite was encapsulated, 3% was liberated, and 63% had intermediate exposure. Chalcopyrite was mainly associated with albite (34%) and ankerite (21%); 15% of chalcopyrite had a free surface. Twenty-four percent of chalcopyrite was encapsulated, 7% was liberated, and 68% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Ankerite	35.86	35
Quartz	25.91	24
Albite	22.19	23
Chlorite	7.79	9
Pyrite	6.61	7
Muscovite	0.56	
Ilmenite	0.33	
Rutile	0.28	2
Apatite	0.20	
Kspar	0.11	
Chromite	0.05	
Amphibole	0.02	
Gersdorffite	0.02	
Siderite	0.02	
Chalcopyrite	0.01	
Tourmaline	0.01	
Biotite	<0.01	
Calcite	<0.01	
Epidote	<0.01	
Monazite	<0.01	
Paragonite	<0.01	
Sphene	<0.01	
FeClay	<0.001	
Galena	<0.001	
Gold	<0.001	
Magnetite	<0.001	
Pyrophyllite	<0.001	
Pyrrhotite	<0.001	
Xenotime	<0.001	



BSE image of bright coarse-grained euhedral pyrite and fine-grained anhedral pyrite disseminated in mixed gangue (albite and ankerite).

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Chlorite	Gersdorffite	Muscovite	Pyrite	Quartz	Rutile	Free Surface	OTHER
Chalcopyrite	34.31	21.55	5.26	1.25	1.66	15.35	4.65	0.36	14.78	0.85
Galena	0.00	0.00	0.00	0.00	0.00	77.92	15.99	0.00	6.09	0.00
Gersdorffite	1.83	38.85	31.35	0.00	0.00	7.59	7.81	1.49	8.97	2.11
Pyrite	30.01	27.56	8.91	0.06	1.83	0.00	9.48	0.53	19.85	1.77
Pyrrhotite	29.72	11.20	0.00	0.00	0.00	35.18	1.64	0.00	22.26	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	23.93	68.43	7.64
Galena	89.19	10.81	0.00
Gersdorffite	33.71	63.00	3.29
Pyrite	1.00	91.08	7.92
Pyrrhotite	81.13	11.32	7.55

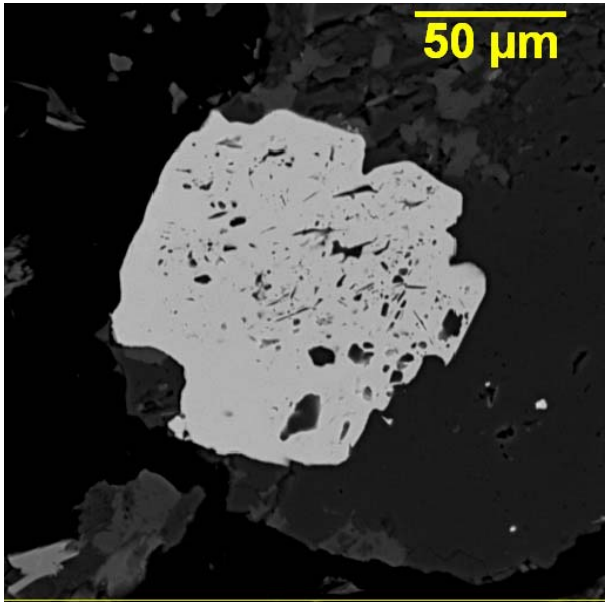
Pyrite Particle Size by Percent Passing

P-value	µm
P50	102.30
P80	192.10

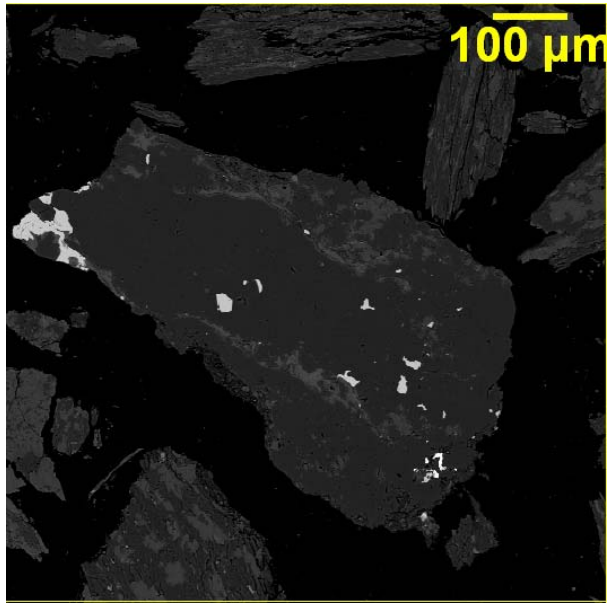
07PMD522, 126-136.5m (HC-27) **-** Predominately composed of ankerite, paragonite, quartz, and chlorite. Albite detected by MLA was most likely exaggerated in the expense of other gangue minerals due to difficulty in segmenting phases with similar gray levels. Lesser amounts of calcite were also detected. MLA measured trace amounts of pyrite (0.14%), chalcopyrite (0.03%), gersdorffite (0.01%), and <0.01% cobaltite and sphalerite. Pyrite was mainly associated with quartz (17%), ankerite (14%), and paragonite (13%); 37% of pyrite had a free surface. Ten percent of pyrite was encapsulated, 36% was liberated, and 54% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 82µm and 147µm respectively. Pyrite's crystal morphology, displayed in left image below, is mostly subhedral, coarse grained with sieve texture. Chalcopyrite (displayed in right image below) was mainly associated with quartz (28%) and ankerite (11%); 35% of chalcopyrite had a free surface. Twenty-eight percent of chalcopyrite was encapsulated, 15% was liberated, and 56% had intermediate exposure. Gersdorffite was mainly associated with paragonite (28%) and quartz (21%); 14% of gersdorffite had a free surface. Thirty-one percent of gersdorffite was encapsulated, <1% was liberated, and 68% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Ankerite	24.25	30
Paragonite	23.27	24
Quartz	20.93	26
Albite	13.48	
Chlorite	7.17	17
Muscovite	4.27	
Tourmaline	2.83	
Calcite	2.42	2
Epidote	0.57	
Amphibole	0.44	
Pyrite	0.14	<1
Apatite	0.06	
Rutile	0.06	
Chalcopyrite	0.03	
Ilmenite	0.03	
Gersdorffite	0.01	
Pyrophyllite	0.01	
Chromite	<0.01	
Cobaltite	<0.01	
FeClay	<0.01	
Iron	<0.01	
Monazite	<0.01	
Siderite	<0.01	
Sphalerite	<0.01	
Biotite	<0.001	
Enstatite	<0.001	
Kspar	<0.001	
Sphene	<0.001	
Xenotime	<0.001	



BSE image of bright subhedral pyrite with sieve texture in dark gray quartz.



BSE image of bright chalcopyrite grains in a chlorite (light gray) and quartz (dark gray) particle.

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Calcite	Chlorite	Muscovite	Paragonite	Pyrite	Quartz	Tourmaline	Free Surface	OTHER
Chalcopyrite	4.82	10.92	2.23	6.23	2.22	8.02	0.94	27.74	1.40	34.86	0.62
Cobaltite	15.84	4.53	0.00	4.53	6.31	17.33	0.00	27.46	0.40	23.59	0.00
Gersdorffite	7.31	13.83	0.00	8.65	2.85	27.79	0.00	21.37	4.53	13.58	0.09
Pyrite	5.95	13.69	1.23	6.40	2.44	12.95	0.00	16.84	2.32	37.13	1.05
Sphalerite	0.00	3.65	7.01	11.59	0.82	0.00	1.56	25.35	0.00	50.02	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	28.33	56.22	15.45
Cobaltite	62.02	5.85	32.13
Gersdorffite	31.40	68.14	0.47
Pyrite	10.23	53.52	36.24
Sphalerite	38.35	37.27	24.38

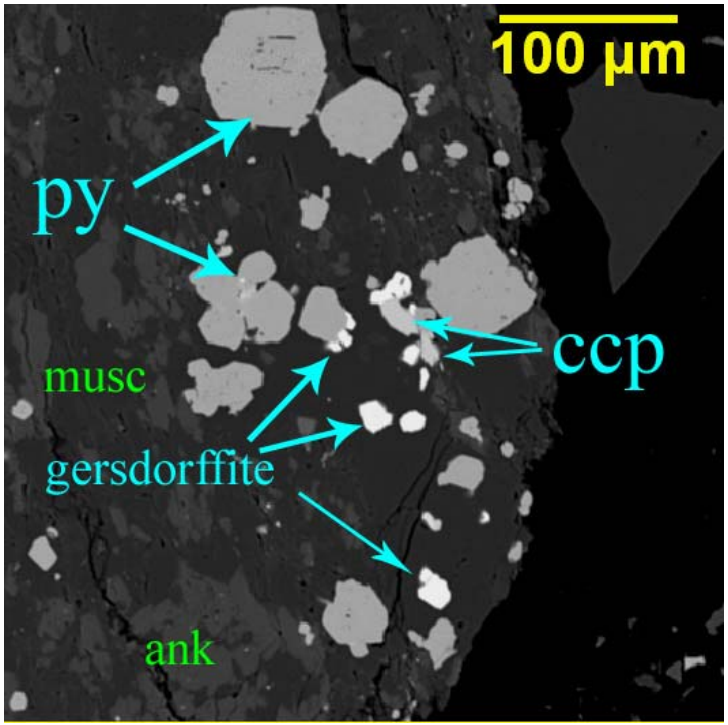
Pyrite Particle Size by Percent Passing

P-value	µm
P50	82.19
P80	147.08

06PMD470, 85-88m (HC-28) **-** Predominately composed of ankerite, albite, quartz, chlorite, and muscovite/sericite. Lesser amounts pyrite and rutile were also detected. MLA measured minor amounts of pyrite (3.63%) along with trace amounts of gersdorffite (0.02%), chalcopyrite (0.01%), and <0.001% cobaltite, pyrrhotite and sphalerite Pyrite was mainly associated with albite (21%), muscovite/sericite (18%), and ankerite (15%); 26% of pyrite had a free surface. Three percent of pyrite was encapsulated, 12% was liberated, and 84% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 98µm and 257µm respectively. Pyrite's crystal morphology, displayed in image below, is subhedral to euhedral, coarse to fine-grained with some sieve texture. Gersdorffite was mainly associated with muscovite/sericite (41%); 9% of gersdorffite had a free surface. Seventy-nine percent of gersdorffite was encapsulated, 6% was liberated, and 15% had intermediate exposure. Chalcopyrite was mainly associated with albite (23%) and pyrite (20%); 14% of chalcopyrite had a free surface. Seventy percent of chalcopyrite was encapsulated, 8% was liberated, and 22% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Ankerite	31.45	35
Albite	22.61	25
Muscovite	17.79	11
Quartz	10.56	13
Chlorite	10.52	13
Pyrite	3.63	3
Paragonite	2.27	
Tourmaline	0.44	
Epidote	0.15	
Ilmenite	0.12	
Amphibole	0.10	
Rutile	0.10	<1
Apatite	0.08	
Kspar	0.07	
Calcite	0.04	
Gersdorffite	0.02	
Chalcopyrite	0.01	
Biotite	<0.01	
Monazite	<0.01	
Siderite	<0.01	
Xenotime	<0.01	
Chromite	<0.001	
Cobaltite	<0.001	
Electrum	<0.001	
FeClay	<0.001	
Gold	<0.001	
Iron	<0.001	
Pyrophyllite	<0.001	
Pyrrhotite	<0.001	
Sphalerite	<0.001	
Sphene	<0.001	



BSE image of white gersdorffite, bright gray chalcopyrite (ccp), and light gray subhedral/euhedral pyrite grains encapsulated in muscovite/sericite (musc, dark gray) and ankerite (ank, medium gray).

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Chalcopyrite	Chlorite	Gersdorffite	Muscovite	Paragonite	Pyrite	Quartz	Free Surface	OTHER
Chalcopyrite	23.39	12.85	0.00	7.56	4.22	12.64	0.00	19.86	3.90	14.45	1.14
Cobaltite	12.94	0.00	0.00	48.91	0.00	5.27	0.00	0.00	19.53	13.35	0.00
Gersdorffite	13.76	11.36	3.16	5.87	0.00	40.50	0.88	7.59	5.94	9.33	1.60
Pyrite	21.44	14.77	0.30	8.56	0.15	18.03	1.67	0.00	7.08	26.37	1.64
Pyrrhotite	0.00	16.92	0.00	3.61	0.00	6.80	3.61	44.80	10.44	13.82	0.00
Sphalerite	0.00	73.85	0.00	0.00	0.00	0.00	0.00	10.30	12.37	3.48	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	70.28	21.72	8.00
Cobaltite	19.51	80.49	0.00
Gersdorffite	78.96	14.67	6.36
Pyrite	3.41	84.15	12.44
Pyrrhotite	24.56	75.44	0.00
Sphalerite	98.15	0.00	1.85

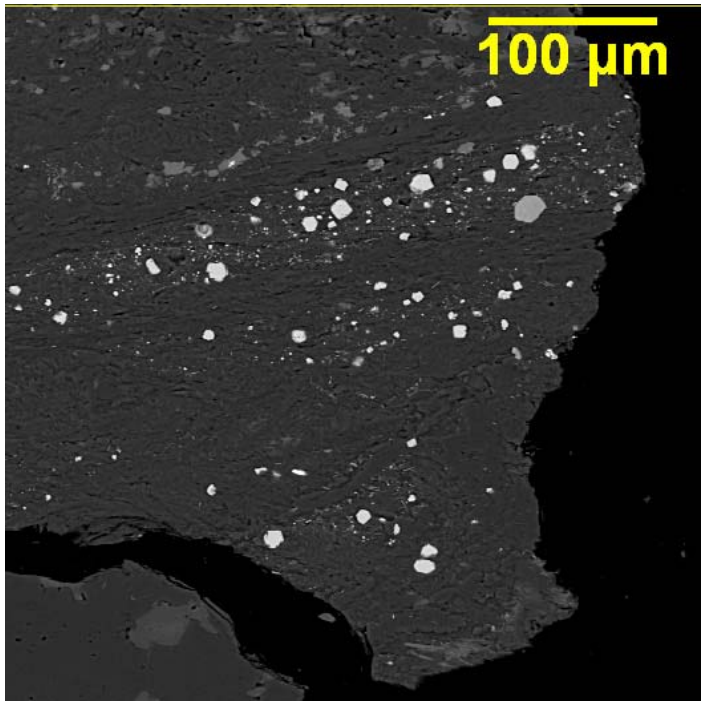
Pyrite Particle Size by Percent Passing

P-value	µm
P50	98.20
P80	257.35

08PMD657A, 101.5-111.5m (HC-29) **-** Predominately composed of ankerite, quartz, albite, and muscovite/sericite. Lesser amounts of chlorite, siderite, and rutile were also detected. Paragonite detected by MLA was most likely exaggerated in the expense of albite due to difficulty in segmenting both phases with such similar gray levels. MLA measured trace amounts of pyrite (0.13%), 0.01% chalcopyrite and gersdorffite, and <0.001% cobaltite. Pyrite was mainly associated with muscovite/sericite (34%), and paragonite (28%); 12% of pyrite had a free surface. Twenty-nine percent of pyrite was encapsulated, 15% was liberated, and 56% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 19µm and 39µm respectively. Pyrite's crystal morphology, displayed in image below, is anhedral to euhedral, some coarse, but was mostly finely-grained disseminated pyrite. Chalcopyrite was mainly associated with ankerite (35%); 24% of chalcopyrite had a free surface. Forty-four percent of chalcopyrite was encapsulated, 15% was liberated, and 41% had intermediate exposure. Gersdorffite was mainly associated with paragonite (41%) and muscovite/sericite (32%); 10% of gersdorffite had a free surface. 62% of gersdorffite was encapsulated, 5% was liberated, and 33% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Ankerite	32.62	39
Quartz	27.57	27
Muscovite	16.56	9
Paragonite	15.22	
Chlorite	4.76	5
Albite	1.19	15
Siderite	1.06	2
Tourmaline	0.33	
Apatite	0.22	
Pyrite	0.13	
Rutile	0.12	2
Ilmenite	0.10	
Amphibole	0.06	
Monazite	0.03	
Chalcopyrite	0.01	
Epidote	0.01	
Gersdorffite	0.01	
Calcite	<0.01	
FeClay	<0.01	
Kspar	<0.01	
Magnetite	<0.01	
Biotite	<0.001	
Chromite	<0.001	
Cobaltite	<0.001	
Enstatite	<0.001	
Iron	<0.001	
Pyrophyllite	<0.001	
Sphene	<0.001	
Xenotime	<0.001	
Zircon	<0.001	



BSE image of bright subhedral/euhedral coarse and fine-grained disseminated pyrite in dark gray muscovite/sericite.

Sulfide Mineral Associations

MINERAL	Ankerite	Chlorite	Gersdorffite	Ilmenite	Muscovite	Paragonite	Pyrite	Quartz	Siderite	Free Surface	OTHER
Chalcopyrite	34.60	6.94	0.00	0.00	8.86	5.14	0.81	10.67	7.98	23.72	1.29
Cobaltite	0.00	3.21	4.46	0.00	20.05	28.84	10.55	19.31	0.00	13.58	0.00
Gersdorffite	6.20	3.71	0.00	0.26	31.58	41.40	2.35	2.77	0.81	10.25	0.67
Pyrite	5.67	3.94	0.13	1.15	33.87	27.83	0.00	11.98	0.71	12.41	2.31

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	44.30	40.75	14.95
Cobaltite	30.77	69.23	0.00
Gersdorffite	61.88	32.91	5.21
Pyrite	28.87	55.82	15.32

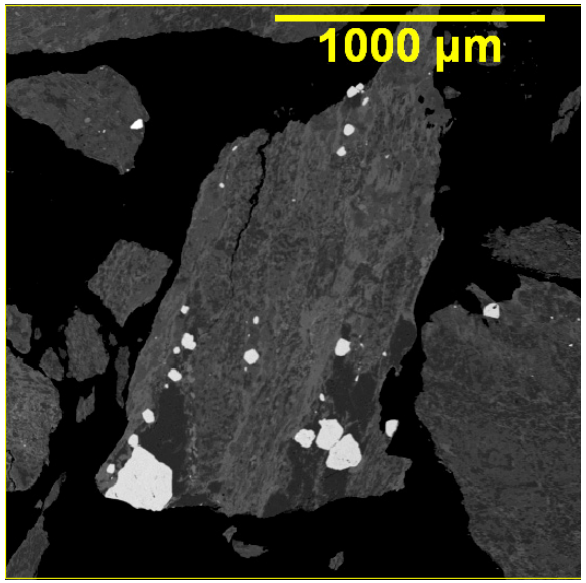
Pyrite Particle Size by Percent Passing

P-value	µm
P50	18.96
P80	39.10

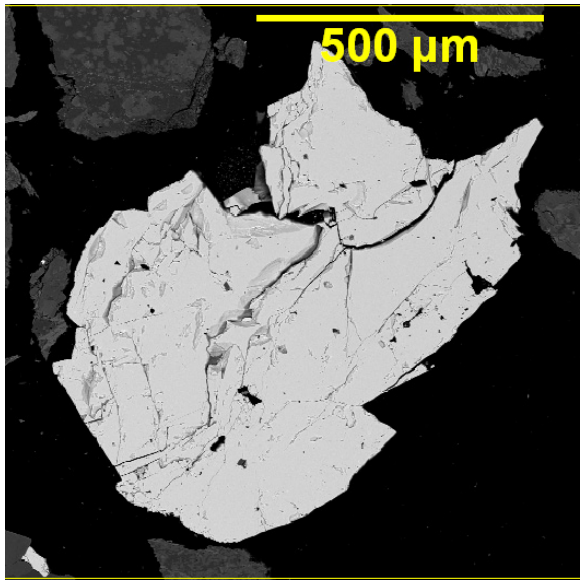
08PMD657A, 90.5-91m (HC-30) **-** Predominately composed of ankerite, quartz, and chlorite. Lesser amounts of muscovite/sericite, albite, calcite, and rutile were also detected. MLA measured trace amounts of chalcopyrite (0.79%), pyrite (0.72%), and <0.001% pyrrhotite. Calculated Cu (2.88%) is slightly higher than measured Cu (~2%), but is still in agreement with relatively elevated amount of chalcopyrite detected in the sample. Pyrite was mainly associated with ankerite (32%) and quartz (20%); 20% of pyrite had a free surface. 4% of pyrite was encapsulated, 3% was liberated, and 92% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 182µm and 238µm respectively. Pyrite's crystal morphology, displayed in left image below, is subhedral to euhedral, coarse grained with sieve texture. Chalcopyrite (large liberated particle displayed in right image below) was mainly associated with ankerite (32%); 47% of chalcopyrite had a free surface. Two percent of chalcopyrite was encapsulated, 73% was liberated, and 25% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Ankerite	52.45	37
Quartz	19.02	23
Chlorite	14.72	29
Albite	7.63	2
Muscovite	1.44	6
Rutile	1.01	1
Amphibole	0.97	
Chalcopyrite	0.79	
Pyrite	0.72	
Paragonite	0.50	
Calcite	0.32	1
Apatite	0.13	
Kspar	0.10	
Biotite	0.08	
Ilmenite	0.06	
Tourmaline	0.05	
Epidote	<0.01	
Iron	<0.01	
Monazite	<0.01	
Siderite	<0.01	
Sphene	<0.01	
FeClay	<0.001	
Pyrrhotite	<0.001	
Xenotime	<0.001	



BSE image of bright subhedral/euhedral pyrite in mixed gangue (ankerite, chlorite, and quartz).



BSE image of a large liberated chalcopyrite grain measuring 1000 x 600 microns in size

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Chlorite	Muscovite	Paragonite	Pyrite	Quartz	Free Surface	OTHER
Chalcopyrite	0.39	31.94	9.41	0.89	0.03	0.76	9.34	46.89	0.35
Pyrite	4.67	31.58	17.70	2.66	1.33	0.00	19.98	19.74	2.34
Pyrrhotite	0.00	20.31	0.00	0.00	0.00	52.89	24.65	2.15	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	1.62	25.31	73.07
Pyrite	4.23	92.44	3.33
Pyrrhotite	0.00	100.00	0.00

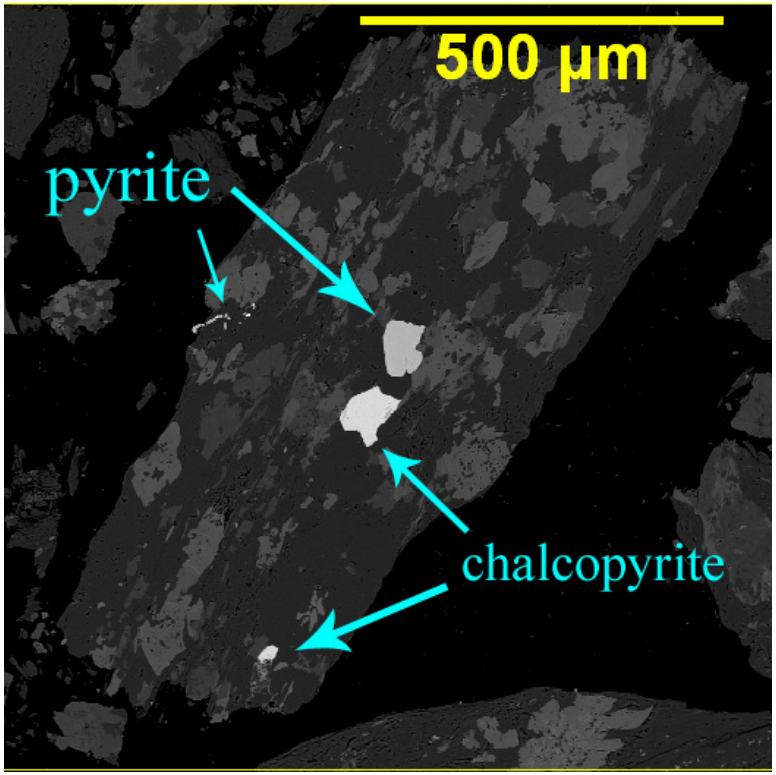
Pyrite Particle Size by Percent Passing

P-value	µm
P50	181.56
P80	238.44

07SBD374, 53.4-64.5m (HC-31) **-** Predominately composed of ankerite, quartz, and paragonite. Lesser amounts of muscovite/sericite, chlorite, siderite, and rutile were also detected. MLA measured trace amounts of pyrite (0.14%), chalcopyrite (0.04%), and <0.01% cobaltite and gersdorffite. Pyrite was mainly associated with quartz (20%) and muscovite/sericite (12%); 33% of pyrite had a free surface. Nineteen percent of pyrite was encapsulated, 32% was liberated, and 49% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 61µm and 98µm respectively. Pyrite's crystal morphology, displayed in image below, is subhedral to euhedral, and coarse grained. Chalcopyrite (also displayed in image below) was mainly associated with quartz (39%) and chlorite (20%); 17% of chalcopyrite had a free surface. Forty-nine percent of chalcopyrite was encapsulated, 4% was liberated, and 47% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Ankerite	27.19	35
Quartz	23.81	32
Paragonite	21.35	14
Muscovite	12.30	4
Chlorite	5.70	9
Siderite	3.73	3
Albite	3.47	
Tourmaline	1.50	
Rutile	0.26	2
Ilmenite	0.23	
Pyrite	0.14	
Apatite	0.08	
Amphibole	0.07	
Calcite	0.05	
Epidote	0.05	
Chalcopyrite	0.04	
Magnetite	0.01	
Cobaltite	<0.01	
FeClay	<0.01	
Gersdorffite	<0.01	
Kspar	<0.01	
Monazite	<0.01	
Pyrophyllite	<0.01	
Sphene	<0.01	
Biotite	<0.001	
Iron	<0.001	
Xenotime	<0.001	
Zircon	<0.001	



BSE image of bright chalcopyrite and very light gray pyrite encapsulated in mixed gangue of siderite (light gray), ankerite (medium gray), and quartz (dark gray).

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Chalcopyrite	Chlorite	Muscovite	Paragonite	Pyrite	Quartz	Rutile	Siderite	Tourmaline	Free Surface	OTHER
Chalcopyrite	2.00	9.82	0.00	19.72	1.60	4.21	2.91	38.89	0.08	0.82	1.72	16.65	1.58
Cobaltite	0.00	4.02	1.28	17.97	14.35	4.37	11.14	34.03	1.57	0.26	3.77	6.59	0.64
Gersdorffite	0.00	5.85	2.62	5.62	15.55	12.84	11.26	14.55	0.60	4.64	0.00	25.99	0.48
Pyrite	1.31	7.97	1.12	4.74	12.06	9.95	0.00	20.38	0.22	3.31	3.89	32.82	2.23

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	48.58	47.09	4.33
Cobaltite	91.89	5.58	2.52
Gersdorffite	47.23	33.29	19.48
Pyrite	19.30	48.61	32.09

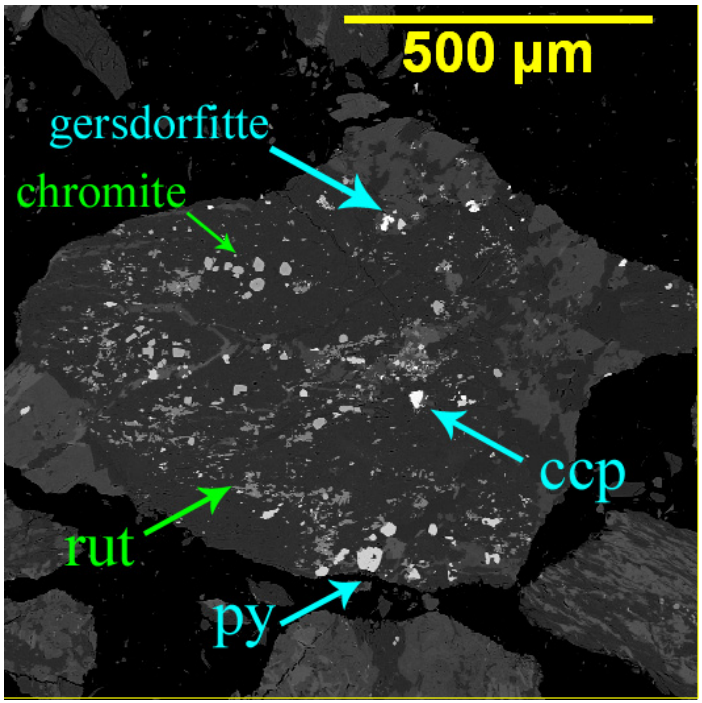
Pyrite Particle Size by Percent Passing

P-value	µm
P50	61.10
P80	97.52

08SBD380, 7.2-14m (HC-32) **-** Predominately composed of ankerite, quartz, and chlorite. Lesser amounts of paragonite, tourmaline, muscovite/sericite, and rutile were also detected. MLA measured trace amounts of pyrite (0.96%), gersdorffite (0.03%), chalcopyrite (0.01%), and <0.01% cobaltite. Pyrite was mainly associated with quartz (18%), ankerite (13%), and chlorite (13%); 36% of pyrite had a free surface. Three percent of pyrite was encapsulated, 29% was liberated, and 67% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 288µm and 514µm respectively. Pyrite's crystal morphology, displayed in image below, is anhedral to euhedral, coarse grained with slight sieve texture. Gersdorffite (also shown in image below) was mainly associated with chlorite (26%) and ankerite (19%); 12% of gersdorffite had a free surface. Forty-nine percent of gersdorffite was encapsulated, 9% was liberated, and 43% had intermediate exposure. Chalcopyrite was mainly associated with ankerite (32%) and quartz (23%); 18% of chalcopyrite had a free surface. Fifty-six of chalcopyrite was encapsulated, 7% was liberated, and 36% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Quartz	35.77	30
Ankerite	29.06	33
Chlorite	13.04	21
Paragonite	10.72	9
Tourmaline	4.89	3
Muscovite	3.79	2
Albite	1.18	
Pyrite	0.96	1
Rutile	0.18	1
Ilmenite	0.15	
Amphibole	0.11	
Apatite	0.04	
Chromite	0.04	
Gersdorffite	0.03	
Calcite	0.01	
Chalcopyrite	0.01	
Cobaltite	<0.01	
Epidote	<0.01	
FeClay	<0.01	
Iron	<0.01	
Monazite	<0.01	
Pyrophyllite	<0.01	
Siderite	<0.01	
Biotite	<0.001	
Kspar	<0.001	
Sphene	<0.001	
Xenotime	<0.001	
Zircon	<0.001	



BSE image of bright gersdorffite, chalcopyrite (ccp), and pyrite (py) grains encapsulated in albite (dark gray) and ankerite (light gray). Light gray rutile (rut) and chromite inclusions are also detected in this particle.

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Chlorite	Gersdorffite	Muscovite	Paragonite	Pyrite	Quartz	Tourmaline	Free Surface	OTHER
Chalcopyrite	3.46	31.60	5.14	0.89	4.34	1.08	7.05	22.78	4.45	18.28	0.94
Cobaltite	0.00	5.92	13.04	1.31	1.24	32.15	0.46	8.97	16.54	19.12	1.26
Gersdorffite	1.90	19.39	26.34	0.00	4.21	10.87	1.55	15.24	6.23	12.41	1.86
Pyrite	1.89	13.03	12.86	0.24	3.94	4.15	0.00	18.43	8.02	36.15	1.30

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	56.43	36.43	7.14
Cobaltite	62.38	20.31	17.31
Gersdorffite	48.54	42.58	8.89
Pyrite	3.24	67.38	29.38

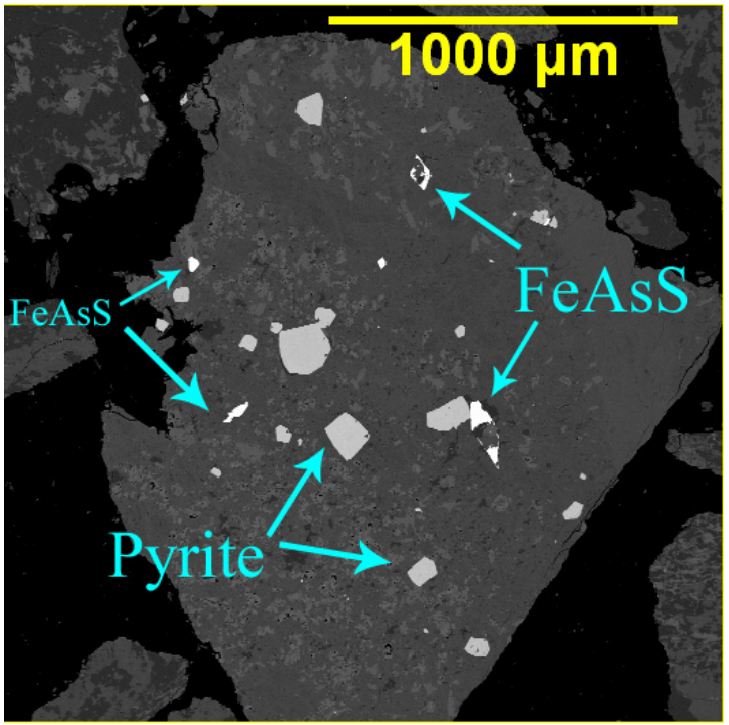
Pyrite Particle Size by Percent Passing

P-value	µm
P50	288.49
P80	514.09

08SBD380, 23-33.5m (HC-33) **-** Predominately composed of ankerite, quartz, and chlorite. Lesser amounts of paragonite, calcite, and rutile were also detected. MLA measured trace amounts of pyrite (0.57%), 0.02% arsenopyrite and chalcopyrite, gersdorffite (0.01%), <0.01% cobaltite, and <0.001% pyrrhotite. Pyrite was mainly associated with paragonite (23%) and ankerite (22%); 17% of pyrite had a free surface. Three percent of pyrite was encapsulated, 7% was liberated, and 90% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 159µm and 554µm respectively. Pyrite's crystal morphology, displayed in image below, is subhedral to euhedral, coarse grained with sieve texture. Arsenopyrite (also displayed in image below) and chalcopyrite were mainly associated with ankerite (57-60%); 12% arsenopyrite and 13% chalcopyrite had a free surface. Ninety-nine of arsenopyrite and 90% of chalcopyrite had intermediate exposure. Gersdorffite was mainly associated with chlorite (24%), quartz (15%), and ankerite (14%); 11% of gersdorffite had a free surface. Seventy-four percent of gersdorffite was encapsulated, 3% was liberated, and 23% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Ankerite	45.51	43
Quartz	24.26	25
Chlorite	9.53	18
Paragonite	6.38	9
Albite	4.99	
Muscovite	4.05	3
Tourmaline	2.87	
Siderite	1.07	
Pyrite	0.57	1
Amphibole	0.39	
Rutile	0.08	1
Ilmenite	0.07	
Epidote	0.06	
Apatite	0.04	
Magnetite	0.03	
Arsenopyrite	0.02	
Calcite	0.02	<1
Chalcopyrite	0.02	
Chromite	0.01	
Gersdorffite	0.01	
Cobaltite	<0.01	
FeClay	<0.01	
Monazite	<0.01	
Pyrophyllite	<0.01	
Scheelite	<0.01	
Biotite	<0.001	
Iron	<0.001	
Kspar	<0.001	
Platinum	<0.001	
Pyrrhotite	<0.001	
Sphene	<0.001	
Xenotime	<0.001	



BSE image of white arsenopyrite (FeAsS) and light grey subhedral/euhedral pyrite in a chlorite (medium gray) and ankerite (dark gray) particle.

Sulfide Mineral Associations

MINERAL	Albite	Amphibole	Ankerite	Chalcopyrite	Chlorite	Muscovite	Paragonite	Pyrite	Quartz	Rutile	Siderite	Tourmaline	Free Surface	OTHER
Arsenopyrite	0.00	0.00	59.92	0.00	6.28	2.25	2.48	4.11	12.62	0.00	0.00	0.22	12.12	0.00
Chalcopyrite	0.00	0.00	57.29	0.00	2.17	0.00	0.24	10.40	16.77	0.00	0.00	0.00	12.95	0.18
Cobaltite	5.82	1.01	20.61	0.00	11.19	7.68	12.42	0.00	22.16	1.06	0.00	2.33	15.25	0.46
Gersdorffite	4.21	0.18	14.32	0.00	24.34	6.51	13.08	4.27	14.89	0.98	0.23	6.21	10.69	0.10
Pyrite	0.93	0.01	21.54	0.50	14.04	8.35	22.60	0.00	4.21	0.44	0.81	8.69	16.59	1.30
Pyrrhotite	0.00	0.00	2.20	1.37	0.00	0.00	0.00	89.75	0.00	0.00	6.67	0.00	0.00	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Arsenopyrite	0.12	98.70	1.18
Chalcopyrite	7.09	90.83	2.07
Cobaltite	56.39	26.09	17.53
Gersdorffite	73.51	23.01	3.48
Pyrite	2.93	90.14	6.93
Pyrrhotite	100.00	0.00	0.00

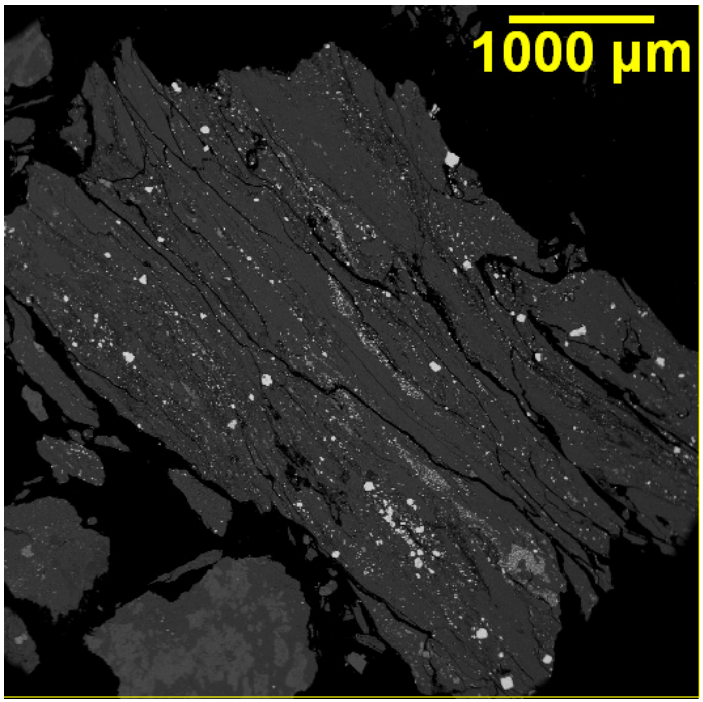
Pyrite Particle Size by Percent Passing

P-value	µm
P50	158.61
P80	553.73

08SBD382, 7.43-12.82m (HC-34) **-** Predominately composed of quartz, ankerite, and pyrophyllite. Lesser amounts of paragonite, muscovite/sericite, chlorite, and rutile were also detected. MLA detected only minor amounts of pyrophyllite (3.19%) compared to XRD (13%) due to difficulties segmenting similar gray level phases, which is most likely the reason for elevated MLA quantities of muscovite/sericite and paragonite compared to XRD values. MLA measured minor amounts of pyrite (1.93%) and trace amounts of pyrrhotite (0.15%), chalcopyrite (0.03%), <0.01% sphalerite, and <0.001% gersdorffite. Pyrite was mainly associated with quartz (29%), muscovite/sericite (28%), and paragonite (23%); 6% of pyrite had a free surface. Four percent of pyrite was encapsulated, 4% was liberated, and 92% had intermediate exposure. Pyrite had a P_{50} and P_{80} P50 and P80 of 29µm and 218µm respectively. Pyrite's crystal morphology, displayed in image below, is anhedral to subhedral, some coarse grained but mostly finely grained disseminated pyrite. Pyrrhotite was mainly associated with tourmaline (28%) and had a free surface of 6%. Seven percent of pyrrhotite was encapsulated, and 93% had intermediate exposure. Chalcopyrite was mainly associated with ankerite (43%) and quartz (28%); 3% of chalcopyrite had a free surface. Seventy-one percent of chalcopyrite was encapsulated, <1% was liberated, and 29% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Quartz	45.26	53
Muscovite	13.66	6
Paragonite	13.24	4
Ankerite	11.90	20
Albite	4.42	
Pyrophyllite	3.19	13
Tourmaline	2.74	
Pyrite	1.93	2
Kspar	0.87	
Siderite	0.82	
Chlorite	0.71	1
Biotite	0.33	
Amphibole	0.22	
Apatite	0.22	
Ilmenite	0.18	
Pyrrhotite	0.15	
Rutile	0.06	1
Epidote	0.04	
Chalcopyrite	0.03	
Monazite	0.01	
Zircon	<0.01	
Calcite	<0.01	
FeClay	<0.01	
Sphalerite	<0.01	
Sphene	<0.01	
Anhydrite	<0.001	
Chromite	<0.001	
Gersdorffite	<0.001	
Iron	<0.001	
Magnetite	<0.001	



Low magnification BSE image of fine-grained disseminated pyrite in dark gray paragonite.

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Biotite	Chalcopyrite	Chlorite	Ilmenite	Kspar	Muscovite	Paragonite	Pyrite	Pyrophyllite	Pyrrhotite	Quartz	Siderite	Tourmaline	Free Surface	OTHER
Chalcopyrite	1.67	43.32	0.09	0.00	1.71	0.21	0.03	0.94	2.11	3.38	0.22	0.96	28.63	12.98	0.46	2.58	0.73
Gersdorffite	15.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.49	17.54	0.00	11.35	37.52	0.00	0.00	0.00	0.00
Pyrite	5.47	1.14	0.23	0.07	0.30	0.08	0.22	27.55	23.22	0.00	4.69	0.19	29.06	0.04	0.80	6.51	0.42
Pyrrhotite	2.66	0.00	13.94	0.65	5.59	2.42	6.45	8.94	11.90	6.63	0.00	0.00	6.10	0.42	27.80	6.10	0.37
Sphalerite	0.00	25.58	0.00	2.02	3.00	0.00	0.00	0.00	5.47	2.27	0.00	0.00	36.76	24.91	0.00	0.00	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	70.50	28.66	0.84
Gersdorffite	100.00	0.00	0.00
Pyrite	3.71	92.02	4.27
Pyrrhotite	6.79	93.20	0.02
Sphalerite	100.00	0.00	0.00

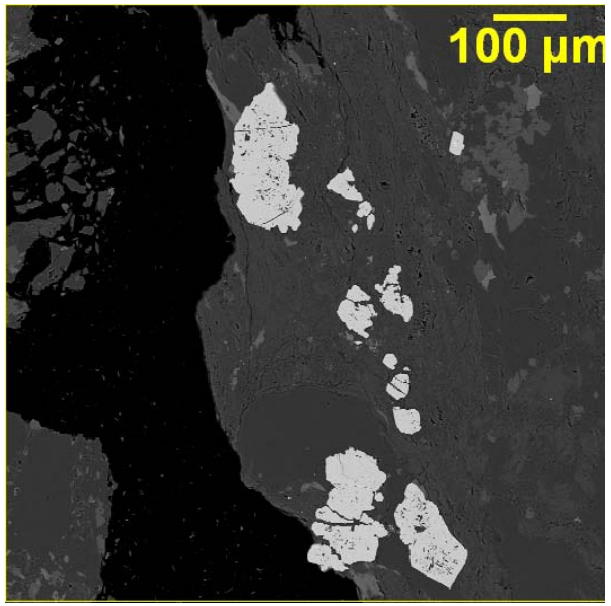
Pyrite Particle Size by Percent Passing

P-value	µm
P50	29.23
P80	217.90

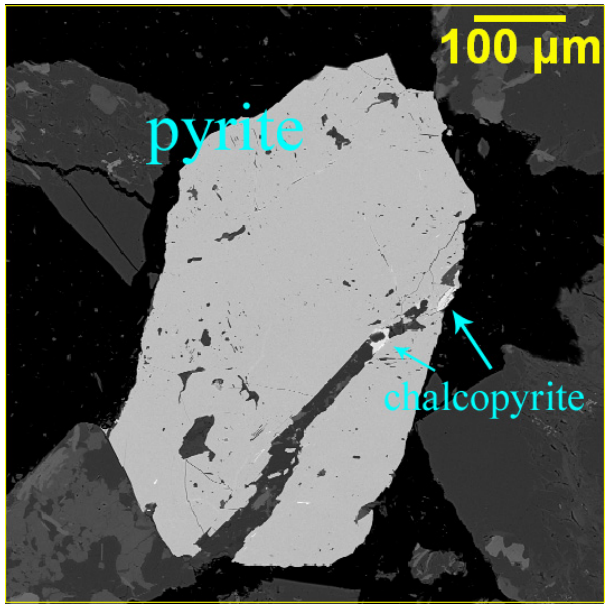
08SBD382, 267.5-276.52m (HC-35) **-** Predominately composed of quartz, muscovite/sericite, albite, and ankerite. Lesser amounts of chlorite, paragonite, and rutile were also detected. MLA measured trace amounts of pyrite (0.90%), <0.01% chalcopyrite, cobaltite, galena, gersdorffite, and sphalerite, and <0.001% pyrrhotite and tetrahedrite. Pyrite was mainly associated with quartz (23%) and muscovite/sericite (21%); 43% of pyrite had a free surface. Two percent of pyrite was encapsulated, 3% was liberated, and 95% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 273µm and 435µm respectively. Pyrite's crystal morphology, displayed in images below, is subhedral to euhedral, and coarse grained with sieve texture.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Quartz	48.75	39
Muscovite	24.53	20
Albite	10.35	18
Ankerite	9.47	12
Chlorite	3.32	6
Paragonite	1.07	3
Pyrite	0.90	
Siderite	0.75	
Apatite	0.26	
Rutile	0.15	1
Tourmaline	0.15	
Ilmenite	0.11	
Amphibole	0.04	
Kspar	0.04	
Zircon	0.04	
Monazite	0.02	
Biotite	<0.01	
Calcite	<0.01	
Chalcopyrite	<0.01	
Cobaltite	<0.01	
Epidote	<0.01	
FeClay	<0.01	
Galena	<0.01	
Gersdorffite	<0.01	
Magnetite	<0.01	
Sphalerite	<0.01	
Gold	<0.001	
Pyrophyllite	<0.001	
Pyrrhotite	<0.001	
Sphene	<0.001	
Tetrahedrite	<0.001	
Xenotime	<0.001	



BSE image of coarse-grained pyrite with sieve texture encapsulated in muscovite/sericite and quartz.



BSE image of subhedral pyrite with bright chalcopyrite inclusions.

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Chalcopyrite	Chlorite	Muscovite	Paragonite	Pyrite	Quartz	Siderite	Free Surface	OTHER
Chalcopyrite	7.44	12.62	0.00	3.38	18.19	2.09	8.18	29.34	2.10	15.48	1.20
Cobaltite	6.70	4.77	0.00	16.65	7.59	0.00	0.00	59.68	0.00	4.32	0.30
Galena	0.00	1.69	0.00	0.00	3.38	0.00	0.00	29.91	52.05	12.97	0.00
Gersdorffite	11.78	5.50	0.00	3.51	22.00	0.00	3.94	33.18	0.00	19.15	0.94
Pyrite	6.79	1.89	0.67	1.52	21.44	0.67	0.00	22.74	0.53	42.62	1.13
Pyrrhotite	0.00	0.00	8.53	0.00	0.00	0.00	46.92	0.00	0.00	44.54	0.00
Tetrahedrite	0.00	16.76	50.65	0.00	0.00	0.00	0.00	32.59	0.00	0.00	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	68.22	25.43	6.35
Cobaltite	90.79	6.89	2.32
Galena	88.83	1.06	10.11
Gersdorffite	50.98	37.78	11.24
Pyrite	1.99	94.61	3.40
Pyrrhotite	59.02	0.00	40.98
Sphalerite	21.53	64.41	14.06
Tetrahedrite	100.00	0.00	0.00

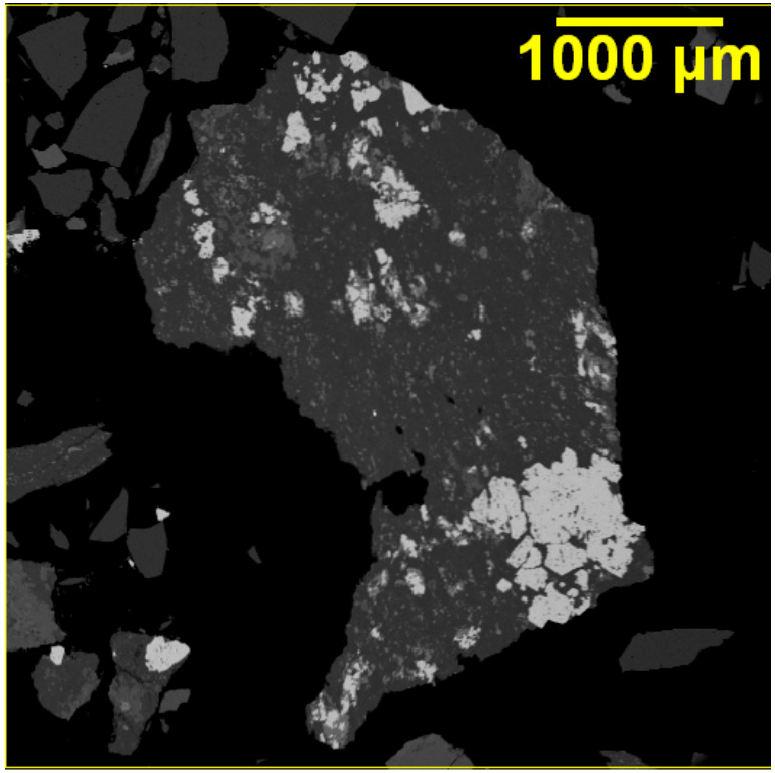
Pyrite Particle Size by Percent Passing

P-value	µm
P50	273.43
P80	434.78

08TDD631, 33.5-37.3m (HC-36) **-** Predominately composed of quartz, ankerite, and muscovite/sericite. Lesser amounts of pyrite, paragonite, and rutile were also detected. MLA measured relatively elevated amounts of pyrite (6.17%), however total sulfur (4.37%) from chemical analyses suggests that XRD's pyrite value of 9% is more accurate. MLA also detected trace amounts of chalcopyrite and pyrrhotite (<0.01%), and <0.001% sphalerite. Pyrite was mainly associated with muscovite/sericite (21%) and ankerite (15%); 27% of pyrite had a free surface. One percent of pyrite was encapsulated, 9% was liberated, and 89% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 266µm and 438µm respectively. Pyrite's crystal morphology, displayed in image below, is subhedral to euhedral, and coarse to fine-grained with sieve texture.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Quartz	61.23	58
Ankerite	11.95	18
Muscovite	11.79	10
Pyrite	6.17	9
Paragonite	3.66	3
Albite	2.90	
Siderite	0.72	
Apatite	0.52	
Ilmenite	0.30	
Amphibole	0.27	
Rutile	0.18	2
Chlorite	0.12	
Magnetite	0.07	
Calcite	0.06	
Tourmaline	0.03	
Epidote	0.01	
Chalcopyrite	<0.01	
Kspar	<0.01	
Monazite	<0.01	
Pyrrhotite	<0.01	
Xenotime	<0.01	
FeClay	<0.001	
Iron	<0.001	
Pyrophyllite	<0.001	
Sphalerite	<0.001	
Sphene	<0.001	



Low magnification BSE image of coarse and fine-grained pyrite with sieve texture encapsulated in dark gray muscovite/sericite.

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Chalcopyrite	Chlorite	Ilmenite	Magnetite	Muscovite	Paragonite	Pyrite	Pyrrhotite	Quartz	Rutile	Siderite	Free Surface	OTHER
Chalcopyrite	4.04	1.71	0.00	0.00	0.00	0.00	0.00	0.00	82.23	2.34	4.30	0.00	0.82	4.11	0.45
Pyrite	8.96	14.91	0.64	1.18	1.28	0.67	20.90	3.15	0.00	0.75	9.16	1.05	8.21	27.42	1.72
Pyrrhotite	1.79	2.80	1.32	0.00	0.00	1.28	6.99	0.47	54.50	0.00	1.35	0.00	21.30	7.58	0.61
Sphalerite	0.00	88.48	0.00	0.00	0.00	0.00	5.43	0.00	0.00	0.00	6.09	0.00	0.00	0.00	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	47.02	52.98	0.00
Pyrite	1.42	89.16	9.42
Pyrrhotite	78.38	17.39	4.23
Sphalerite	100.00	0.00	0.00

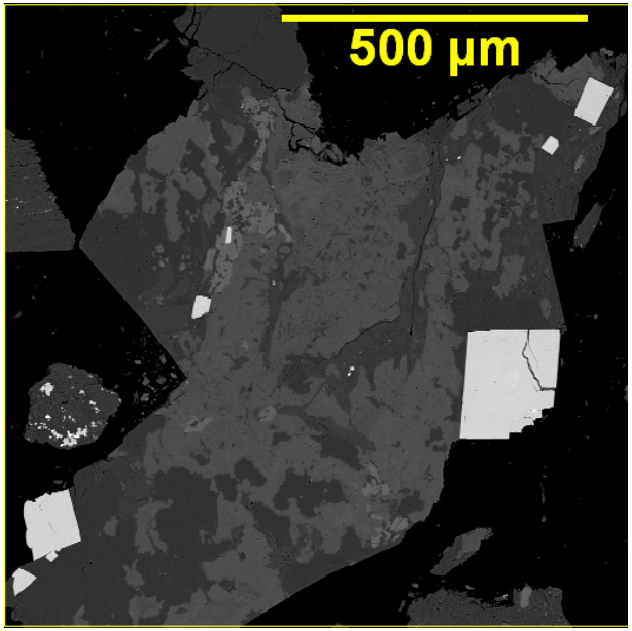
Pyrite Particle Size by Percent Passing

P-value	µm
P50	266.48
P80	437.94

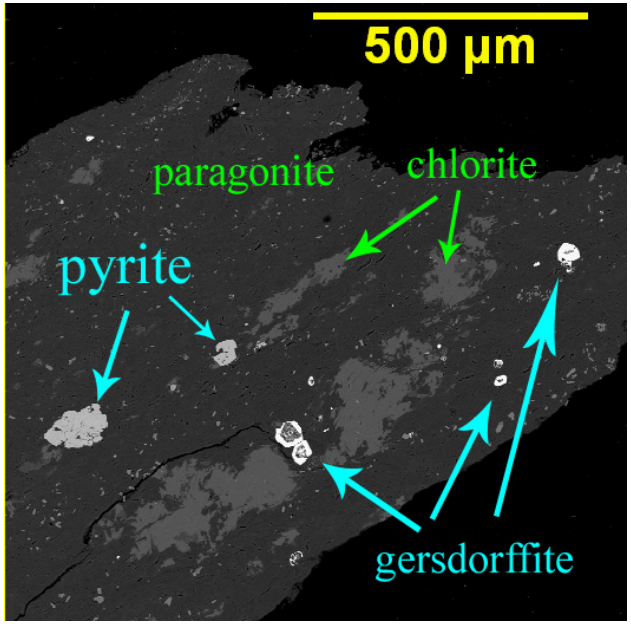
94NOD124, 259-263.5m (HC-37) **-** Predominately composed of ankerite, quartz, and paragonite. Lesser amounts of muscovite/sericite, albite, tourmaline, chlorite, and rutile were also detected. MLA measured minor amounts of pyrite (2.14%), slightly higher than XRD's pyrite value, is in agreement with total sulfur (1.33%) from chemical analyses. MLA also measure trace amounts of gersdorffite (0.07%), chalcopyrite (0.01%), <0.01% sphalerite, and <0.001% arsenopyrite. Pyrite was mainly associated with paragonite (24%) and muscovite/sericite (14%); 27% of pyrite had a free surface. Two percent of pyrite was encapsulated, 26% was liberated, and 71% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 302µm and 533µm respectively. Pyrite's crystal morphology, displayed in left image below, is subhedral to euhedral, and mostly coarse grained with some sieve texture; less common is finely grained disseminated pyrite. Gersdorffite (shown in right image below) was also mainly associated with paragonite (42%); 13% of gersdorffite had a free surface. Thirty-eight percent of gersdorffite was encapsulated, 7% was liberated, and 55% had intermediate exposure. Chalcopyrite was mainly associated with quartz (29%) and ankerite (21%); 13% of chalcopyrite had a free surface. Seventy-four percent of chalcopyrite was encapsulated, 6% was liberated, and 20% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Ankerite	29.54	34
Quartz	26.63	28
Paragonite	20.83	13
Muscovite	12.48	6
Albite	3.53	7
Chlorite	2.16	2
Pyrite	2.14	1
Tourmaline	1.76	7
Ilmenite	0.25	
Rutile	0.25	2
Amphibole	0.10	
Calcite	0.09	
Epidote	0.07	
Gersdorffite	0.07	
Apatite	0.04	
Chromite	0.02	
Chalcopyrite	0.01	
FeClay	<0.01	
Monazite	<0.01	
Siderite	<0.01	
Sphalerite	<0.01	
Xenotime	<0.01	
Arsenopyrite	<0.001	
Biotite	<0.001	
Electrum	<0.001	
Kspar	<0.001	
Pyrophyllite	<0.001	
Pyrrhotite	<0.001	



BSE image of bright euhedral pyrite in light gray ankerite and dark gray quartz.



BSE image of bright gersdorffite grains and light gray pyrite encapsulated in dark gray paragonite and medium gray chlorite.

Sulfide Mineral Associations

MINERAL	Albite	Ankerite	Chlorite	Gersdorffite	Muscovite	Paragonite	Pyrite	Quartz	Tourmaline	Free Surface	OTHER
Arsenopyrite	0.00	46.53	0.00	0.00	0.00	0.00	16.17	24.22	0.00	13.07	0.00
Chalcopyrite	0.71	21.25	1.39	1.16	12.55	3.05	14.72	29.37	1.26	13.24	1.30
Gersdorffite	0.46	11.85	2.88	0.00	13.70	42.23	1.40	11.70	1.50	12.95	1.34
Pyrite	3.03	9.12	1.80	0.14	13.90	24.07	0.00	15.13	5.12	26.60	1.10
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	69.86	0.00	0.00	0.00	0.00	0.00	16.21	0.00	13.93	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Arsenopyrite	97.56	0.00	2.44
Chalcopyrite	74.56	19.72	5.72
Gersdorffite	38.08	55.15	6.77
Pyrite	2.38	71.20	26.42
Pyrrhotite	100.00	0.00	0.00
Sphalerite	0.30	99.70	0.00

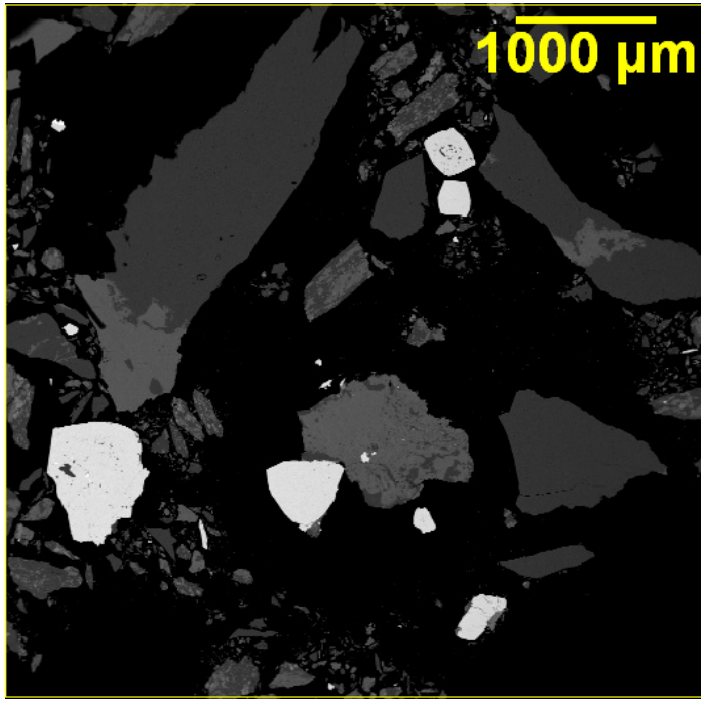
Pyrite Particle Size by Percent Passing

P-value	µm
P50	301.79
P80	532.73

94NOD124, 277.5-280m (HC-38) **-** Predominately composed of quartz, ankerite, and paragonite. Lesser amounts of muscovite/sericite, pyrite, chlorite, albite, siderite, tourmaline, and rutile were also detected. MLA detected major amounts of muscovite/sericite (12.96%) compared to XRD (2%) due to difficulties segmenting similar gray level phases, which is most likely the reason for lower MLA quantities of quartz compared to XRD values. MLA measured relatively elevated amounts of pyrite (5.66%), which is in agreement with total sulfur (2.59%) from chemical analyses. MLA also detected trace amounts of chalcopyrite (0.06%), and <0.01% cobaltite, gersdorffite, pyrrhotite, sphalerite, and tetrahedrite. Pyrite was mainly associated with muscovite/sericite (13%) and ankerite (10%); 60% of pyrite had a free surface. Less than1% of pyrite was encapsulated, 20% was liberated, and 80% had intermediate exposure. Pyrite had a P_{50} and P_{80} of 354µm and 498µm respectively. Pyrite's crystal morphology, displayed in image below, is subhedral to euhedral, with large coarse grained particles with sieve texture. Chalcopyrite was mainly associated with ankerite (22%) and muscovite/sericite (15%); 20% of chalcopyrite had a free surface. Five percent of chalcopyrite was encapsulated, 6% was liberated, and 89% had intermediate exposure.

Mineral Weight %

	MLA	XRD
Mineral	Wt%	Wt%
Quartz	33.35	41
Ankerite	25.50	28
Muscovite	12.96	2
Paragonite	11.66	13
Pyrite	5.66	4
Chlorite	2.99	1
Albite	2.73	5
Siderite	2.11	2
Tourmaline	1.26	3
Rutile	0.43	2
Ilmenite	0.42	
Epidote	0.26	
Magnetite	0.24	
Apatite	0.12	
Amphibole	0.11	
Calcite	0.10	
Chalcopyrite	0.06	
FeClay	0.01	
Monazite	0.01	
Cobaltite	<0.01	
Gersdorffite	<0.01	
Iron	<0.01	
Pyrophyllite	<0.01	
Pyrrhotite	<0.01	
Sphalerite	<0.01	
Tetrahedrite	<0.01	
Xenotime	<0.01	
Anhydrite	<0.001	
Barite	<0.001	
Biotite	<0.001	
Electrum	<0.001	
Gold	<0.001	
Kspar	<0.001	



Low magnification BSE image of bright subhedral/euhedral pyrite grains which are mostly liberated.

Sulfide Mineral Associations

MINERAL	Ankerite	Chalcopyrite	Chlorite	Cobaltite	Muscovite	Paragonite	Pyrite	Quartz	Rutile	Siderite	Tourmaline	Free Surface	OTHER
Chalcopyrite	21.63	0.00	4.50	0.00	15.41	3.02	12.20	15.12	0.00	6.63	0.26	20.48	0.76
Cobaltite	21.41	0.00	15.97	0.00	12.73	1.10	11.47	19.30	1.33	1.84	0.00	12.69	2.16
Gersdorffite	8.64	0.00	39.61	1.01	0.00	19.18	13.73	8.39	0.00	5.10	0.00	4.34	0.00
Pyrite	10.17	0.56	1.77	0.04	12.66	7.54	0.00	3.87	0.64	0.75	1.22	59.53	1.24
Pyrrhotite	4.88	0.00	4.21	0.50	2.38	5.60	18.96	2.60	0.00	17.21	0.59	43.06	0.00
Sphalerite	5.81	0.00	0.00	0.00	0.00	0.00	9.73	0.00	0.00	0.93	0.00	82.86	0.67
Tetrahedrite	2.32	13.02	0.00	0.00	0.00	8.20	30.13	0.00	0.00	0.00	0.00	46.35	0.00

Sulfide Exposure

Free Surface of Particle (%)	0% (not exposed)	0% < x < 100%	100% (liberated)
Chalcopyrite	5.05	89.03	5.93
Cobaltite	80.83	8.83	10.34
Gersdorffite	32.04	67.96	0.00
Pyrite	0.46	79.80	19.74
Pyrrhotite	12.65	79.86	7.48
Sphalerite	0.11	47.41	52.48
Tetrahedrite	0.00	98.70	1.30

Pyrite Particle Size by Percent Passing

P-value	µm
P50	354.02
P80	497.89