Wolverine Mine

Tailings Humidity Cells Decommissioning

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February 2014

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1. Introduction

Environmental characterization of the Wolverine Mine tailings was initiated by Klohn Crippen in 2005 to support the Wolverine Mine environmental assessment. The purpose of the testing program was to identify the geochemical, metal leaching and acid rock drainage (ML/ARD) characteristics of tailings and waste rock materials. Both static and kinetic testing was employed in the characterization of samples. A detailed summary of the initial characterization work was provided in Appendix IV of the environmental assessment (KC, 2006).

Four tailings humidity cells were constructed in 2005 to assess the geochemical behaviour of unsaturated tailings under humid, aerobic conditions. The humidity cells were comprised of materials generated by experimental lock cycle testing using rock generated by bulk sampling conducted in 2005. Each of the four cells represented a likely tailings composition based on the best mine planning information available at the time.

Two samples, the Lynx Diluted Composite (Lynx) and Wolverine Diluted Composite (Wolv), ran for 63 weeks. The cells were decommissioned in 2006 once the mine plan and mineral processes were clearly defined, and it became apparent that these individual ore types did not behave significantly differently from the overall ore composites.

The Overall Ore Composite (OC) and Overall Diluted Ore Composite (OD) tailings humidity cells showed ML/ARD characteristics and were left running for several years to observe leachate chemistry and more conclusively determine the time required for Neutralization Potential depletion and the onset to acid generation. Beginning in 2010, the OD cell exhibited acidic leachate chemistry (after 250 weeks). The OC cell remained neutral throughout the testing program. The OC and OD cells ran a total of 345 and 339 weeks, respectively, until they were decommissioned in January 2012.

The following report provides a summary of the tailings sample selection, humidity cell set-up, operation, and decommissioning procedures. Pre-test and post-test geochemical characterization of the sample material is also included. Recommendations for further geochemical characterization test work are also provided.

2. Sample Selection and Preparation

Geochemical characterization was carried out on tailings samples representing possible tailings blends from the Wolverine Mine Project. To assess the geochemical characteristics of the tailings, four ore composite types were prepared and examined in 2005. The four samples were prepared with lock cycle tests (LCT) carried out to simulate the milling process. It was estimated at the time the process would produce three tailing sub-streams: ~2% pre-float concentrate tails (PFC), 88% rougher tails (Ro), and 10% cleaner scavenger tails (CS). The composite samples for kinetic testing included the following:

- **Combined Overall Diluted Ore Composite Tailings (OD).** Combined the three tailings streams generated by using ore and dilution rock from both Wolverine and Lynx ore zones.

- **Combined Overall Ore Composite Tailings (OC).** Combined the tailings generated from using only ore from the Wolverine and Lynx ore zones, and did not include any dilution rock. The sample was a composite of two lock cycle tests.

- **Combined Wolverine Composite Ore with Dilution Rock Tailings (Wolv)**. Combined all three tailings streams generated from ore samples prepared including dilution rock from the Wolverine ore zone.

- **Combined Lynx Ore with Dilution Rock Composite Tailings (Lynx).** Combined all three tailings streams generated from ore samples prepared that included dilution rock from the Lynx ore zone.

Subsequent to the testing program, the milling procedure was modified and the dense media separation (DMS), which produced a low specific gravity gravel sized by-product (DMS float), which mainly contained the dilution waste rock products, was dropped from the process. The implication of this change is that more dilution waste rock is milled through the overall process, and will be subsequently deposited in the tailings. Therefore, at this time, OD is considered to be the most representative tailings sample of the tailings that are presently being generated at the mine.

3. Pre-Test Characterization

The intent of pre-test characterization was to establish an understanding of the material composition of the test samples. Pre-test characterization of the humidity cell test material was carried out in 2005 under direction of Klohn Crippen and followed the Draft Guidelines and Recommendation Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia (Price, 1997). Mineral composition, solid phase analysis, and acid-base accounting (ABA) were carried out on the samples. Test procedures and results are presented in the following sections.

3.1 Mineralogy Analysis

Mineral assemblage percentages were assessed using optical microscopy on the four samples and the results are summarized in Table 1. In addition, quantitative phase analysis using x-ray diffraction (XRD) with Rietveld refinement was carried out, which helped identify the carbonate and sulphide species. The following conclusions were reported by Klohn Crippen (2006a):

- Pyrite is the dominant sulphide, with moderate concentrations of quartz and muscovite. Minor sulphides (arsenopyrite and sphalerite) were not detected, although these were detected in the optical mineralogical analysis (<1.8%).
- The abundance of reactive carbonates and non-carbonate minerals (<10% total), relative to the high sulphide content indicated that the materials are likely acid generating.
- The abundance of reactive carbonates indicated that there would be a lag time of likely several years prior to onset of acid generation.
- Rietveld analyses identified the main carbonates as dolomite (5% to 7.4%), calcite (2.6% to 3.6%) and siderite (0.4% to 0.5%).

Trace element analyses by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) were carried out on an *aqua regia* digest of the tailings samples, to quantify the solid-phase concentrations of various elements within the samples. When measured sample concentrations are compared to known crustal abundances, it can be determined which elements may be of environmental concern under neutral or acidic drainage conditions. At the time of the analyses, anomalous elemental concentrations were defined by Klohn Crippen as greater than five times the normal crustal abundance as listed in Appendix 3 of Price (1997). Thirteen trace elements

(Table 4) showed concentrations greater than five times crustal abundance in most of the samples. The results suggested that following the onset of acidic conditions, the release of metal(loid)s from mineral phases, particularly from the sulphide phases, may occur. Furthermore, elements that are mobile under neutral pH conditions may have the potential to be released prior to the onset of acidic conditions.

Table 1: Pre-test Mineral Assemblages and Modal Abundance

MINERAL	Tailings Sample			
	OD	OC	WOLV	LYNX
Pyrite	53.1	60.1	38.3	60.3
Quartz	20.9	17.1	26.7	16.7
Carbonate	10.5	10.6	14.2	11.6
Muscovite	11.9	5.2	14.3	8.9
Chlorite	1	1.1	0.9	0
Sphalerite	1.1	1.6	1.3	1.8
Pyrrhotite	0.5	1.6	2.1	0
Amphibole	0	0.6	0.5	0
Arsenopyrite	0.3	0.8	0	0.3
Pyroxene	0.2	0.3	1.5	0
Chalcopyrite	0.5	0.4	0.2	0
Galena	0	0.4	0	0.8
Biotite	0	0.2	0	0
Magnetite	0	0.1	0	0
Total	**100**	**100**	**100**	**100**

3.2 Acid Base Accounting (ABA)

Acidic drainage will only result when the rate of acid generation exceeds the rate of acid neutralization. Acid Base Accounting (ABA) is a series of analyses and calculations used to estimate the potential for mineral weathering to produce acidic drainage. ABA includes analysis for rinse and paste pH, sulphur species, acid generation potential (AP), and acid neutralization potential (NP). Laboratory ABA testing was carried out in 2005 under the direction of Klohn Crippen and results are presented in Table 2. Key observations as reported by Klohn Crippen (2006a) were:

- All samples had high sulphide content and a low NP and were likely to produce acid rock drainage.

- The samples had enough NP (carbonate neutralization potential of 52.3-106 kg $CaCO_3$/t) to remain at a near-neutral pH, when initially exposed to oxygen. This was further supported by the relatively high paste pH values of 7.27 to 7.42.

- Most samples indicated the presence of non-carbonate neutralization potential, possibly from the muscovite, clinochlore and kaolinite, indicated by the mineralogical analysis (Section 3.1).

Table 2: Pre-Test Tailings ABA Results

PARAMETER	UNITS	OD	OC	WOLV	LYNX
Paste pH	-	7.27	7.42	7.35	7.36
Fizz Rate	-	2	3	2	2
Total S	%S	26.6	29.2	19.7	31.2
Acid Leachable SO_4^{2-}	%S	2.04	2.51	1.74	0.74
Sulphide S	%S	22.9	25	15.7	27.8
Insoluble SO_4^{2-}	%S	0.005	0.005	0.005	0.005
Organic S	%S	1.67	1.73	2.34	2.68
AP	kg $CaCO_3$/t	715	781	489	869
Sobek NP	kg $CaCO_3$/t	82.5	72.8	94.6	49.4
Sobek NP/AP	-	0.12	0.09	0.19	0.06
Net NP	kg $CaCO_3$/t	-632	-708	-395	-820
C(t)	%C	1.56	1.48	2.14	1.27
TOC	%C	0.62	na	0.98	0.48
TIC	%C	0.94	na	1.2	0.79
Carb NP	kg $CaCO_3$/t	98.3	59.4	106	52.3
Carb NP/AP	-	0.14	0.08	0.22	0.06

Note: Red text indicates measured value less than detection limit and listed as one half of the method detection limit.

3.3 Metals Analysis

Trace element analyses by ICP-MS were carried out on the tailings samples in 2005 by SGS Lakefield, under the direction of Klohn Crippen. Solid samples were subjected to near-total digestion in a mixture of strong oxidizing acids (HNO_3 and HCl), known as *aqua regia*, in order to dissolve most mineral phases. Digests were then quantitatively analyzed for a suite of major, minor and trace elements. The elemental analyses by ICP-MS as reported by Klohn Crippen (2005b) are presented in Table 3.

Table 3: Pre-test ICP-MS Solid Phase Results

Element	Unit	Crustal Abundance[1]	Tailings Samples			
			OD	OC	WOLV	LYNX
Ag	mg/kg	0.080	55	59	82	54
Al	%	8.4	0.60	0.43	1.0	0.28
As	mg/kg	1.8	2,700	2,700	1,200	4,100
Ba	mg/kg	390	53	38	66	50
Be	mg/kg	2.0	0.17	0.10	0.24	0.12
Bi	mg/kg	0.0082	11	7.5	19	6.4
B	mg/kg	9.0	2.5	1.5	2.5	2.5
Ca	%	4.7	2.5	2.3	2.7	2.4
Cd	mg/kg	0.16	97	140	74	110
Co	mg/kg	29	43	37	48	39
Cr	mg/kg	122	200	120	160	210
Cu	mg/kg	68	820	1,100	1,100	820
Fe	%	6.2	23	28	18	27
Hg	mg/kg	0.086	3.6	3.2	4.0	3.2
K	%	1.8	0.17	0.21	0.25	0.11
Li	mg/kg	18	1.6	0.15	5.5	0.10
Mg	%	2.8	1.0	0.75	1.6	0.52
Mn	mg/kg	1,060	670	680	620	700
Mo	mg/kg	1.2	32	28	25	45
Na	%	2.3	0.014	0.011	0.015	0.010
Ni	mg/kg	99	60	65	56	63
P	mg/kg	1,120	320	290	520	190
Pb	mg/kg	13	3,900	3,500	5,100	5,600
Sb	mg/kg	0.20	170	220	310	180
Se	mg/kg	0.050	364	361	464	336
Sn	mg/kg	2.1	13	11	10	16
Sr	mg/kg	384	53	49	59	48
Ti	mg/kg	6,320	68	54	82	53
Tl	mg/kg	0.72	19	16	13	24
U	mg/kg	2.3	4.7	3.9	6.0	3.4
V	mg/kg	136	37	29	49	33
Zn	mg/kg	76	9,800	19,000	8,000	11,000

Note 1: Crust as a Whole in: Abundances of chemical elements in the Earth's Crust and chondrites in Appendix 3 of Price (1997).

Red text indicates measured value was less than detection limit and is presented as one half of the method detection limit.

Elemental analysis by XRF was also performed to provide a better estimate of elemental concentrations that are generally refractory to the *aqua regia* digest, including aluminosilicate minerals (Al, Si). The results of the Whole Rock Analyses, presented in elemental concentrations, are included in Table 4.

Table 4: Pre-test Elemental Concentrations Calculated from the Whole Rock Data

Element	Elemental Concentration (wt. %)			
	OD	OC	WOLV	LYNX
Si	12.53	11.31	16.5	9.63
Al	2.48	2.06	3.39	1.8
Fe	12.14	13.01	9.72	14.83
Mg	1.27	1.09	1.98	0.69
Ca	2.7	2.36	2.99	2.59
Na	0.18	0.19	0.14	0.17
K	0.5	0.4	0.68	0.38
Ti	0.07	0.05	0.09	0.05
P	0.02	0.02	0.03	0.01
Mn	0.07	0.09	0.06	0.08
Cr	0.02	0.02	0.02	0.02
V	0.02	0.02	0.04	0.02

4. Humidity Cell Testing

For sulphidic geologic materials, the humidity cell is the recommended kinetic test for predicting primary reaction rates under aerobic weathering conditions (Price, 2010). The resulting data provides a measure of rates of elemental release, acid generation and acid neutralization under the geochemical conditions encountered in the test. Humidity cell data can be used to estimate the time to mineral exhaustion, time to onset of acid generation, and waste rock and tailings drainge chemistry.

4.1 Set-up

The following description of humidity cell set-up was provided by Klohn Crippen (2006b). The humidity cells were constructed using acrylic tubing and base plate with an approximately 20 cm inside diameter and 10 cm height. The base plate was glued to the tube and threaded with a nylon hose adapter to which a length of tubing was attached allowing for leachate drainage into a collection container. A perforated PVC support plate was positioned inside the cell approximately 1.3 cm above the base plate and covered with six layers of nylon mesh. A nylon adapter was threaded into the side of the cell between the support plate, and the base plate and a length of tubing was connected from the side adapter to a humidifier to facilitate the inflow of humid air to the cell. A dry air line was also connected to each cell. Each cell was covered with a removable acrylic lid. The modifications made to the tailings flood leach humidity cell were adopted to facilitate the movement of water through the finer grained tailings. A saturated 1.0 kg sample of tailings was used to charge each cell. The overall depth of tailings within each humidity cell was approximately five centimetres. The OC humidity cell is depicted in Photo 1.

Photo 1: OC Humidity Cell (January 29, 2012)

4.2 Operation

At the end of each weekly cycle, the volume of leachate collected in the container for the tailings flood leach humidity cell was recorded. The leachate was filtered through a Gelman magnetic filter funnel fitted with a membrane filter of pore size 0.45 μm and analyzed by ICP-MS for a suite of elements as well as for pH, conductivity, acidity, alkalinity and sulphate.

4.3 Results

The primary objective of the humidity cell testing was to measure reaction rates under specific geochemical conditions and to calculate times for onset of acid generation. Weekly leachate volume, concentration, and sample mass were combined to calculate mass loading rates with units mg/kg/wk. The leachate chemistry and loading rates were compiled into a spreadsheet file titled “120724_Wolverine_Tailings_HC_database.xlsm”. A digital version of the data compilation file accompanies this report. The following sections provide a short summary of relevant analytical results for each of the four humidity cells.

4.3.1 pH

The pH values for all humidity cells over the duration of the testing program are presented graphically in Figure 1. The Wolv and Lynx cells began at neutral pH and then fell until week four, where they then returned to neutral pH and remained at nearly neutral levels for the remainder of the testing program.

The OC cell remained at nearly neutral pH levels for the duration of the testing program. The OC cell appeared to be undergoing a very slight decrease in pH from approximately week 200 (pH 6.8) until shutdown at week 345 (pH 6.4).

The OD cell had an initial pH of pH 7.0 (week 0), and pH dropped substantially over weeks 1-3 until recovering by week 4 when the pH rose to near neutral conditions and remained stable until approximately week 250 (4.8 years). This initial pH drop is believed to be associated with the relatively rapid oxidation of the thiosalts present in the tailings voids water. After week 250 the pH dropped steadily as a result of the onset of sulphide-oxidation induced acidic drainage conditions. At the end of the testing program, leachate pH of the OD cell had reached a minimum value of pH 3.1. The rate of drop in pH appeared to be slowing down between week 315 and shutdown of the cell (week 339). Although it is not possible to predict pH beyond the timeframe of the testing program by extrapolation, the pH might be expected to continue decrease and eventually stabilize at a lower, more acidic pH level. It is also possible that the pH could reach a minimum level and then rebound to a higher level before reaching a stable level.

4.3.2 Sulphate

Sulphate production rate is monitored in humidity cells to assess the depletion of sulphur species from the tailings samples because the process of oxidation of sulphides into sulphate can lead to acidic drainage conditions. Until the initial sulphate has been flushed from the humidity cell, the sulphate production rate does not necessarily reflect sulphate produced through the sulphide oxidation process. Prior to depletion of the original sulphate from the sample, it is likely that a majority of the sulphate measured is due to flushing of the original sulphate from the sample with only some sulphate produced due to sulphide oxidation. Therefore, in humidity cell testing, it is commonly assumed that sulphide oxidation is not taking place until flushing of all of the original sulphate measured during the pre-test ABA characterization is complete. A mass balance of the sulphur species for each cell is included in the ABA discussion in Section 6.1. Sulphate production rates are presented for each cell in Figure 2.

4.3.3 Metal Loading Rates

Each of the cells underwent an initial flush where metal loading rates were initially high for some parameters, but stabilized out at a lower level at a later date. Pre-test ICP-MS analysis showed that zinc (Zn) and selenium (Se) were present at elevated levels in the solid samples. Se and Zn are mobile under neutral drainage conditions, and loading rates for those metals were observed at elevated levels among all humidity cells, during, and following the initial flush. Zn and Se loading rates are presented in Figure 3 and Figure 4, respectively.

There has been an exponential growth trend in loading rates of various substances from the OD cell since the onset of acid generation conditions (week 232). The copper (Cu) loading rate has risen from around 0.0019 mg/kg/wk and reached as high as 4.1 mg/kg/wk (week 332). Cu loading at the final week (week 339) was 2.7 mg/kg/wk (Figure 5). The trend in Cu loadings is the most pronounced; the increase is ~1400-fold for Cu, ~50-fold for Zn and ~5-fold for Se. The exponential trends in metal loading rates appeared to be levelling off or decreasing between weeks 324 and 339, as the final data point was lower than the previous three.

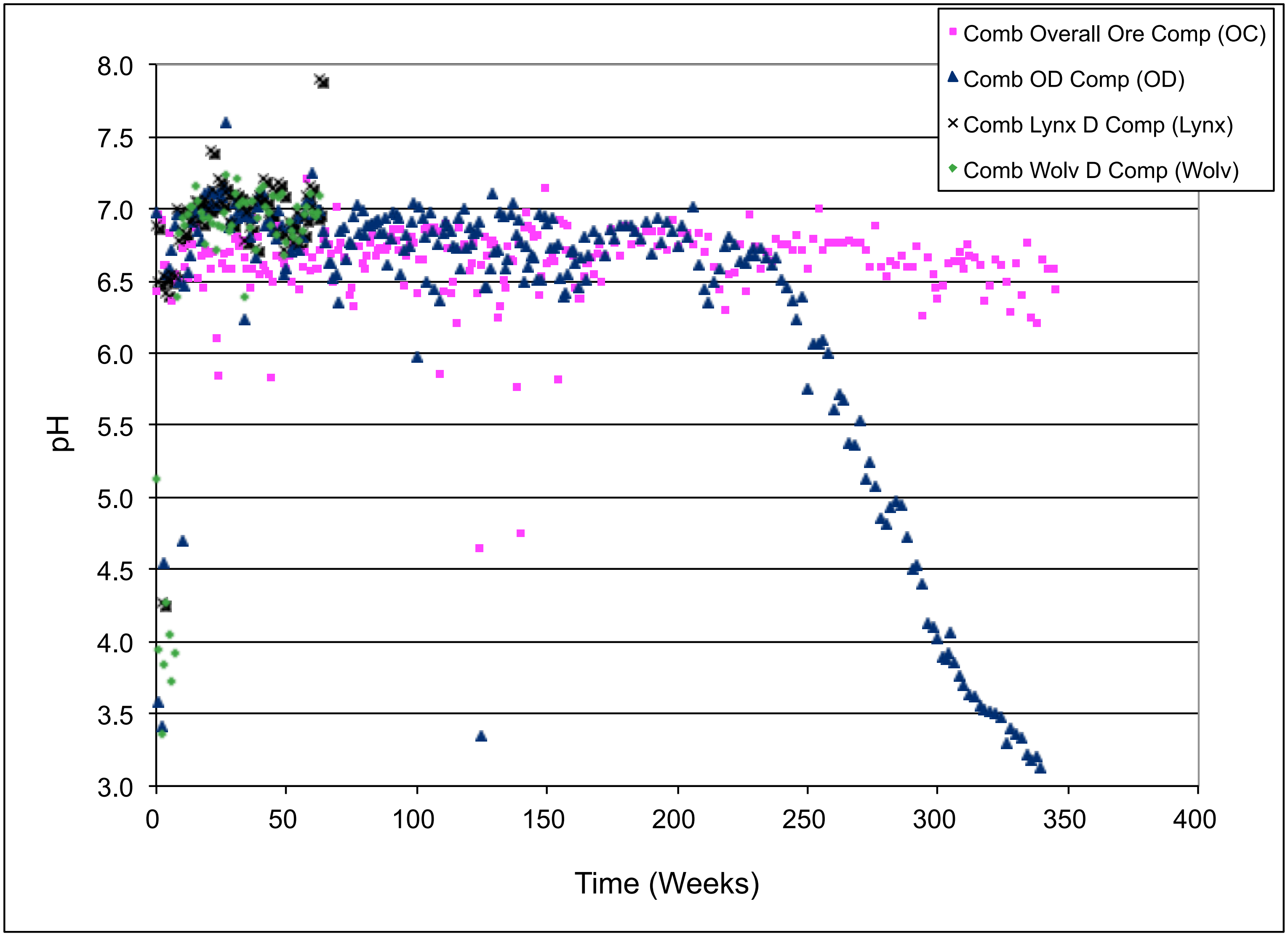

Figure 1: Wolverine Tailings Humidity Cells – pH

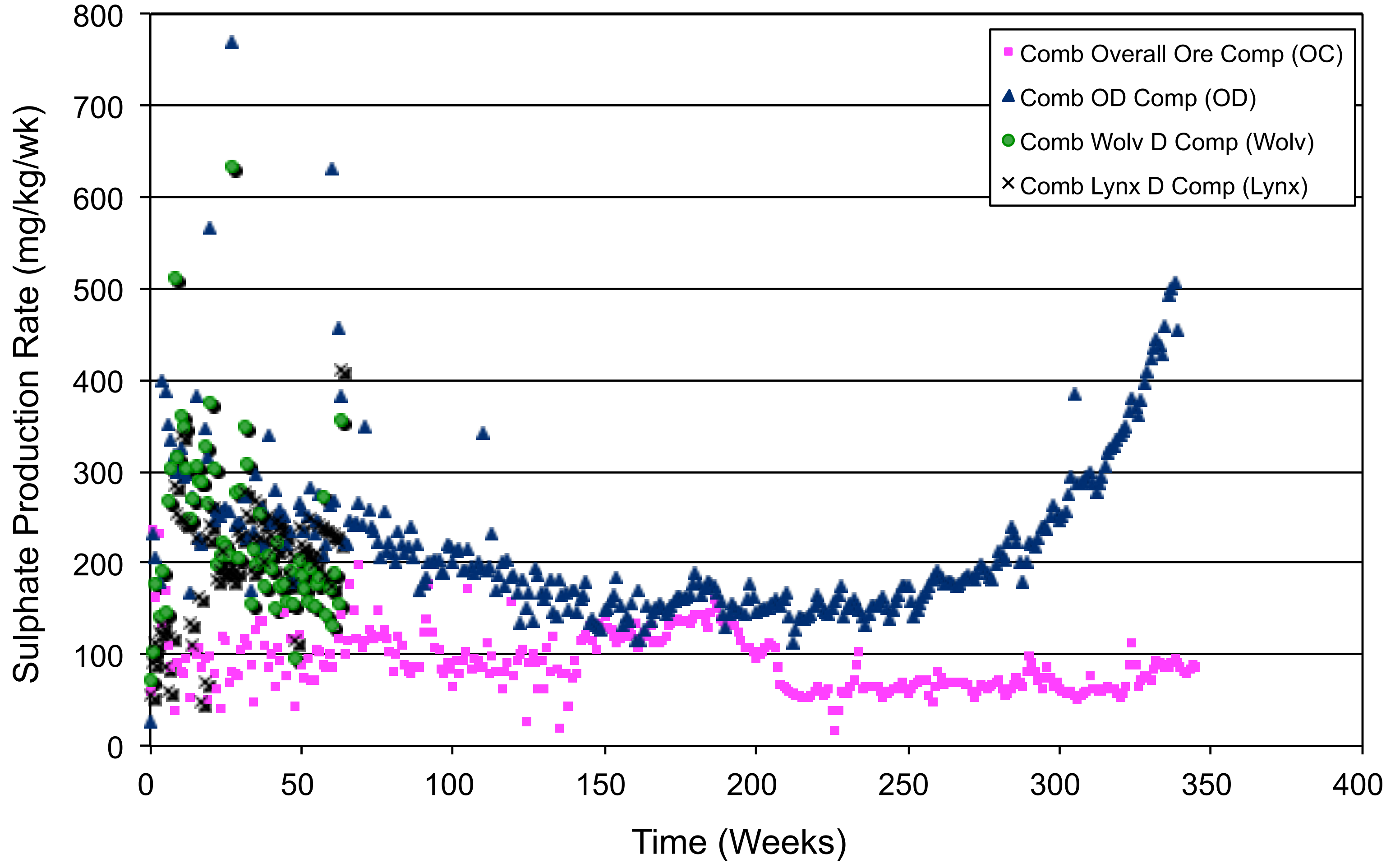

Figure 2: Wolverine Tailings Humidity Cells – Sulphate (SO_4) Production

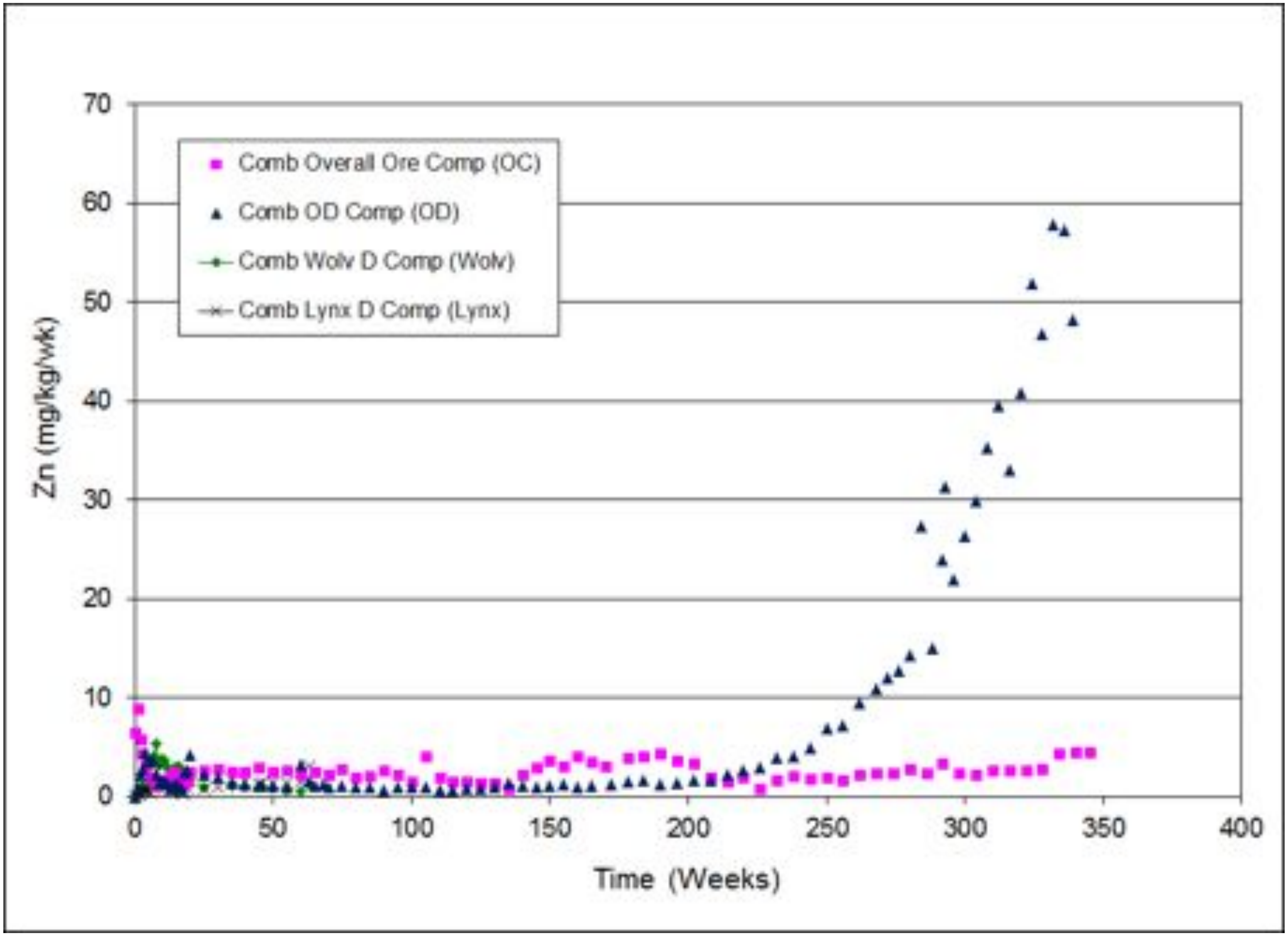

Figure 3: Wolverine Tailings Humidity Cells – Zinc (Zn) Loading Rates

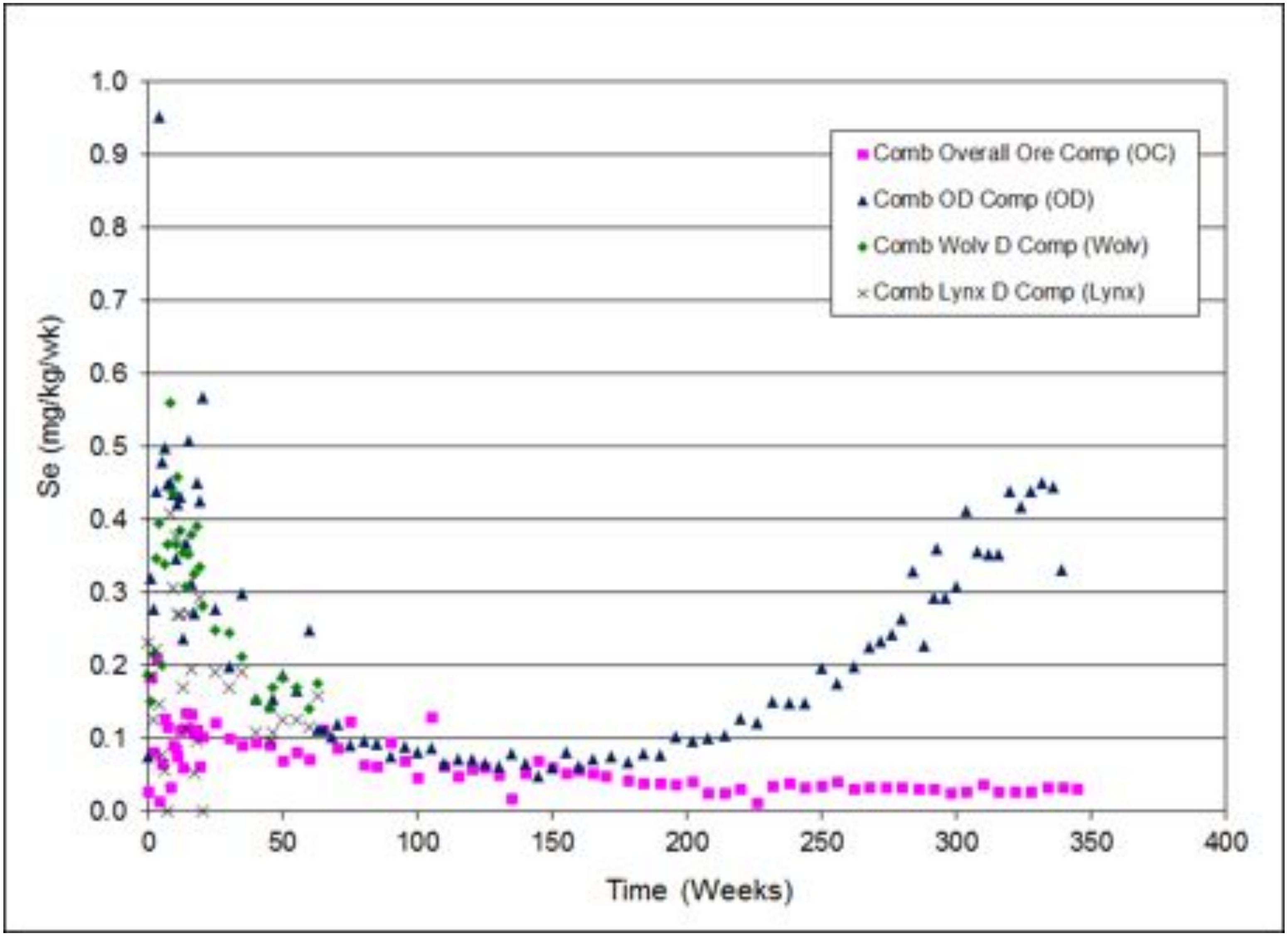

Figure 4: Wolverine Tailings Humidity Cells – Selenium (Se) Loading Rates

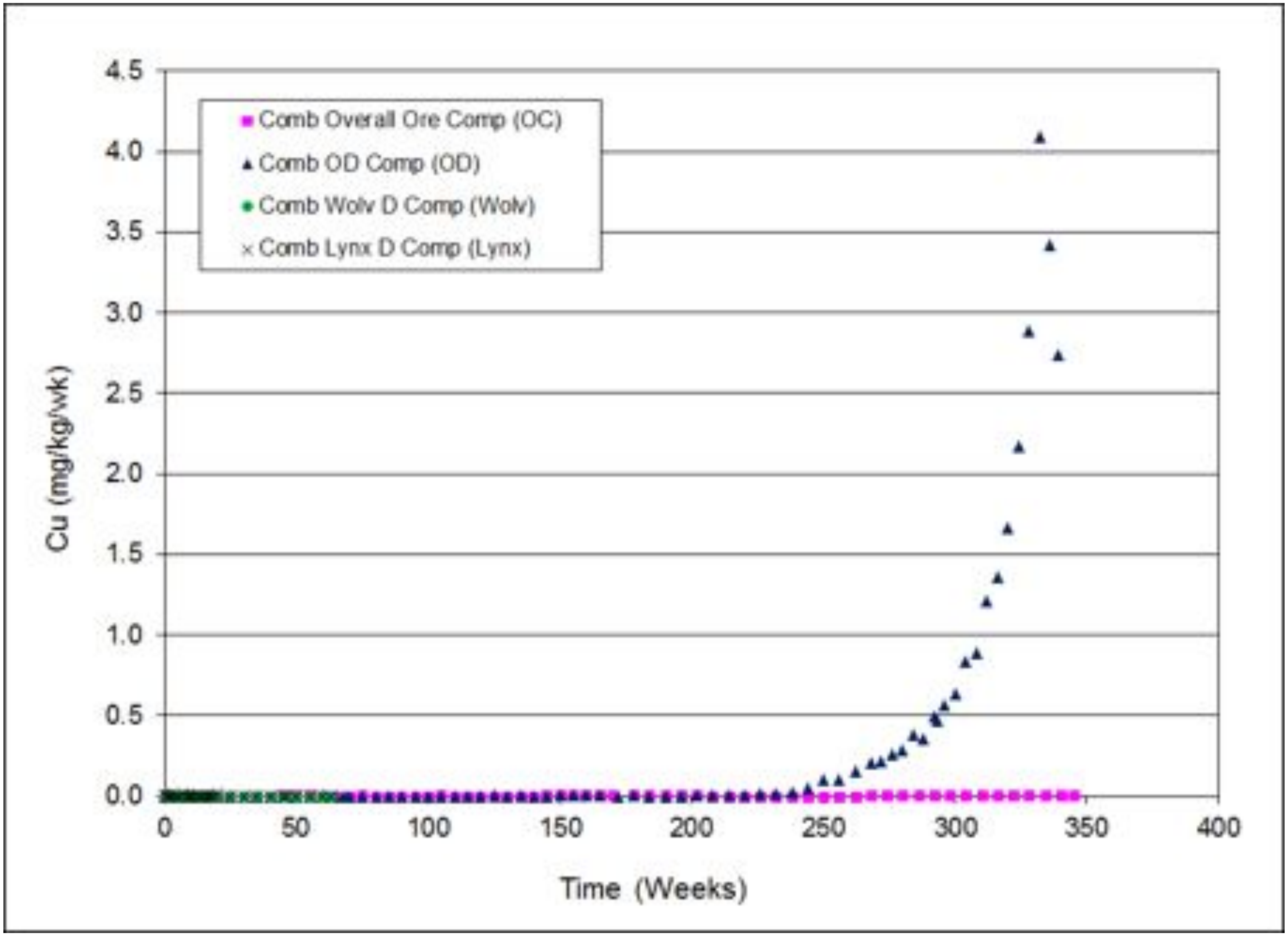

Figure 5: Wolverine Tailings Humidity Cells – Copper (Cu) Loading Rates

4.4 Humidity Cell Decommissioning (Shut-Down)

The Wolv and Lynx cells were each allowed to run for a total of 63 weeks. The cells were decommissioned in 2006 because it had become clear that the two ore types would be processed simultaneously and so separate humidity cells would not be representative of the tailings produced from the milling process. The Overall Ore Composites were continued as they were more suitable for the testing program.

The OC and OD cells were left to run a total of 345 and 339 weeks, respectively, until they were decommissioned in January 2012. Humidity cell closedown procedures were followed as outlined in the MEND Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials (Price, 2009). The following key items were undertaken during the shutdown procedure:

- After the final humidity cell cycle, collect the leachate as per the humidity cell operational procedures. Submit to lab for full suite of leachate water quality analyses.
- Remove the sample from the test cell and carry out a shake flask extraction test with minimum 3:1 (by mass) liquid to volume ratio. Following the procedure, collect the leachate, record leachate volume, and label the sample “final leach”. Carry out full suite of leachate water quality analysis on the “final leach” sample (pH, conductivity, acidity/alkalinity, sulphate, metals by ICP-MS including Hg, thiosalts, Cl, F, CNO, CNS, NO_3, and NH_3).
- Measure the mass of the wet solids. Dry the solids, then measure mass of dry solids.
- Take a representative split from the solid sample and label it “Final Residue”. Submit the split for comprehensive compositional analysis (petrographics, XRD, expanded ABA, ICP metals, Whole Rock Analyses by XRF, shake flask analyses (with pH, sulphate and metals)).

Photos of the Wolv and Lynx samples following decommissioning are provided in Photo 2 and Photo 3. Photos of the OD and OC samples during the decommissioning are presented in Photo 4 to Photo 7. Note the evidence of oxidation in the iron staining visible in the OD cell photos, which is also perhaps slightly evident in the OC cell but is certainly absent from the other cells, which had not been allowed to run for long enough for iron staining to become evident.

Photo 2: Wolverine Diluted Tailings in the Humidity Cell (October 6, 2006)

Photo 3: Lynx Diluted Tailings in the Humidity Cell (October 6, 2006)

Photo 4: OD Tailings in the Humidity Cell (January 29, 2012)

Photo 5: OD Tailings Sample Placed on Sheet for Drying (January 29, 2012)

Photo 6: OC Tailings in the Humidity Cell (January 29, 2012)

Photo 7: OC Tailings Sample Placed on Sheet for Drying (January 29, 2012)

5. Post-Test Characterization

Post-test characterization was carried out on the tailings samples following shutdown of the cells. Characterization work included mineralogy (optical microscopy and x-ray diffraction), ABA, metals analysis and shake flask testing. The results of the post-test characterization are presented below, and a comparison between pre-test and post-test characterization results is presented in Section 6.

5.1 Mineralogy Analysis

Mineral assemblage percentages of the post-test Wolv and Lynx tailings samples were assessed in 2007 by SGS using optical microscopy and the results are summarized in Table 5. In addition, quantitative phase analysis using x-ray diffraction (XRD) with Rietveld refinement was carried out, which helped identify the carbonate and sulphide species. The post-test mineral assemblages by QEMSCAN and subsequent quantitative phase analysis by Rietveld XRD of the OC and OD tailings samples were carried out in 2012 by SGS and are summarized in Table 6. The full analytical results are provided in Appendix A.

Table 5: Post-Test Mineral Assemblages for final Wolv and Lynx Samples

Mineral	QEMSCAN		Rietveld - XRD	
	WOLV	LYNX	WOLV	LYNX
Pyrite	40	67.6	36.1	64.7
Quartz	25.4	15.1	30.7	17.4
K-Feldspar	1.2	1.4		
Muscovite / Sericite	7	2.1	14.8	8.8
Biotite	3.3	0.8	1.3	1.2
Chlorite	5.9	0.3		
Pyriboles	0.9	0.2		
Plagioclase	0.1	0		
Talc	0.2	0		
Garnet	0	0		
Clay Minerals	4.4	3.9		
Calcite	0.5	0.4	0.5	
Ankerite	1.3	0.6		
Dolomite	4.5	1.6	6.8	3.2
Siderite	0.1	0		
Gypsum	0.3	0.5	3.2	4.9
Jarosite	1.9	2.6		
Rutile	0.2	0.1		
Fe-oxides	0.7	0.5		
Ilmenite	0.2	0.1		
Sphalerite	1	1		
Pyrrhotite	0.3	0.1	1.6	
Chalcopyrite	0.2	0.1		
Arsenopyrite	0.2	0.7		
Chlinochlore			4.9	
Other Trace (<0.05 wt.%)	0.3	0.2		
Total	**100**	**100**	**100**	**100**

Table 6: Post-Test Mineral Assemblages for final OC and OD samples

Mineral	QEMSCAN		Rietveld - XRD	
	OD	OC	OD	OC
Pyrite	60.0	69.0	57.3	62.3
Quartz	19.7	11.9	29.4	24.9
Muscovite	7.5	4.9	11.2	8.01
Biotite	3.5	1.8		
Ankerite/Dolomite	0.8	3.9	0.81	3.72
Sphalerite	0.8	3.0		
Chlorites	2.1	1.5	1.33	1.05
Clays	1.8	1.0		
Siderite	0.8	0.5		
Other Silicates	0.8	0.7		
Fe-Ti Oxides	0.7	0.2		
Arsenopyrite	0.2	0.6		
Apatite	0.3	0.2		
Zincite	0.2	0.3		
Chalcopyrite	0.1	0.3		
Pyrrhotite	0.1	0.1		
Galena	<0.1	<0.1		
Other/Accessory	0.4	0.1		
Total	**100**	**100**	**100**	**100**

5.2 Acid Base Accounting (ABA)

ABA testing was carried out on the post-test samples to measure the amount of sulphur species, acid generating potential (AP) and neutralizing potential (NP) remaining in the samples following the humidity cell testing procedure. Analyses on the Wolv and Lynx samples were carried out by SGS. OC and OD analyses were carried out in January 2012 and reported by SGS. Post-test ABA results for all four samples are presented in Table 7. The full analytical results are provided in Appendix B.

Table 7: Post-Test Tailings ABA Results

Parameter	Units	OD	OC	WOLV	LYNX
Paste pH	pH units	5.65	7.06	7.05	6.45
Fizz Rate	---	1	2	2	2
Total S	%	23.2	27.6	18.6	27.1
Acid Leachable SO_4^{2-}	%	0.005	0.005	0.005	0.005
Sulphide S	%	23.2	27.6	17.1	29.0
AP	kg $CaCO_3$/t	725	862	534	906
NP	kg $CaCO_3$/t	11.5	46.5	73.00	39.2
Net NP	kg $CaCO_3$/t	-714	-816	-461	-867
NP/AP	ratio	0.02	0.05	0.14	0.04
C(t)	%	0.727	1.22	1.912	0.865
CO_3	%	0.533	1.29	2.426	0.895

Red text indicates measured value less than detection limit and listed as one half of the method detection limit.

The absence of measurable sulphate reflects the lengthy flushing the cells had undergone, followed by the shake flask extraction prior to the post-test solid phase analyses. This combination removed all the soluble sulphate present in the samples prior to the test as well as any sulphate generated through oxidation of the material.

5.3 Metals Analysis

Metals analysis was carried out on the post-test solids to measure the metals remaining in the samples after the humidity cell testing procedure. Analyses on the Wolv and Lynx samples were carried out by SGS in 2007. OC and OD analyses were carried out in January 2012 and reported by SGS (2012c). Results are presented in Table 8 and the full analytical results are provided in Appendix C.

Table 8: Post-test ICP-MS Solid Phase Results

Element	Unit	Crustal Abundance[1]	Tailings Samples			
			OD	OC	WOLV	LYNX
Ag	mg/kg	0.080	56	63	86	59
Al	%	8.4	3.1	2.4	0.84	0.21
As	mg/kg	1.8	2,600	2,900	1,200	3,700
Ba	mg/kg	390	3,900	1,900	57	32
Be	mg/kg	2.0	1.4	1.2	0.20	0.05
Bi	mg/kg	0.0082	9.8	10	18	4.9
Ca	%	4.7	0.45	1.1	2.2	1.8
Cd	mg/kg	0.16	53	130	75	100
Co	mg/kg	29	29	33	40	32
Cr	mg/kg	122	440	430	91	110
Cu	mg/kg	68	640	960	1,100	850
Fe	%	6.2	35	35	20	30
Hg	mg/kg	0.086	3.9	5.5		
K	%	1.8	1.3	1.1	0.31	0.12
Li	mg/kg	18	29	23	4.2	0.10
Mg	%	2.8	0.86	1.0	1.4	0.37
Mn	mg/kg	1,060	470	730	600	590
Mo	mg/kg	1.2	36	36	28	47
Na	%	2.3	0.040	0.029	0.010	0.0055
Ni	mg/kg	99	45	54	60	66
P	mg/kg	1,120	410	330		
Pb	mg/kg	13	4,100	4,300	4,500	4,600
Sb	mg/kg	0.20	280	280	290	200
Se	mg/kg	0.050	370	470	530	430
Sn	mg/kg	2.1	21	20	9.0	14
Sr	mg/kg	384	37	49	52	36
Ti	mg/kg	6,320	550	450	62	39
Tl	mg/kg	0.72	36	34	12	23
U	mg/kg	2.3	6.4	6.5	6.5	3.9
V	mg/kg	136	240	200	34	26
Y	mg/kg		9.8	10	10	6.2
Zn	mg/kg	76	6,800	17,000	8,300	11,000

Note 1: Crust as a Whole in Abundances of chemical elements in the Earth's Crust and chondrites in Appendix 3 of Price (1997).

Red text indicates measured value less than detection limit and listed as one half of the method detection limit.

5.4 Shake Flask Extraction Test Analysis

Prior to mineralogy, ABA, and metals analyses, the final contents of the humidity cells underwent a shake flask extraction testing (shake flask test) procedure, as described in Section 4.4. The leachate (labelled “final leach”) water quality was analysed to determine the amount of soluble materials that remained on the tailings and in the pore water after the samples were removed from the cells. Analyses on the Wolv and Lynx samples were carried out by SGS in 2007. OC and OD analyses were carried out in January 2012 and reported by SGS, and results are summarized in Table 9 with the full analytical results are provided in Appendix D.

Table 9: Post-Test Tailings Shake Flask Test Results

Parameter	Units	Tailings Sample			
		OD	OC	WOLV	LYNX
Sample Mass	(g)	1,000	1,000	1,095	1,069
Volume D.I. Water Added	mL	3,000	3,000	3,000	3,000
Initial pH	units	5.3	6.5	6.7	6.7
Final pH	units	5.4	7.1	7.1	6.9
pH	units	6.5	6.9	7.1	7.2
Alkalinity	mg/L as $CaCO_3$	16	17	51	41
Acidity	mg/L as $CaCO_3$	522	37	116	40
Conductivity	µS/cm	2,960	2,050	2,300	2,260
F	mg/L	0.030	0.080	0.19	0.16
Cl	mg/L	1.0	1.0	3.6	1.0
SO4	mg/L	2,200	1,300	1,500	1,500
CN(T)	mg/L	0.005	0.005	0.005	0.005
CNO	mg/L	0.5	0.5	0.5	0.5
CNS	mg/L	0.1	0.1	1	1
Thiosalts (total)	as S_2O_3 mg/L	5	5	80	40
NH_3+NH_4	as N mg/L	0.10	0.20	0.10	0.05
NO3	as N mg/L	0.025	0.025	0.25	0.090
Ag	mg/L	0.00041	0.00005	0.00015	0.00015
Al	mg/L	0.0004	0.0008	0.0050	0.0050
As	mg/L	0.11	0.0064	0.0080	0.0025
Ba	mg/L	0.039	0.029	0.033	0.035
Be	mg/L	0.00001	0.00001	0.00080	0.00020
Bi	mg/L	0.000005	0.000005	0.000500	0.000300
B	mg/L	0.032	0.0086	0.020	0.023

Parameter	Units	Tailings Sample			
		OD	OC	WOLV	LYNX
Ca	mg/L	573	539	611	614
Cd	mg/L	2.1	1.2	0.36	0.29
Co	mg/L	0.14	0.0087	0.061	0.060
Cr	mg/L	0.00025	0.00025	0.00150	0.00150
Cu	mg/L	0.38	0.014	0.003	0.004
Fe	mg/L	0.012	0.0015	0.0050	0.0050
Hg	mg/L	0.00005	0.00030	0.00005	0.00005
Li	mg/L	0.0020	0.0005	0.0050	0.0040
K	mg/L	1.5	0.80	0.84	2.0
Mg	mg/L	62	4.4	21	23
Mn	mg/L	28	2.1	22	5.2
Mo	mg/L	0.00012	0.00330	0.00080	0.00080
Na	mg/L	5.2	4.0	0.42	0.72
Ni	mg/L	0.63	0.024	0.15	0.13
P	mg/L	0.0045	0.012	0.0050	0.030
Pb	mg/L	0.057	0.0097	0.053	0.017
Sb	mg/L			0.005	0.010
Se	mg/L	3.0	0.19	0.28	0.45
Si	mg/L	6.5	1.1	0.97	0.62
Sn	mg/L	0.00006	0.00035	0.0050	0.0040
Sr	mg/L	1.2	0.57	1.2	0.90
Ti	mg/L	0.0008	0.0003	0.0005	0.0005
Tl	mg/L	0.017	0.013	0.007	0.0005
U	mg/L	0.00016	0.000085	0.00080	0.00100
V	mg/L	0.00006	0.00014	0.0040	0.0040
Zn	mg/L	328	38	33	17

Red text indicates measured value less than detection limit and listed as one half of the method detection limit.

6. Mass Balance Assessment

The intent of humidity cell testing is to assess the rate of chemical leaching, time to onset of acid generation, and time until mineral exhaustion in the test material. Pre-test characterization results can be used in conjunction with the humidity cell results and post-test characterization results, to assess the amount of depletion of materials from the samples that occurred over the duration of the humidity cell testing program. The results can also provide insight as to which minerals in the test material did and did not react during kinetic testing. An ABA-based mass balance was carried out to assess the time to AP and NP depletion. Metal content mass balance was carried out to assess the rate of mineral exhaustion based on the humidity cell results.

6.1 ABA

ABA calculations are intended to track the amount of NP, AP, and sulphur species remaining in a sample by comparing the initial content that was measured during the pre-testing program, with the mass of substances released in the humidity cells. In some cases, the time to depletion of neutralizing potential (NP) and onset of acidic drainage conditions can be predicted from the calculations. Once the original sulphate is flushed from the tailings humidity cell, the sulphate measured in the leachate can be attributed to sulphide oxidation, and the time to sulphide depletion can then be estimated. If the time to sulphide depletion is shown to be longer than the time to NP depletion, the time to onset of acidic conditions can also be estimated. However, until all of the initial sulphate has been flushed from a cell, the time to sulphide depletion and subsequent acid generation cannot be estimated.

ABA calculations (Table 10) indicate that the initial sulphate had been depleted from the OD cell by approximately week 303 (5.8 years). Therefore, it was assumed that sulphate production subsequent to week 303 can be attributed to sulphide depletion. Based on the most recent five sulphate production rates for the OD cell, the time to depletion of initial sulphide from the sample was calculated to be 28 years following the depletion of initial sulphate from the sample. Because initial sulphate had not yet been depleted from the Wolv, Lynx, and OC cells prior to decommissioning, the time to depletion of sulphide from those samples could not be predicted. The calculated time to depletion of initial sulphate for Wolv, Lynx and OC and is presented in Table 10.

Mass balance calculations (Table 10) indicated that the OD cell had approximately 99% of initial NP remaining at the onset of acidic conditions (week 232), and 89% of the original NP remaining upon closure of the cell (week 339), indicating that the readily soluble calcite was consumed, and the remaining NP was not capable of buffering the leachate at a pH above pH 3.1. However, the small amount of reactive/available NP in the OD sample did keep the humidity cell pH in the neutral range for almost 5 years of weekly flushing at room temperature. Because initial sulphate depletion or onset of acidic conditions did not occur in the Lynx, Wolv, and OC cells, it was not possible to evaluate the time for NP depletion in those tailings samples. All that can be noted is that leachate pH remained near neutral at the end of the respective test periods. Mass balance results for sulphate, sulphide, and NP are presented Table 10.

Table 10: Depletion of Sulphur Species and NP from Humidity Cell Samples

		OD	OC	WOLV	LYNX
Sulphate and Sulphide Depletion					
Initial SO_4 - S	mg/kg	20,400	25,100	17,400	7,400
Initial S_2 - S	mg/kg	229,000	249,600	157,000	278,000
Cumulative SO_4 - S production to date	mg/kg	24,789	10,601	4,946	4,312
Remaining SO_4 – S (by difference)	mg/kg	0	14,499	12,454	3,088
Remaining S_2 – S (by sulphate removal)	mg/kg	224,604	249,600	157,000	278,000
SO_4 Production (5 sample average[1])	mg/kg/wk	465	87	210	255
SO_4 - S Production (5 sample average[1])	mg/kg/wk	155	29	70	85
Time to Initial SO_4 - S depletion[2]	years	5.8	16.3	4.6	1.9
Time to Initial S_2 - S depletion[3]	years	28	-	-	-
NP Depletion					
Initial NP	mg $CaCO_3$/kg	82,500	72,800	94,600	49,400
Cumulative Open System NP Consumption	mg $CaCO_3$/kg	9,135	153	0	0
Calculated Remaining NP	mg $CaCO_3$/kg	73,365	72,647	94,600	49,400
Open System NP Consumption Rate (5 sample average[1])	mg $CaCO_3$/kg/wk	268	0	0	0
Time to NP Depletion[2]	years	12	-	-	-

1. $S0_4$ and NP production rates were calculated based on the average value from the final five samples in order to reduce the effects of natural weekly variation in leachate water quality results.
2. From beginning of humidity cell testing.
3. From time at which initial sulphate becomes depleted from the sample.

6.2 Metals Analysis

A mass balance was carried out to assess the total mass of metals that was leached from the four tailings samples over the duration of the testing program. The following theoretical relationship represents conservation of mass of substances in the tailings samples following the humidity cell testing program:

$$m_i = m_{HC} + m_{SF} + m_f$$

where

m_i	is the initial metals content in the tailings sample (mg) calculated from the values reported in Table 3.
m_{HC}	is the total mass (mg) of solutes leached from the humidity cells. Calculated in the HC database, provided with this report.
m_{SF}	is the total mass (mg) of solutes washed from the tailings sample during the shake flask test procedure. Calculated from values in Table 9.
m_f	is the final metals content in the tailings sample (mg) calculated from the values reported in Table 8.

The fraction of the initial metals content that was depleted in the humidity cells over the duration of kinetic testing was calculated from the following relationship:

$$\text{Fraction Depleted (\%)} = \left(\frac{m_{HC}+m_{SF}}{m_i}\right)\times 100$$

Results for total mass leached, and fraction of initial content depleted over the testing program are presented in Table 11 to Table 14 for the four cells. Solid phase metals content (by ICP-MS) on the final sample is included in the summary tables for reference. In theory, the final metals content should equal the initial metals content minus the mass of metals leached from the samples. For some parameters and some tailings samples, final metal content results were either higher or lower than what would be calculated using the mass balance equation from the laboratory data. The following reasons are potential sources of error:

- ICP-MS should be regarded as accurate to +/- 25% for both the initial and final metals content analysis.

- The solid phase metals content results are based on ICP-MS analysis on a sub-sample (total mass of a few grams) taken from the tailings humidity cell sample (approximately 1 kg). There may be some heterogeneity among the humidity cell tailings sample from which the initial and final content sub-samples were taken, leaving potential for minerals to be present in different proportions among different sub-samples.

Therefore, it is often difficult to get convergence of the mass balance equation from the laboratory analytical results. However, the results and mass balance calculations do illustrate order of magnitude (months / years / decades) estimates for time to exhaustion of various metals that could be expected if laboratory loading rates were sustained in the tailings samples for an indefinite amount of time.

Some parameters were routinely below the laboratory detection limit during humidity cell testing. In this assessment, humidity cell leachate that was below detection limit was treated to be equal to half the laboratory detection limit. In some cases, this assumption could overestimate the actual concentration of a given substance by one or more orders of magnitude. Subsequently, the total mass leached during humidity cell testing could be overestimated as well. Parameters with all or most of their humidity cell leachate values below detection limit have been identified in the summary tables (Table 11 to Table 14).

Table 11: Wolv Humidity Cell Mass Metals Leached from a 1 kg Sample

Parameter		Initial Content (mg)	Final Content (mg)	Mass Extracted (mg)		Fraction Extracted (%)
				Humidity Cell	Shake Flask	
Silver	Ag	82	86	0.11	0.00045	0.14
Aluminum	Al	10,000	8,400	0.17	0.015	0.0019
Arsenic	As	1,200	1,200	0.18	0.024	0.017
Barium	Ba	66	57	0.74	0.099	1.3
Beryllium	Be	0.24	0.20	0.046	0.0024	20
Bismuth	Bi	19	18	0.0028	0.0015	0.023
Boron	B	2.5		0.14	0.060	7.9
Calcium	Ca	27,000	22,000	5,553	1,833	27
Cadmium	Cd	74	75	1.9	1.1	4.0
Cobalt	Co	48	40	0.43	0.18	1.3
Chromium	Cr	160	91	0.031	0.0045	0.022
Copper	Cu	1,100	1,100	0.080	0.0090	0.0081
Iron	Fe	180,000	200,000	0.23	0.015	0.00014
Mercury	Hg	4.0		0.0014	0.00015	0.038
Potassium	K	2,500	3,100	0.056	2.5	0.10
Lithium	Li	5.5	4.2	48	0.015	873
Magnesium	Mg	16,000	14,000	867	62	5.8
Manganese	Mn	620	600	38	67	17
Molybdenum	Mo	25	28	0.0097	0.0024	0.050
Sodium	Na	150	100	75	1.3	51
Nickel	Ni	56	60	0.86	0.45	2.4
Phosphorous	P	520		0.92	0.015	0.18
Lead	Pb	5,100	4,500	0.53	0.16	0.013
Antimony	Sb	310	290	0.47	0.015	0.16
Selenium	Se	464	530	16	0.84	3.6
Tin	Sn	10	9.0	0.10	0.015	1.2
Strontium	Sr	59	52	17	3.6	34
Titanium	Ti	82	62	0.050	0.0015	0.063
Thallium	Tl	13	12	0.16	0.021	1.3
Uranium	U	6.0	6.5	0.0027	0.0024	0.084
Vanadium	V	49	34	0.051	0.012	0.13
Zinc	Zn	8,000	8,300	99	100	2.5

Red text indicates that all or most of the input values were less than detection limit, and assumed to be one half of the method detection limit in mass loading calculations.

Table 12: Lynx Humidity Cell Mass Metals Leached from a 1 kg Sample

Parameter		Initial Content (mg)	Final Content (mg)	Mass Extracted (mg)		Fraction Extracted (%)
				Humidity Cell	Shake Flask	
Silver	Ag	54	59	0.069	0.00045	0.13
Aluminum	Al	2,800	2,100	0.14	0.015	0.0054
Arsenic	As	4,100	3,700	0.12	0.0075	0.0030
Barium	Ba	50	32	0.75	0.10	1.7
Beryllium	Be	0.12	0.050	0.042	0.00060	36
Bismuth	Bi	6.4	4.9	0.0026	0.00090	0.055
Boron	B	2.5		0.13	0.069	8.0
Calcium	Ca	24,000	18,000	4,354	1,842	26
Cadmium	Cd	110	100	1.5	0.86	2.1
Cobalt	Co	39	32	0.21	0.18	1.0
Chromium	Cr	210	110	0.011	0.0045	0.0073
Copper	Cu	820	850	0.10	0.012	0.014
Iron	Fe	270,000	300,000	0.22	0.015	0.000085
Mercury	Hg	3.2		0.0013	0.00015	0.045
Potassium	K	1,100	1,200	0.055	5.9	0.54
Lithium	Li	0.10	0.10	19	0.012	19,171
Magnesium	Mg	5,200	3,700	843	68	18
Manganese	Mn	700	590	47	16	9.0
Molybdenum	Mo	45	47	0.014	0.0024	0.036
Sodium	Na	100	55	51	2.2	54
Nickel	Ni	63	66	0.44	0.39	1.3
Phosphorous	P	190		0.83	0.090	0.48
Lead	Pb	5,600	4,600	0.28	0.050	0.0059
Antimony	Sb	180	200	0.44	0.030	0.26
Selenium	Se	336	430	9.5	1.4	3.2
Tin	Sn	16	14	0.16	0.012	1.1
Strontium	Sr	48	36	17	2.7	40
Titanium	Ti	53	39	0.046	0.0015	0.089
Thallium	Tl	24	23	0.26	0.0015	1.1
Uranium	U	3.4	3.9	0.0019	0.0030	0.15
Vanadium	V	33	26	0.029	0.012	0.12
Zinc	Zn	11,000	11,000	76	51	1.2

Red text indicates that all or most of the input values were less than detection limit, and assumed to be one half of the method detection limit in mass loading calculations.

Table 13: OC Humidity Cell Mass Metals Leached from a 1 kg Sample

Parameter		Initial Content (mg)	Final Content (mg)	Mass Extracted (mg)		Fraction Extracted (%)
				Humidity Cell	Shake Flask	
Silver	Ag	59	63	0.11	0.00015	0.18
Aluminum	Al	4,300	24,000	0.30	0.0024	0.0070
Arsenic	As	2,700	2,900	0.39	0.019	0.015
Barium	Ba	38	1,900	2.8	0.088	7.7
Beryllium	Be	0.10	1.2	0.048	0.000030	48
Bismuth	Bi	7.5	10	0.0039	0.000015	0.052
Boron	B	1.5		0.33	0.026	23
Calcium	Ca	23,000	11,000	11,450	1,617	57
Cadmium	Cd	140	130	24	3.6	20
Cobalt	Co	37	33	0.44	0.026	1.2
Chromium	Cr	120	430	0.054	0.00075	0.046
Copper	Cu	1,100	960	0.69	0.041	0.066
Iron	Fe	280,000	350,000	0.92	0.0045	0.00033
Mercury	Hg	3.2	5.5	0.0074	0.00090	0.26
Potassium	K	2,100	11,000	2.0	2.4	0.21
Lithium	Li	0.15	23	43	0.0015	28,576
Magnesium	Mg	7,500	10,000	945	13	13
Manganese	Mn	680	730	106	6.2	17
Molybdenum	Mo	28	36	0.14	0.0099	0.52
Sodium	Na	110	290	38	12	46
Nickel	Ni	65	54	0.54	0.071	0.95
Phosphorous	P	290	330	2.0	0.036	0.70
Lead	Pb	3,500	4,300	2.4	0.029	0.069
Antimony	Sb	220	280	0.72	0	0.33
Selenium	Se	361	470	19	0.58	5.4
Tin	Sn	11	20	0.077	0.0011	0.71
Strontium	Sr	49	49	27	1.7	58
Titanium	Ti	54	450	0.078	0.00090	0.15
Thallium	Tl	16	34	0.51	0.039	3.4
Uranium	U	3.9	6.5	0.058	0.00026	1.5
Vanadium	V	29	200	0.035	0.00042	0.12
Zinc	Zn	19,000	17,000	886	113	5.3

Red text indicates that all or most of the input values were less than detection limit, and assumed to be one half of the method detection limit in mass loading calculations.

Table 14: OD Humidity Cell Mass Metals Leached from a 1 kg Sample

Parameter		Initial Content (mg)	Final Content (mg)	Mass Extracted (mg)		Fraction Extracted (%)
				Humidity Cell	Shake Flask	
Silver	Ag	55	56	0.12	0.0012	0.23
Aluminum	Al	6,000	31,000	61	0.0012	1.0
Arsenic	As	2,700	2,600	2.0	0.34	0.085
Barium	Ba	53	3,900	3.1	0.12	6.0
Beryllium	Be	0.17	1.4	0.051	0.000030	30
Bismuth	Bi	11	9.8	0.0040	0.000015	0.036
Boron	B	2.5		0.35	0.097	18
Calcium	Ca	25,000	4,500	21,057	1,719	91
Cadmium	Cd	97	53	35	6.3	42
Cobalt	Co	43	29	2.9	0.41	7.8
Chromium	Cr	200	440	0.99	0.00075	0.49
Copper	Cu	820	640	91	1.1	11
Iron	Fe	230,000	350,000	953	0.036	0.41
Mercury	Hg	3.6	3.9	0.0014	0.00015	0.042
Potassium	K	1,700	13,000	10	4.5	0.86
Lithium	Li	1.6	29	79	0.0060	4,963
Magnesium	Mg	10,000	8,600	4,475	187	47
Manganese	Mn	670	470	276	83	54
Molybdenum	Mo	32	36	0.13	0.00036	0.42
Sodium	Na	140	400	59	16	53
Nickel	Ni	60	45	7.8	1.9	16
Phosphorous	P	320	410	2.7	0.014	0.85
Lead	Pb	3,900	4,100	10	0.17	0.26
Antimony	Sb	170	280	0.66	0	0.39
Selenium	Se	364	370	64	8.9	20
Tin	Sn	13	21	0.15	0.00018	1.1
Strontium	Sr	53	37	47	3.6	96
Titanium	Ti	68	550	0.10	0.0024	0.16
Thallium	Tl	19	36	0.68	0.050	3.8
Uranium	U	4.7	6.4	0.44	0.00048	9.3
Vanadium	V	37	240	0.086	0.00018	0.23
Zinc	Zn	9,800	6,800	2,801	984	39

Red text indicates that all or most of the input values were less than detection limit, and assumed to be one half of the method detection limit in mass loading calculations.

An overall metals mass balance of the OD cell was conducted for all parameters analyzed, and the results are summarized in Table 15 for parameters of interest: Ca, Cd, Cu, Mg, Se and Zn. The initial content for Ca and Mg were taken from Table 4 to better reflect the solid phase concentration. Mass balances for the other three cells were not conducted as the Wolv and Lynx cells did not run for long enough to release enough contaminants to conduct a mass balance, and as the OC cell did not achieve acidic conditions, the total quantity of metals leached were also inadequate to perform an accurate mass balance.

To evaluate the results of the humidity cell mass balance, the following relationship (from the equation above) should exist:

$$m_i - m_f = m_{HC} + m_{SF}$$

Total Removed = Total Flushed

A very good correlation exists between the total removed (initial – final content) and the total flushed (humidity cell leachate + shake flask extract) for Ca, Cd, Mg and Zn (Table 15). The selenium final content was greater than the initial content; however, as discussed above, each analytical result is only accurate to +/- 25%, meaning the actual initial value could range from 273 – 455 mg and the final value could range from 277 – 462 mg. Additionally, the analytical method for selenium has been greatly improved from 2005 (when initial analysis was conducted), to 2012, with current methods having less interference from other parameters. For copper, the total flushed value was half that of the total removed, however, these values are still within the limits of analytical uncertainty. Overall, the mass balance results confirm the validity of the laboratory humidity cell test program.

Table 15: OD Humidity Cell Metals Mass Balance

Parameter		Initial Content (mg)	Final Content (mg)	Total Removed (mg)	Mass Flushed (mg)		Total Flushed (mg)
					Humidity Cell	Shake Flask	
Calcium	Ca	*27,000*	4,500	22,500	21,057	1,719	22,776
Cadmium	Cd	97	53	44	35	6	41
Copper	Cu	820	640	180	91	1	92
Magnesium	Mg	*12,700*	8,600	4,100	4,475	187	4,662
Selenium	Se	364	370	-6	64	9	73
Zinc	Zn	9,800	6,800	3,000	2,801	984	3,785

NOTE: Values in italics were taken from Table 4 instead of Table 3, to better reflect the true solid phase concentration.

7. Conclusions

While stable long term leaching rates had not been achieved in the four tailings humidity cells prior to decommissioning, the tests illustrated the following characteristics about the samples:

- The tests have indicated that the onset of acid generation in lab conditions could take approximately 5 years for tailings comparable to the OD sample. It was not possible to predict time to onset of acid generation for the Wolv, Lynx and OC cells.
- The majority of the NP in the OD cell was not capable of buffering the leachate to a pH above pH 3.1 However, the relatively small amount of reactive/available NP did keep the OD humidity cell pH in the neutral range for almost 5 years of weekly flushing at room temperature. The time to onset of acidic drainage under site conditions, for tailings comparable to those in the OD sample, would be expected to be considerably longer than that experienced in the laboratory humidity cell.
- Initial flush and neutral pH drainage leaching rates that could be expected given controlled laboratory conditions:
    - All samples showed elevated rates of leaching for Se and Zn for neutral pH drainage. When the drainage became acidic, as in the OD cell, the leaching rates for Cu, Se, and Zn increased exponentially over time, in response to the drop in pH.

A mass balance for the OD cell was carried out to assess the total mass of metals that were leached from the tailings samples over the duration of the testing program. A very good correlation was seen for Ca, Cd, Mg, and Zn. This finding confirms the validity of the laboratory humidity cell test program.

8. Closure

We trust this humidity cell decommissioning report meets your requirements for the Wolverine tailings kinetic testing program. If you have any questions, please contact the undersigned.

Yours truly,

Marsland Environmental Associates Ltd.

Rob Griffith, P.Eng.	Rob Marsland, P.Eng.
Project Engineer	Senior Environmental Engineer

/attach – digital version only of data compilation spreadsheet

9. References

Klohn Crippen, 2006a. Wolverine Technical Study. Prepared by Klohn Crippen. February 3, 2006.

Klohn Crippen, 2006b. Wolverine Environmental Assessment – Appendix IV – Geochemical Characterization. Prepared for Yukon Zinc Corp. Prepared by Klohn Crippen. February 10, 2006.

Price, 2009. Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials. MEND Report 1.20.1.

Price, 1997. DRAFT Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia. Prepared for the British Columbia Ministry of Energy, Mines and Petroleum Resources.

YZC, 2011. Wolverine Project Monitoring and Surveillance Plan – Version 2011-03. Prepared for: Yukon Energy, Mines and Resources. Prepared by: Yukon Zinc Corporation. October 28, 2011.

Appendix A: Final Mineralogy Analysis

QUANTITATIVE PHASE ANALYSIS OF TWO POWDER SAMPLES USING THE RIETVELD METHOD AND X-RAY POWDER DIFFRACTION DATA.

(Project 10961-002 - P.O. 18042)

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February 27, 2007

EXPERIMENTAL METHOD

The two samples “**Combined Wolverine D Composite Tails Final Washed Solids**” and “**Combined Lynx D Composite Tails Final Washed Solids**” were reduced into fine powder to the optimum grain-size range for X-ray analysis (<10μm) grinding under ethanol in a vibratory McCrone Micronising Mill for 7 minutes. Step-scan X-ray powder-diffraction data were collected over a range 3-80°2θ with CoKα radiation on a standard Siemens (Bruker) D5000 Bragg-Brentano diffractometer equipped with an Fe monochromator foil, 0.6 mm (0.3°) divergence slit, incident- and diffracted-beam Sollers slits and a Vantec-1 strip detector. The long fine-focus Co X-ray tube was operated at 35 kV and 40 mA, using a take-off angle of 6°.

RESULTS AND DISCUSSION

The X-ray diffractograms were analyzed using the International Centre for Diffraction Database PDF-4 using Search-Match software by Siemens (Bruker). X-ray powder-diffraction data were refined with Rietveld Topas 3 (Bruker AXS).

The results of quantitative phase analysis by Rietveld refinement are given in Table 1. These amounts represent the relative amounts of crystalline phases normalized to 100%. The Rietveld refinement plots for the samples are shown in Figures 1-2.

Table 1. Results of quantitative phase analysis (wt. %)

Mineral	**Ideal formula**	**Combined Lynx D**	**Combined Wolverine D**
Quartz	SiO_2	17.4	30.7
Muscovite	$KAl_2AlSi_3O_{10}(OH)_2$	8.8	14.8
Biotite	$K(Mg,Fe^{2+})_3AlSi_3O_{10}(OH)_2$	1.2	1.3
Clinochlore	$(Mg,Fe^{2+})_5Al(Si_3Al)O_{10}(OH)_8$		4.9
Calcite	$CaCO_3$		0.5
Gypsum	$CaSO_4 \cdot 2H_2O$	4.9	3.2
Dolomite	$CaMg(CO_3)_2$	3.2	6.8
Pyrite	FeS_2	64.7	36.1
Pyrrhotite	$Fe_{1-x}S$		1.6
Total		100.0	100.0

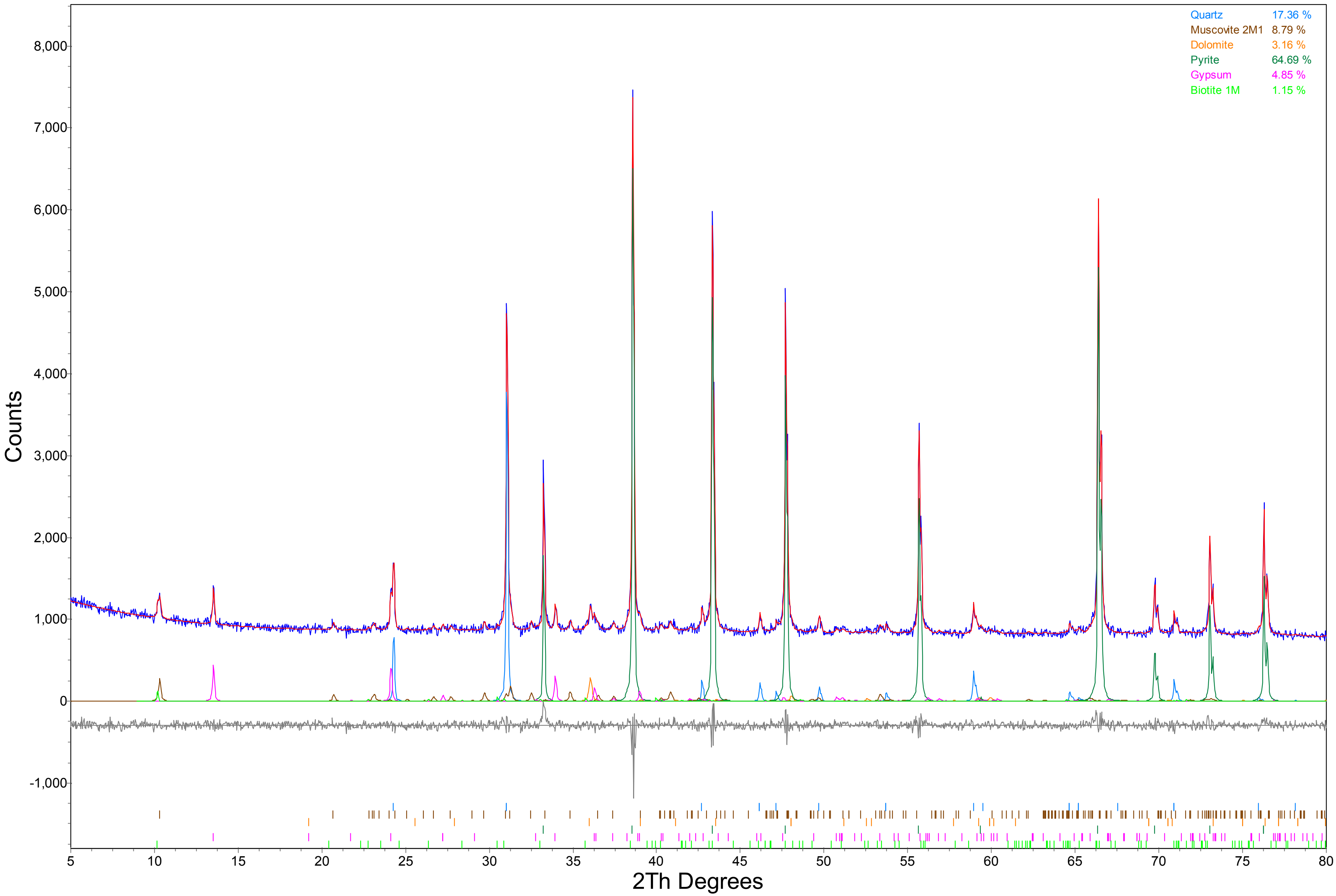

Figure 1. Rietveld refinement plot of sample **SGS Combined Lynx D** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below – difference between observed and calculated intensities; vertical bars, positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

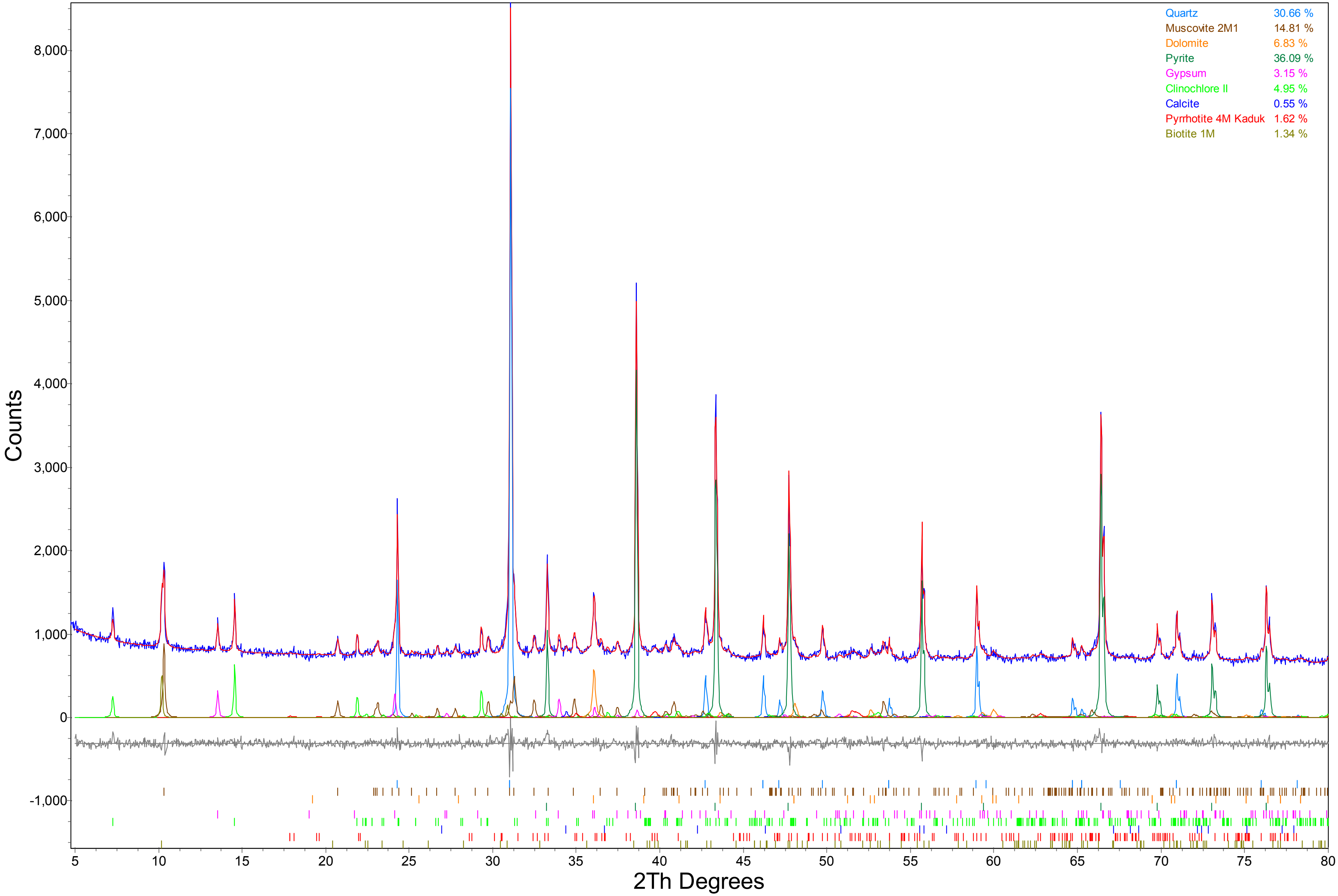

Figure 2. Rietveld refinement plot of sample **SGS Combined Wolverine D** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below – difference between observed and calculated intensities; vertical bars, positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

An Investigation into

MINERALOGICAL CHARACTERIZATION OF TWO HUMIDITY CELL FINAL WASHED SOLIDS

prepared for

YUKON ZINC CORPORATION

LR 10961-002 – MI5015-FEB07
April 2, 2007

NOTE:
This report refers to the samples as received.

The practice of this Company in issuing reports of this nature is to require the recipient not to publish the report or any part thereof without the written consent of SGS Minerals Services.

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Introduction

Two humidity cell final washed solids (labelled as Comb. Wolverine D Comp Tail and Comb. Lynx D Comp Tail) were submitted to SGS Mineral Technologies for mineralogical examination. The purpose of the investigation was to determine the bulk mineral assemblage and textural characteristics of the mineral species within the tailings. The proportions of sulphides and carbonates were particularly noteworthy, due to the environmental implications of the relative stability of the tailings. A bulk modal analysis (by QEMSCAN technology) and optical examination were performed on each sample. X-ray diffraction (XRD) analysis was also performed to determine the bulk crystalline mineral assemblage as well as any water soluble phases. Carbonate grains were examined using scanning electron microscopy (SEM) equipped with an energy dispersive X-ray spectrometer (EDS).

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Jou Zhou, M.Sc., P.Geo.
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Experimental work by:	*Jennifer Glover, Section Preparation* *Huyun Zhou, Ph.D., XRD Mineralogist* *Stephanie Downing, M.Sc., Optical Microscopy*
Report preparation by:	*Stephanie Downing, M.Sc., Project Mineralogist*

Summary

1. Procedures

Each as-received sample was initially air-dried and micro-riffled to ensure sub-sample representivity for analyses. A representative sub-sample of material was pulverized and submitted for X-ray diffraction (XRD) analysis, in order to determine the bulk crystalline mineral assemblage (Appendix 1). A sub-sample of this material was also pulverized and submitted for whole rock analysis (WRA) by XRF using borate fusion (Appendix 2).

One polished section and one polished thin section per sample were prepared from representative micro-riffled sub-samples. Each polished section was examined optically with a petrographic microscope under incident (reflected) and transmitted light at 50x to 500x magnifications. The mineral assemblage and modal abundance of each sample were determined by compiling both optical data from manual point counting with a bulk mineral analysis (BMA) generated by QEMSCAN technology. The modal analyses and mineral grain size data are presented in Tables 1 and 3. Weight percentages of minerals were calculated from volume percentage using standard grain densities and documented mineral chemistries. A summary of the major calculated elemental oxides for each sample by mineralogical analysis is compared to the whole rock analysis (WRA) of each sample in assay reconciliation tables (Tables 2 and 4).

2. Mineralogical Results

2.1. Modal Analyses

2.1.1. Comb. Wolverine D Comp. Tail Final Washed Solids

Combined microscopic and SEM examination of the Comb. Wolverine D Comp Tail Final Washed Solids indicates that the sample is composed primarily of sulphides (42 wt. % of sample) and silicates (48.4 wt. % of sample) with minor amounts of carbonates (6.4 wt. % of sample), sulphates (2.2 wt. % of sample), and Fe-Ti oxides (1.1 wt. % of sample). A summary of the bulk mineralogy is presented below in Table 1.

Table 1. Summary Modal Analysis for Comb. Wolverine D Comp. Tail

Comb Wolverine D Comp Tail Final Wash Sol.	Formula or chemical composition	Wt.%	Typical Grain Size (µm)
Mineral			
Quartz	SiO_2	25.4	3 to 50
K-Feldspar	$KAlSi_3O_8$	1.2	1 to 15
Muscovite/Sericite	$KAl_2(Si_3Al)O_{10}(OH,F)_2$	7.0	2 to 35
Biotite	$K(Mg,Fe)_3AlSi_3O_{10}(OH,F)_2$	3.3	2 to 25
Chlorite	$(Mg,Al,Fe)_{12}[(Si,Al)_8O_{20}](OH)_{16}$	5.9	1 to 15
Pyriboles	$Ca_2(Mg,Fe)_5(Si_8O_{22})(OH)_2$	0.9	1 to 14
Plagioclase	$(Ca,Na)(Si,Al)_4O_8$	0.1	2 to 30
Talc	$Mg_3Si_4O_{10}(OH)_2$	0.2	1 to 15
Garnet	$Ca_3Al_2(SiO_4)_3$	0.0	1 to 15
Clay Minerals	$Al_2Si_2O_5(OH)_4$	4.4	1 to 15
Calcite	$CaCO_3$	0.5	1 to 20
Ankerite	$Ca(Fe,Mg)(CO_3)_2$	1.3	1 to 16
Dolomite	$CaMg(CO_3)_2$	4.5	2 to 30
Siderite	$FeCO_3$	0.1	1 to 20
Gypsum	$CaSO_4 \cdot 2(H_2O)$	0.3	1 to 15
Jarosite	$KFe_3(SO_4)_2(OH)_6$	1.9	1 to 15
Rutile	TiO_2	0.2	2 to 32
Fe-oxides	Fe_2O_3	0.7	2 to 35
Ilmenite	$FeTiO_3$	0.2	1 to 15
Sphalerite	ZnS	1.0	1 to 18
Pyrite	FeS_2	40.0	2 to 30
Pyrrhotite	$Fe_{1-x}S$	0.3	1 to 20
Chalcopyrite	$CuFeS_2$	0.2	1 to 20
Arsenopyrite	FeAsS	0.2	1 to 20
Other trace (< 0.05)	variable	0.3	1 to 15
Total		**100.0**	

Table 2 presents assay reconciliation of the Comb. Wolverine D Comp. Tail sample. In general, reconciliation of calculated mineralogical assay versus direct chemical assay is good, demonstrating confidence in mineralogical results. Due to the variable density of the minerals (pyrite denser than silicates), a slight over-estimation of sulphur and iron by calculated mineralogical assay may occur. In order to minimize this effect, the polished sections were prepared with graphite impregnation which separates particles and reduces density segregation. Documented mineral chemistries are used for mineralogical assay reconciliation tables for all minerals; therefore actual mineral chemistries will vary slightly from calculated 'book' values.

Table 2. Assay Reconciliation for Comb. Wolverine D Comp. Tail

Comb. Wolverine D Comp Tail Mineral	Wt.%	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	MnO	Cr2O3	C	S_T %	LOI
Quartz	25.4	25.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-Feldspar	1.20	0.78	0.22	0.00	0.00	0.00	0.02	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite/Sericite	7.00	3.16	2.69	0.00	0.00	0.00	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.28
Biotite	3.29	1.37	0.39	0.49	0.07	0.00	0.00	0.36	0.00	0.03	0.00	0.00	0.00	0.16
Chlorite	5.95	1.61	1.13	1.49	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48
Pyriboles	0.88	0.35	0.03	0.25	0.14	0.13	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Plagioclase	0.06	0.03	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.19	0.12	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Garnet	0.03	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clay Minerals	4.40	2.05	1.54	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61
Calcite	0.50	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.16
Ankerite	1.30	0.00	0.00	0.20	0.13	0.48	0.00	0.00	0.00	0.04	0.00	0.15	0.00	0.40
Dolomite	4.50	0.00	0.00	0.18	1.44	0.99	0.00	0.00	0.00	0.00	0.00	0.60	0.00	1.56
Siderite	0.09	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02
Gypsum	0.32	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.07
Jarosite	1.89	0.00	0.00	0.90	0.00	1.04	0.09	0.09	0.00	0.00	0.00	0.00	0.24	0.20
Rutile	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
Fe-oxides	0.71	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.17	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.98	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.63
Pyrite	40.0	0.00	0.00	26.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.4	0.00
Pyrrhotite	0.34	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00
Chalcopyrite	0.18	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06
Arsenopyrite	0.19	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.09
Other trace (< 0.05)	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.10
Total (calc'd)	**100.0**	**34.9**	**6.01**	**33.0**	**2.79**	**3.04**	**0.14**	**1.48**	**0.27**	**0.07**	**0.00**	**0.82**	**22.3**	**4.87**
WRA (by XRF)		**35.3**	**6.13**	**27.1**	**3.09**	**3.13**	**0.29**	**1.57**	**0.13**	**0.09**	**0.04**	**1.91**	**18.6**	**8.99**

2.1.2. Comb. Lynx D Comp. Tail Final Washed Solids

Combined microscopic and SEM examination of the Comb. Lynx D Comp Tail Final Washed Solids indicates that the sample is composed primarily of sulphides (69.7 wt. % of sample) and silicates (23.8 wt. % of sample) with minor amounts of carbonates (2.7 wt. % of sample), sulphates (3.1 wt. % of sample), and Fe-Ti oxides (0.7 wt. % of sample). A summary of the bulk mineralogy is presented below in Table 3.

Table 3. Summary Modal Analyses for Comb. Lynx D Comp. Tail

Comb Lynx D Comp Tail Final Wash Sol.	Formula or chemical composition	Wt.%	Typical Grain Size (µm)
Quartz	SiO_2	15.1	2 to 40
K-Feldspar	$KAlSi_3O_8$	1.4	1 to 30
Muscovite/Sericite	$KAl_2(Si_3Al)O_{10}(OH,F)_2$	2.1	1 to 25
Biotite	$K(Mg,Fe)_3AlSi_3O_{10}(OH,F)_2$	0.8	1 to 20
Chlorite	$(Mg,Al,Fe)_{12}[(Si,Al)_8O_{20}](OH)_{16}$	0.3	1 to 15
Pyriboles	$Ca_2(Mg,Fe)_5(Si_8O_{22})(OH)_2$	0.2	1 to 15
Plagioclase	$(Ca,Na)(Si,Al)_4O_8$	0.0	1 to 15
Talc	$Mg_3Si_4O_{10}(OH)_2$	0.0	1 to 15
Garnet	$Ca_3Al_2(SiO_4)_3$	0.0	---
Clay Minerals	$Al_2Si_2O_5(OH)_4$	3.9	1 to 15
Calcite	$CaCO_3$	0.4	1 to 25
Ankerite	$Ca(Fe,Mg)(CO_3)_2$	0.6	1 to 20
Dolomite	$CaMg(CO_3)_2$	1.6	1 to 20
Siderite	$FeCO_3$	0.0	1 to 15
Gypsum	$CaSO_4 \cdot 2(H_2O)$	0.5	1 to 15
Jarosite	$KFe_3(SO_4)_2(OH)_6$	2.6	1 to 15
Rutile	TiO_2	0.1	2 to 40
Fe-oxides	Fe_2O_3	0.5	2 to 35
Ilmenite	$FeTiO_3$	0.1	1 to 22
Sphalerite	ZnS	1.0	1 to 20
Pyrite	FeS_2	67.6	2 to 35
Pyrrhotite	$Fe_{1-x}S$	0.1	1 to 15
Chalcopyrite	$CuFeS_2$	0.1	1 to 20
Arsenopyrite	FeAsS	0.7	1 to 20
Other trace (< 0.05)	variable	0.2	1 to 15
Total		**100.0**	

Table 4 presents assay reconciliation of the Comb. Lynx D Comp. Tail sample In general, reconciliation of calculated mineralogical assay versus direct chemical assay is good, demonstrating confidence in mineralogical results. As with the previous sample, due to the variable density of the minerals (pyrite denser than silicates), a slight over-estimation of sulphur and iron by calculated mineralogical assay may occur. In order to minimize this effect, the polished sections were prepared with graphite impregnation which separates particles and reduces density segregation. Documented mineral chemistries are used for mineralogical assay reconciliation tables for all minerals; therefore actual mineral chemistries will vary slightly from calculated 'book' values.

Table 4. Assay Reconciliation for Comb. Lynx D Comp. Tail

Comb. Lynx D Comp Tail Mineral	Wt.%	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	MnO	Cr2O3	C	S_T %	LOI
Quartz	15.1	15.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-Feldspar	1.40	0.91	0.26	0.00	0.00	0.00	0.03	0.24	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite/Sericite	2.10	0.95	0.81	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.09
Biotite	0.80	0.33	0.09	0.12	0.02	0.00	0.00	0.09	0.00	0.01	0.00	0.00	0.00	0.04
Chlorite	0.30	0.08	0.06	0.08	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Pyriboles	0.20	0.08	0.01	0.06	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	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
Talc	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Garnet	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
Clay Minerals	3.90	1.82	1.37	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54
Calcite	0.40	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.13
Ankerite	0.60	0.00	0.00	0.09	0.06	0.22	0.00	0.00	0.00	0.02	0.00	0.07	0.00	0.19
Dolomite	1.60	0.00	0.00	0.06	0.48	0.40	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.56
Siderite	0.05	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Gypsum	0.50	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.10
Jarosite	2.60	0.00	0.00	1.24	0.00	1.43	0.13	0.24	0.00	0.00	0.00	0.00	0.33	0.28
Rutile	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Fe-oxides	0.48	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.14	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Sphalerite	1.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.64
Pyrite	67.6	0.00	0.00	45.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.1	0.00
Pyrrhotite	0.11	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
Chalcopyrite	0.15	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05
Arsenopyrite	0.69	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.32
Other trace (< 0.05)	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.07
Total (calc'd)	**100.0**	**19.3**	**2.58**	**49.4**	**0.64**	**2.47**	**0.16**	**0.82**	**0.12**	**0.03**	**0.00**	**0.34**	**37.2**	**3.04**
WRA (by XRF)		**20.6**	**3.26**	**42.6**	**1.02**	**2.66**	**0.53**	**0.91**	**0.08**	**0.08**	**0.05**	**0.87**	**27.1**	**8.99**

2.2. Summary and Mineralogical Overview

Pyrite is the main sulphide mineral among both samples and typically occurs as liberated grains ranging from 1 to 35 µm. Sphalerite (~1 wt. % of each sample) occurs in minor amounts typically as inclusions (1 to 20 µm) in pyrite and other non-opaque gangue minerals. Trace amounts of chalcopyrite (typically as inclusions 1 to 20 µm) and arsenopyrite (typically liberated 1 to 20 µm) account for the remaining sulphides.

Carbonates (typically 1 to 30 µm) are present mainly as ferroan dolomite and ankerite with trace to rare occurrences of calcite and siderite. The distribution of both sulphide and carbonate minerals by composition is presented below in Table 5.

Table 5. Summary of Carbonate and Sulphide Minerals by Sample

Mineral	Formula	Comb Wolverine D Comp Tail		Comb Lynx D Comp Tail	
		wt. %	% dist'n	wt. %	% dist'n
Calcite	$CaCO_3$	0.5	7.8	0.4	15.1
Ankerite	$Ca(Fe,Mg)(CO_3)_2$	1.3	20.3	0.6	22.7
Dolomite	$CaMg(CO_3)_2$	4.5	70.4	1.6	60.4
Siderite	$FeCO_3$	0.1	1.4	0.0	1.8
Total carbonate		**6.4**	**100.0**	**2.6**	**100.0**
Sphalerite	ZnS	1.0	2.4	1.0	1.5
Pyrite	FeS_2	40.0	96.4	67.6	98.2
Pyrrhotite	$Fe_{1-x}S$	0.3	0.8	0.1	0.2
Chalcopyrite	$CuFeS_2$	0.2	0.4	0.1	0.2
Arsenopyrite	FeAsS	0.2	0.5	0.7	1.0
Total sulphide		**41.5**	**100.0**	**68.9**	**100.0**

Minor sulphates (typically as Ca-sulphate and Fe-sulphate) are present in both samples. These occur as rims on pyrite as well as liberated particles (ranging from 1 to 15 µm).

The main silicate minerals among the samples consist of quartz, muscovite/sericite and clay minerals. Minor to trace amounts of feldspars, biotite, chlorite, amphiboles and talc are also present.

Fe-Ti oxides consist of rutile, magnetite, rare goethite, and ilmenite (ranging from 1 to 40 µm).

Appendix 1

X-ray Diffraction Results

Summary of Qualitative X-ray Diffraction Results

Sample	Crystalline Mineral Assemblage (relative proportions based on peak height)			
	Major	**Moderate**	**Minor**	**Trace**
1. Comb Wolverine D Comp Tail Final Washed Sol	quartz	pyrite, mica	dolomite, bassanite, chlorite	*potassium-feldspar, *calcite
2. Comb Lynx D Comp Tail Final Washed Sol	pyrite	quartz	mica, bassanite, potassium-feldspar	*calcite, *dolomite, *jarosite

*Tentative identification due to low concentrations, diffraction line overlap or poor crystallinity

Instrument:	Siemens D5000 diffractometer
Scan Conditions:	Co radiation, graphite monochromator, 40 kV, 30 mA, Step:0.02°, Step time:1s
Interpretations:	JCPDS / ICDD powder diffraction files. Siemens Search / Match software.
Detection Limit:	0.5-2%. Strongly dependent on crystallinity.

Interpretations do not reflect the presence of non-crystalline / amorphous compounds. Mineral proportions are based on relative peak heights and may be strongly influenced by crystallinity, structural group or preferred orientations. Interpretations and relative proportions should be accompanied by supporting petrographic and geochemical data (WRA, ICP-OES).

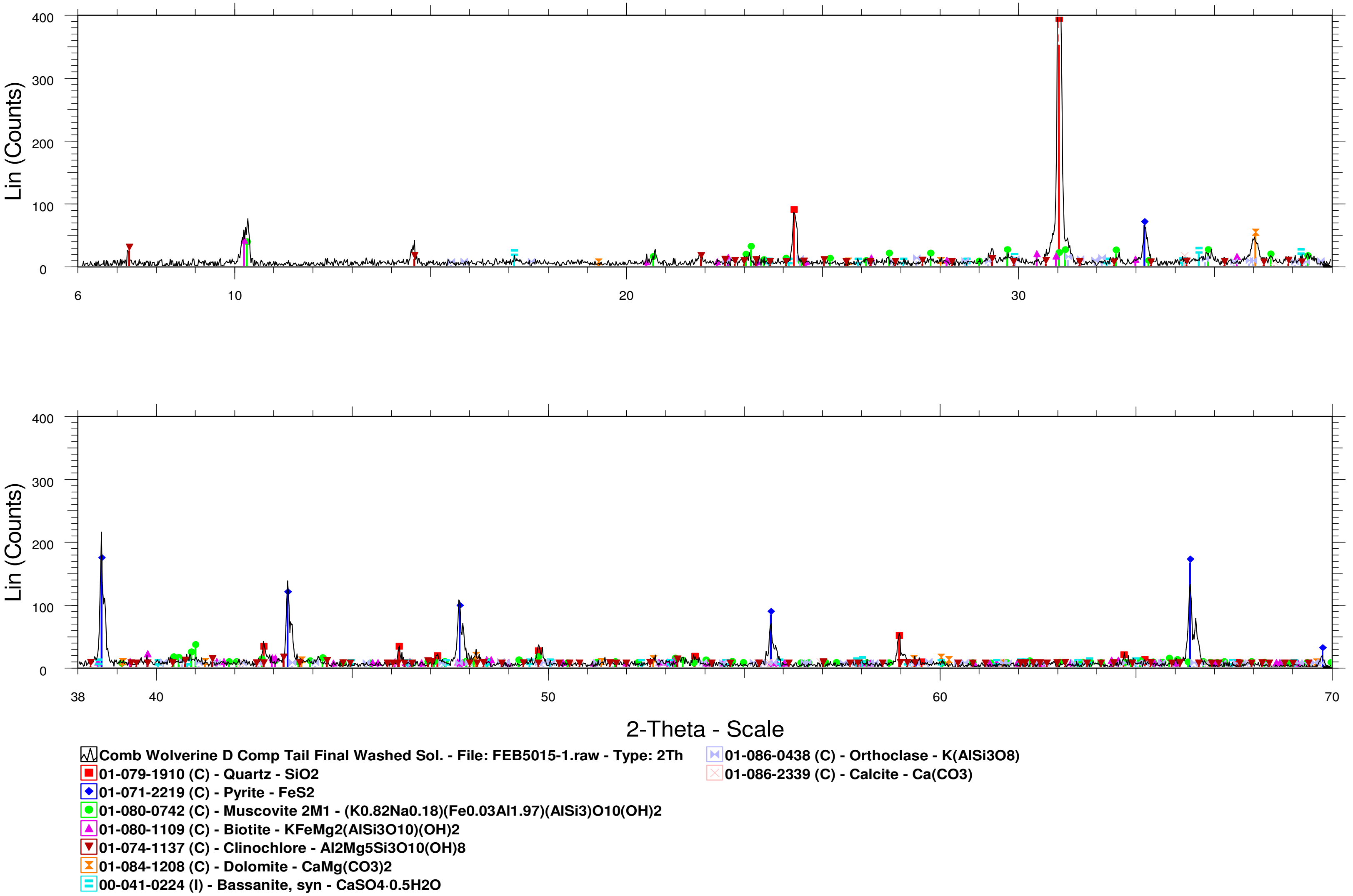
Mineral	**Composition**
Bassanite	$CaSO_4 \cdot 0.5H_2O$
Calcite	$CaCO_3$
Chlorite	$(Fe,(Mg,Mn)_5,Al)(Si_3Al)O_{10}(OH)_8$
Dolomite	$CaMg(CO_3)_2$
Jarosite	$(K)_2Fe_3(SO_4)_2(OH)_6$
Mica	$K(Mg,Fe)Al_2Si_3AlO_{10}(OH)_2$
Potassium-Feldspar	$K(AlSi_3O_8)$
Pyrite	FeS_2
Quartz	SiO_2

<u>Note</u>:
N/A

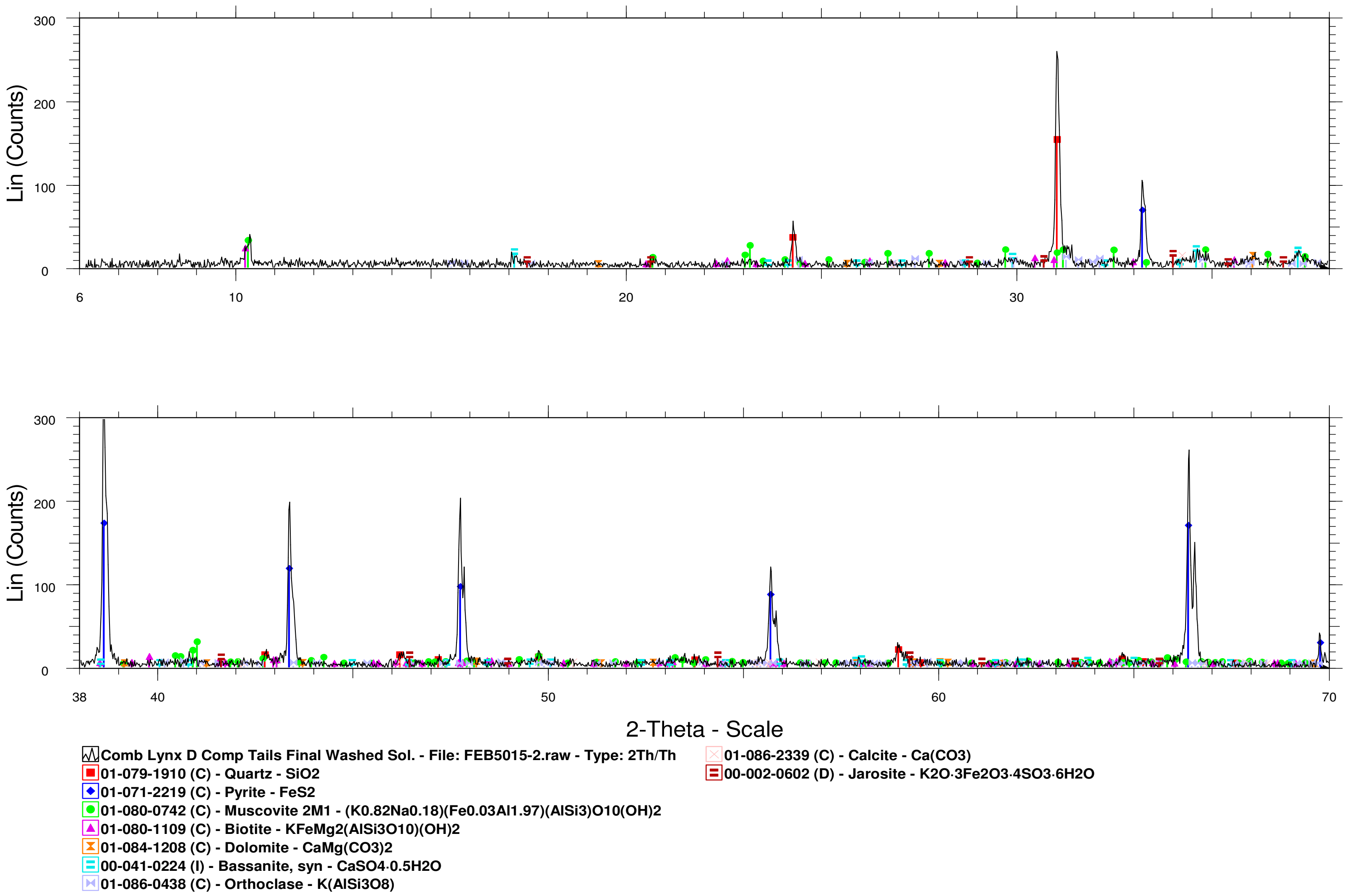
Huyun Zhou, Ph.D.
Project Mineralogist, XRD

Stephanie Downing, M. Sc.
Senior Mineralogist

Comb Wolverine D Comp Tail Final Washed Sol.

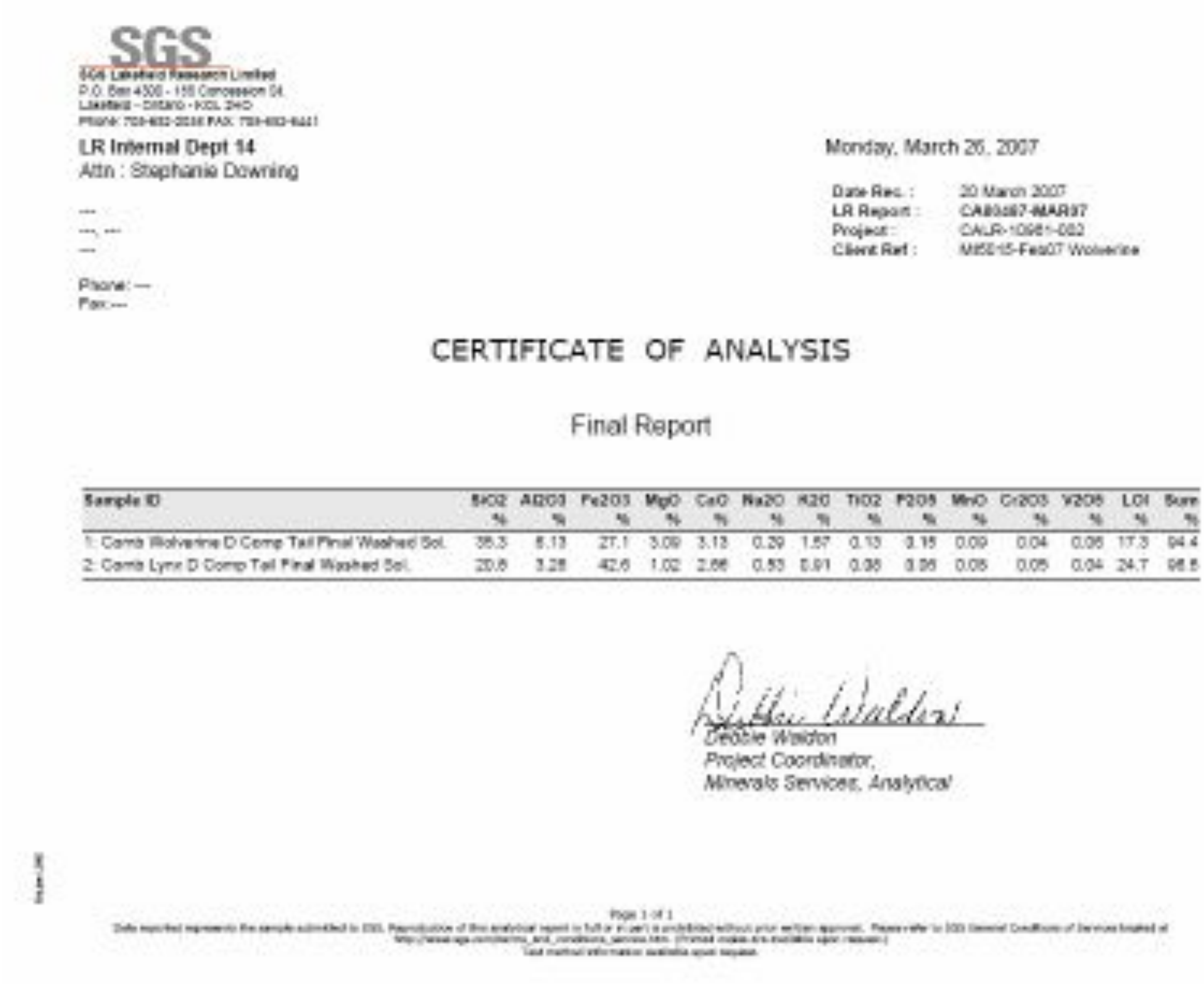


Comb Lynx D Comp Tails Final Washed Sol.



Appendix 2

Chemical Analyses



SGS Lakefield Research Limited
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: [illegible] FAX: [illegible]

LR Internal Dept 14
Attn : Stephanie Downing

---, ---

Phone: ---
Fax: ---

Monday, March 26, 2007

Date Rec. : 20 March 2007
LR Report : CA80467-MAR07
Project : CALR-10961-002
Client Ref : MI5015-Feb07 Wolverine

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	SiO2 %	Al2O3 %	Fe2O3 %	MgO %	CaO %	Na2O %	K2O %	TiO2 %	P2O5 %	MnO %	Cr2O3 %	V2O5 %	LOI %	Sum %
1: Comb Wolverine D Comp Tail Final Washed Sol.	35.3	6.13	27.1	3.09	3.13	0.29	1.57	0.13	0.15	0.09	0.04	0.06	17.3	94.4
2: Comb Lynx D Comp Tail Final Washed Sol.	20.6	3.28	42.6	1.02	2.66	0.53	0.81	0.38	0.06	0.06	0.05	0.04	24.7	96.8

Debbie Waldon
Project Coordinator,
Minerals Services, Analytical

Page 1 of 1

Quantitative X-Ray Diffraction by Rietveld Refinement

Report Prepared for: *Environmental -Analytical*

Project Number/ LIMS No. *Mineralogy/MI5037-MAR12*

Reporting Date: *March 27, 2012*

Instrument: BRUKER AXS D8 Advance Diffractometer

Test Conditions: Co radiation, 40 kV, 35 mA
Regular Scanning: Step: 0.02°, Step time: 1s, 2θ range: 3-80°

Interpretations : PDF2/PDF4 powder diffraction databases issued by the International Center for Diffraction Data (ICDD). DiffracPlus Eva and Topas software.

Detection Limit : 0.5-2%. Strongly dependent on crystallinity.

Contents:

1) Method Summary
2) Summary of Mineral Asemblages
3) Semi-Quantitative XRD Results
4) Chemical Balance(s)
5) XRD Pattern(s)

Bernie C. Yeung, B. Sc.
Mineralogist

Huyun Zhou

Huyun Zhou, Ph.D., P.Geo.
Senior Mineralogist

Method Summary

Mineral Identification and Interpretation:

Mineral identification and interpretation involve matching the diffraction pattern of an unknown material to patterns of single-phase reference materials. The reference patterns are compiled by the Joint Committee on Powder Diffraction Standards - International Center for Diffraction Data (JCPDS-ICDD) database and released on software as Powder Diffraction Files (PDF).

Interpretations do not reflect the presence of non-crystalline and/or amorphous compounds, except when internal standards added by request. Mineral proportions may be strongly influenced by crystallinity, crystal structure and preferred orientations. Minerals or compounds identification and quantitative analysis results should be accompanied by supporting chemical assay data or other tests.

Rietveld Method Quantitative Analysis:

Whole-pattern Rietveld Method Quantitative Analysis is performed by using Topas 4.1 (Bruker AXS), a graphics based profile analysis program built around a general non-linear least squares fitting system, to determine the amount of different phases in a multicomponent sample. Whole pattern analyses are predicated by the fact that the X-ray diffraction pattern is a total sum of both instrumental factors and specimen. Unlike other peak intensity-based methods, the Rietveld method uses a least square approach to refine a theoretical line profile until it matches the obtained experimental patterns.

Rietveld refinement is completed with a set of minerals specifically identified for the sample(s). Zero values indicate that the mineral was included in the refinement calculations, but the calculated concentration was less than 0.05wt%. Minerals not identified by the analyst are not included in refinement calculations for specific samples and are indicated with a dash.

Enviromental - Analytical
Custum XRD/MI4511-SEP10
10/28/2010

Summary of Rietveld Quantitative Analysis X-ray Diffraction Results

Quantitative X-ray Diffraction Results

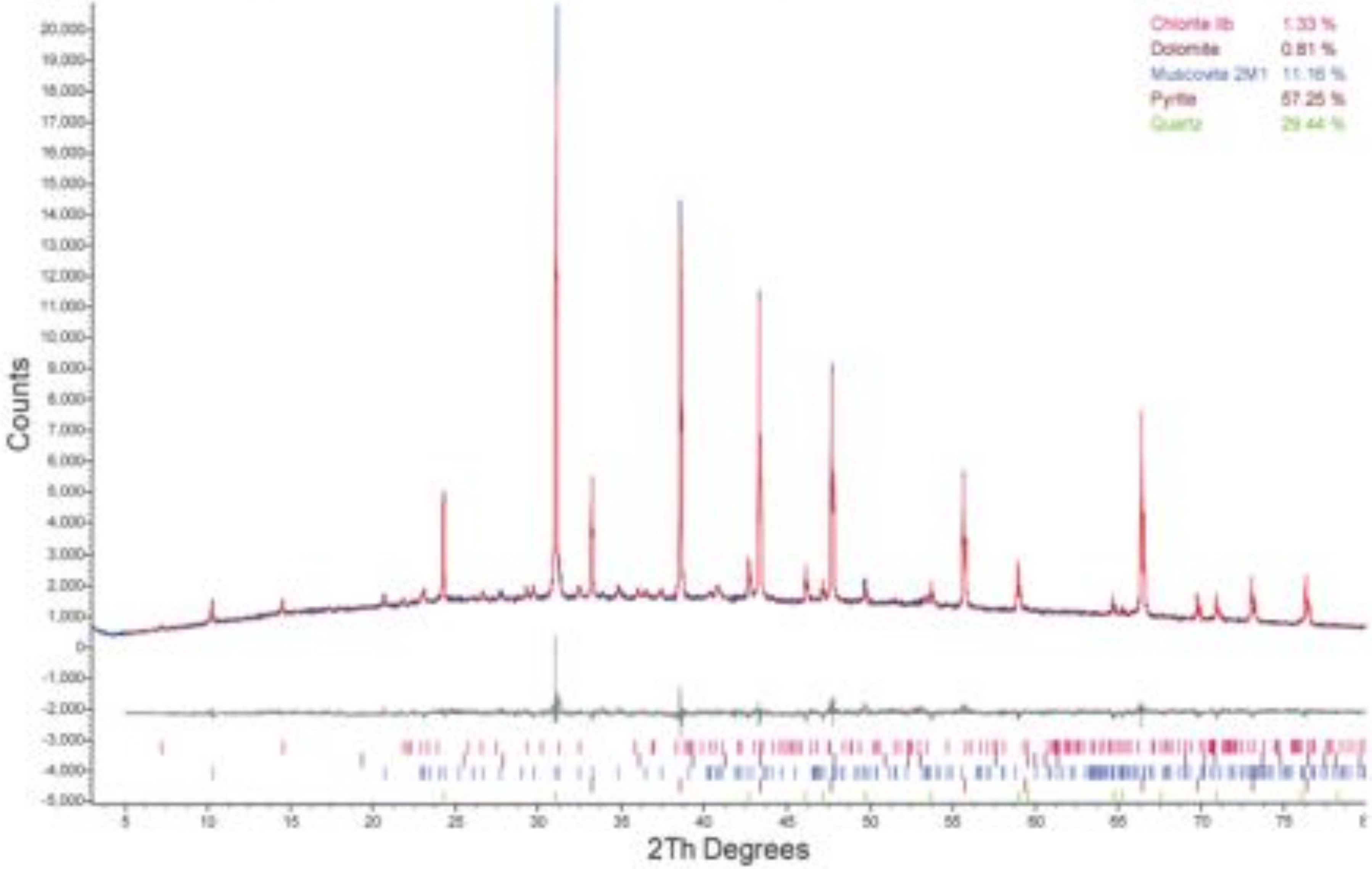
Mineral/Compound	June 29/05 Combined OD Composite Tails Pulv 7-3 Riet (wt %)	Combined RO Cl Sc Tailings Solids Pulv 7-4 Riet (wt %)
Chlorite	1.33	1.05
Dolomite	0.81	3.72
Muscovite	11.2	8.01
Pyrite	57.3	62.3
Quartz	29.4	24.9
TOTAL	100.0	100.0

Zero values indicate that the mineral was included in the refinement, but the calculated concentration is below a measurable value.

Dashes indicate that the mineral was not identified by the analyst and not included in the refinement calculation for the sample.

Mineral/Compound	Formula
Chlorite	$(Mg,Fe)_3(Si,Al)_4O_{10}$
Dolomite	$CaMg(CO_3)_2$
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$
Pyrite	FeS_2
Quartz	SiO_2

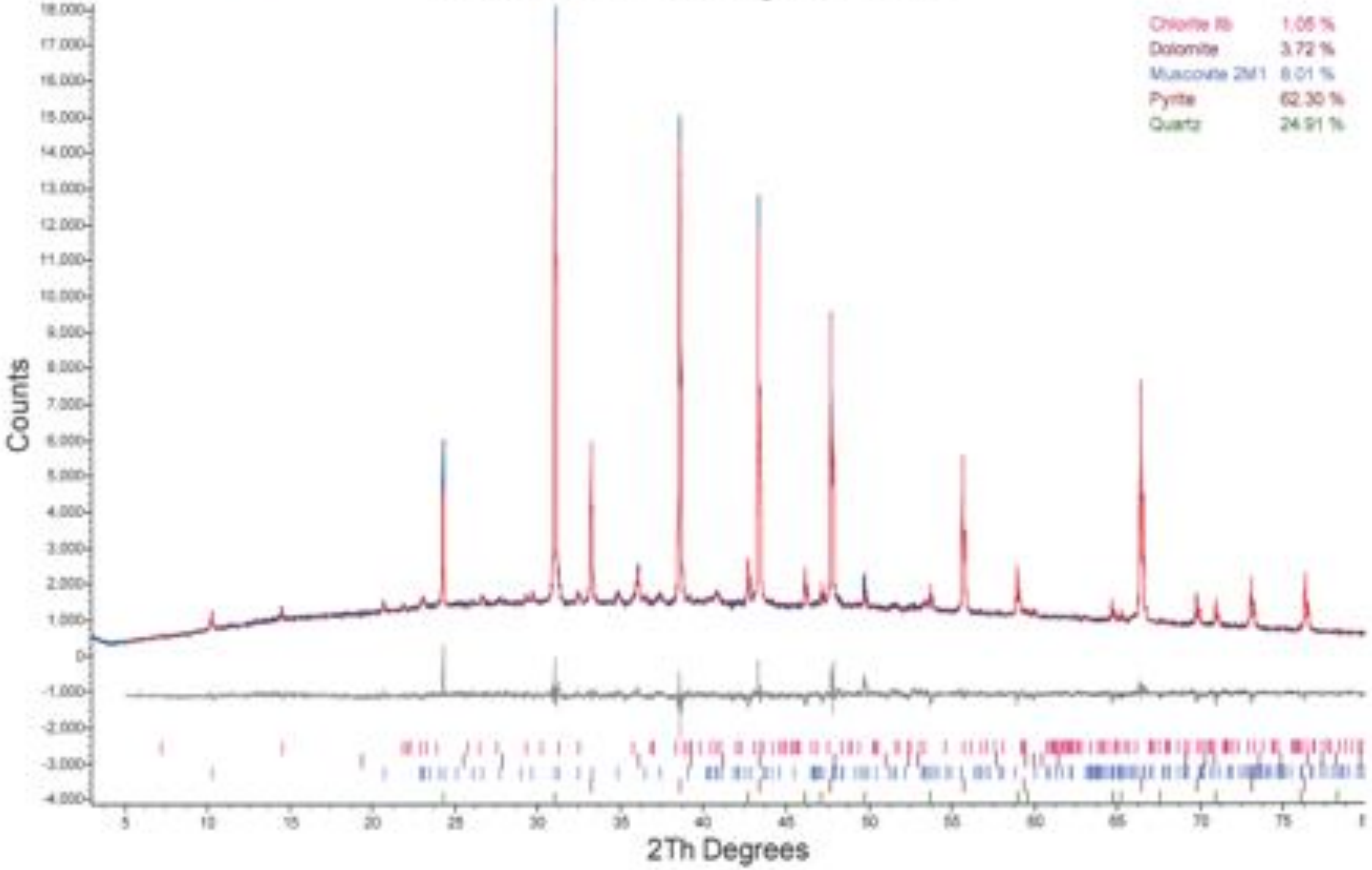
June 29/05 Combined OD Composite Tails Pulv



The Qualitative XRD method (METH # 8-8-1) used by SGS Minerals Services, P.O. Box 4300, 185 Concession Street, Lakefield, Ontario, Canada K0L 2H0.
Tel: (705) 652-2000 Fax: (705) 652-6365. Mini-method available upon request.

Environmental - Analytical
Custum XRD/MI4511-SEP10
10/28/2010

Combined RO Cl Sc Tailings Solids Pulv



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A Petrography Report on

TWO TAILINGS SAMPLES

prepared for

YUKON ZINC

Project: Custom-Min MI5037-MAR12 – Draft Report
June 13, 2012

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Introduction

This report describes a High Definition Mineralogy test program based on QEMSCAN technology (Quantitative Evaluation of Materials by Scanning Electron Microscopy) and optical microscopy to examine the mineralogical characteristics of two tailings samples. The two samples, labelled "June 29/05 Combined OD Composite Tails" and "Combined Ro Cl Sc Tailings Solids", were submitted by Brian Graham of the SGS Environmental Analytical Department on behalf of Yukon Zinc and were given the LIMS number MI5037-MAR12.

Two de-agglomerated graphite-impregnated polished epoxy grain mounts were prepared and submitted for mineralogical analyses using QEMSCAN technology. As well, two polished thin sections were prepared from grain mounts for optical microscopy.

The purpose of this test program was to provide semi-quantitative modal mineralogy, general grain size information, assess the degree of oxidation of pyrite and to comment on the textures and the associative nature of the sulphide minerals.

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Senior Mineralogist - Advanced Mineralogy Facility

Section Preparation by: Scott Young
QEMSCAN Operation by: Amie Brock
Petrography by: Kathryn Sheridan and Stephanie Downing
Report preparation: Kathryn Sheridan and Stephanie Downing
Reviewed by: Stephanie Downing

Mineralogical Characterization

1.1. Mineral Abundance

The mineral distributions of the samples are presented below in Table 1. The samples are mainly composed of pyrite (60% and 69%), quartz (20% and 12%) and micas/clays (15% and 9%, respectively). The other main mineralogical differences between the samples are sphalerite content (0.8% and 3.0%) and ankerite/dolomite content (0.8% and 3.9%, respectively).

Table 1: Mineral Distribution (by QEMSCAN)

Sample	**Mineral**	**June 29/05 Combined OD Composite Tails**	**Combined Ro Cl Sc Tailings Solids**
Avg. Particle Size (µm)		20	26
Mineral Mass(%)	Chalcopyrite	0.1	0.3
	Pyrite	60.0	69.0
	Pyrrhotite	0.1	0.1
	Arsenopyrite	0.2	0.6
	Galena	<0.1	<0.1
	Sphalerite	0.8	3.0
	Zincite	0.2	0.3
	Fe-Ti-Oxides	0.7	0.2
	Quartz	19.7	11.9
	Muscovite	7.5	4.9
	Biotite	3.5	1.8
	Chlorites	2.1	1.5
	Clays	1.8	1.0
	Other Silicates	0.8	0.7
	Ankerite/Dolomite	0.8	3.9
	Siderite	0.8	0.5
	Apatite	0.3	0.2
	Other/Accesssory	0.4	0.1
Calculated Grain Size by Frequency (µm)	Chalcopyrite	7	12
	Pyrite	15	21
	Pyrrhotite	11	14
	Arsenopyrite	10	13
	Galena	5	8
	Sphalerite	9	11
	Zincite	7	8
	Fe-Ti-Oxides	7	7
	Quartz	24	24
	Muscovite	13	15
	Biotite	8	10
	Chlorites	11	14
	Clays	8	8
	Other Silicates	10	9
	Ankerite/Dolomite	16	24
	Siderite	8	12
	Apatite	18	13
	Other/Accesssory	7	7

1.2. Observations from Optical Petrography

1.2.1. June 29/05 Combined OD Composite Tails

This sample is mainly fine-grained (<200 µm). Pyrite typically occurs as liberated grains with an average grain size of 15 µm (by frequency), although some pyrite is found up to 120 µm in size. Quartz tends to be coarse with an average size of 24 µm and maximum size of 240 µm. Micas are found up to 240 µm in length. An overview photomicrograph of the sample is shown in Figure 3.

Sphalerite occurs as fine liberated grains, in binary particles with pyrite (Figure 10), and in complex particles with pyrite and silicates (Figure 9).

Of the two samples, this sample shows the most evidence of sulphide oxidation, although the relative proportion of oxidized grains found is low (<5% of total sulphides). This sample tends to have numerous agglomerations (Figure 5) which are cemented by goethite, an oxidation product of pyrite. Some pyrite grains show oxidation rims of goethite (Figure 6 and Figure 8). Goethite is also found in cracks in the pyrite (Figure 7 and Figure 8). Arsenopyrite also shows signs of oxidation.

1.2.2. Combined Ro Cl Sc Tailings Solids

This sample is coarser-grained than the OD Composite Tails. Most of the pyrite is fine-grained and liberated with an average size of 21 µm, and maximum size of 200 µm, slightly coarser than the OD Composite Tails. Quartz occurs up to 400 µm in size and micas occur up to 680 µm in length. An overview photomicrograph of the sample is shown in Figure 4.

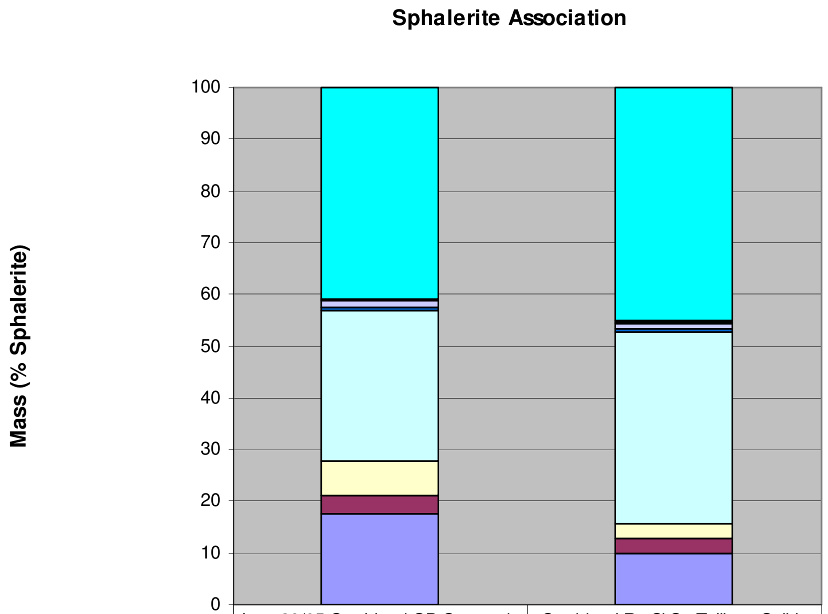
Most of the sphalerite in this sample occurs as attachments with pyrite and complex association (Figure 17), lesser occurs liberated.

There is some evidence of pyrite oxidation as shown in Figure 14 but overall less than 3% of the pyrite shows signs of oxidation. Approximately ten percent of the pyrite is in granular (Figure 15) or porous (Figure 16) form.

1.3. Mineral Associations and Grain Size (by QEMSCAN)

1.3.1. Sphalerite Association and Grain Size

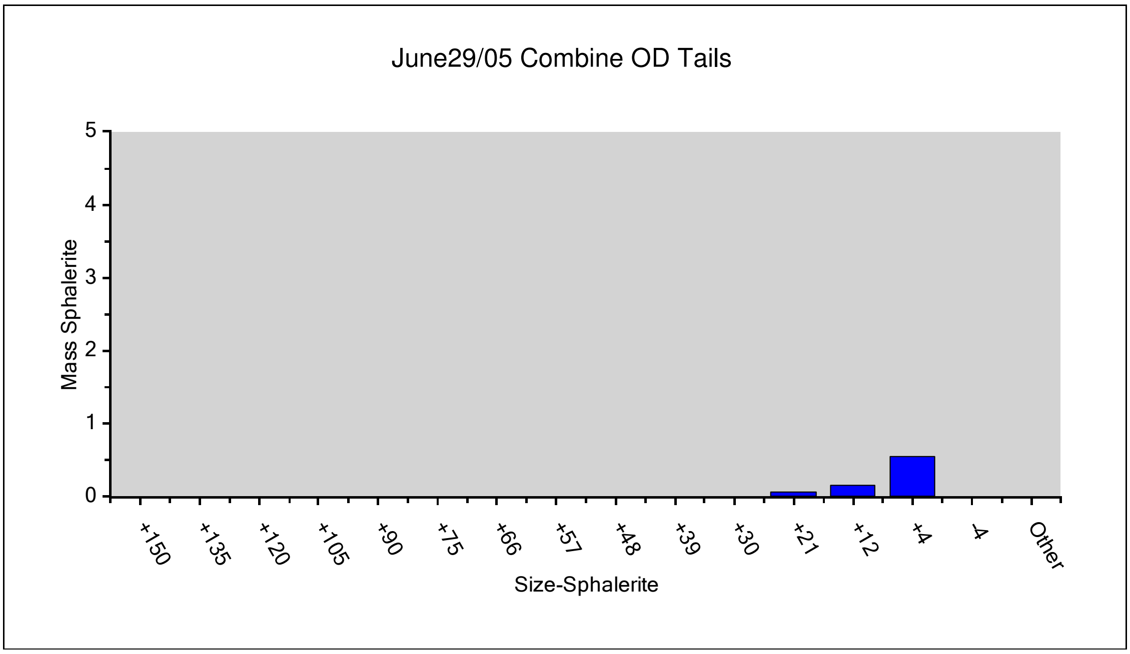
Based on particle mapping mode of QEMSCAN analysis, the main associations of sphalerite in the Tailings are as inclusions and attachments with pyrite (29% and 37%) and in complex association as ternary or greater particles (41% and 45%) for the June29/05 Combine OD Tails and the Combined Ro Cl Sc Tailings Solids, respectively. A lesser proportion occurs as liberated grains (21% and 12%), respectively.

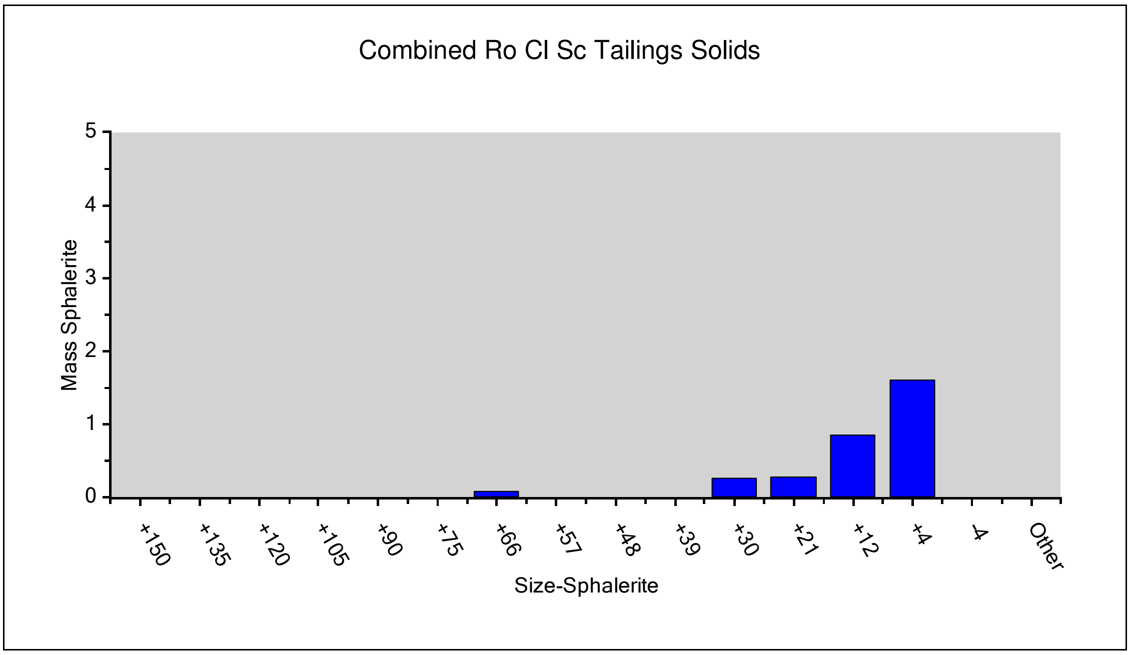


	June 29/05 Combined OD Composite Tails As Rec'd	Combined Ro Cl Sc Tailings Solids As Rec'd
■ Sph:Complex	41.0	45.0
■ Sph:Other	0.06	0.30
■ Sph:Carbs	0.06	0.31
■ Sph:Oxides	0.12	0.00
■ Sph:Phyllo/Clays	1.35	1.17
■ Sph:Hard Sil	0.47	0.57
■ Sph:Other Sulphides	0.06	0.00
■ Sph:Cp	0.00	0.04
■ Sph:Py	29.2	37.0
■ Sph:Inclusions	6.45	2.91
■ Lib Sph	3.58	2.85
■ Free Sph	17.6	9.87

Table 2. Sphalerite Association (by QEMSCAN, Normalized %)

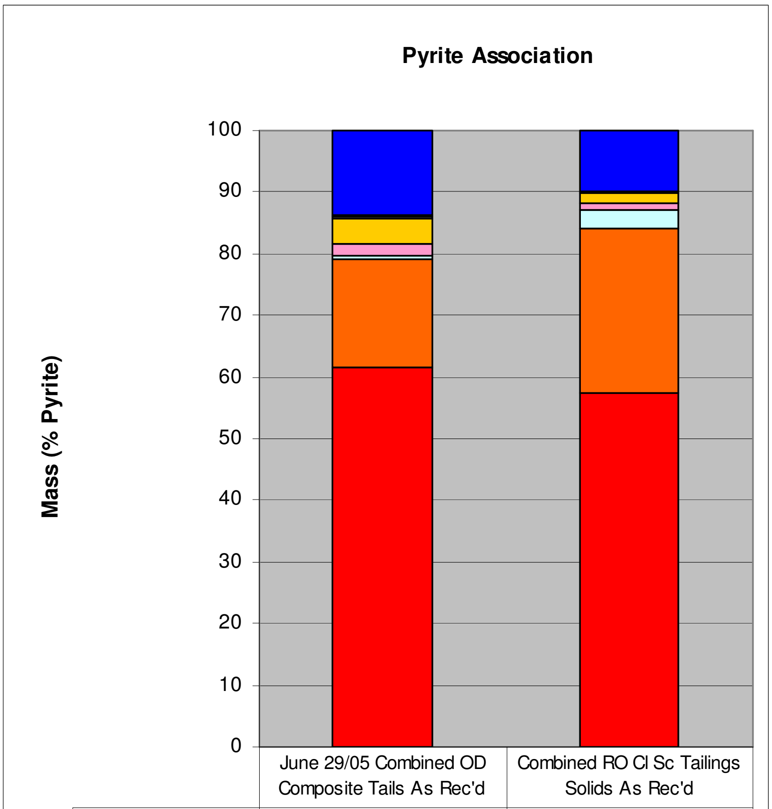
Figure 1. Sphalerite Grain Size by Mass (by QEMSCAN)





1.3.2. Pyrite Association and Grain Size

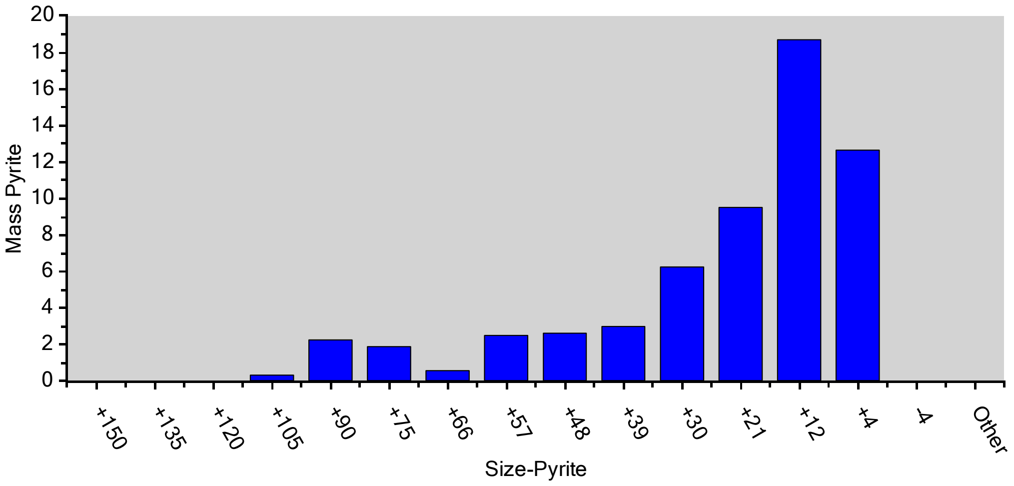
Based on particle mapping mode of QEMSCAN analysis, the main association of pyrite in the Tailings are as free and liberated grains (79% and 84%) and lesser amounts in complex association as ternary or greater particles (14% and 10%) for the June29/05 Combine OD Tails and the Combined Ro Cl Sc Tailings Solids, respectively.



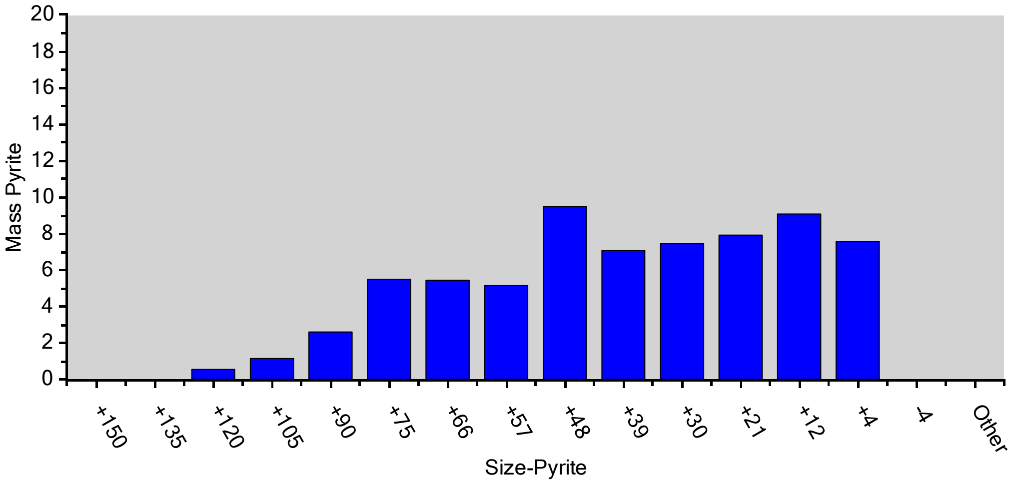
	June 29/05 Combined OD Composite Tails As Rec'd	Combined RO Cl Sc Tailings Solids As Rec'd
■ Barren	0.00	0.00
■ Py:Complex	13.8	9.86
■ Py:Other	0.19	0.02
■ Py:Carbs	0.16	0.31
■ Py:Oxides	0.06	0.02
■ Py:Phyllo/Clays	4.35	1.67
■ Py:Hard Sil	1.75	0.93
■ Py:Other Sulphides	0.02	0.05
■ Py:CuS	0.02	0.07
■ Py:Sph	0.58	3.01
■ Py:Inclusions	0.03	0.03
■ Lib Py	17.4	26.5
■ Free Py	61.7	57.5

Table 3. Pyrite Association (by QEMSCAN, Normalized %)

Figure 2. Pyrite Grain Size by Mass (by QEMSCAN)



June29/05 Combine OD Tails



Combined Ro Cl Sc Tailings Solids

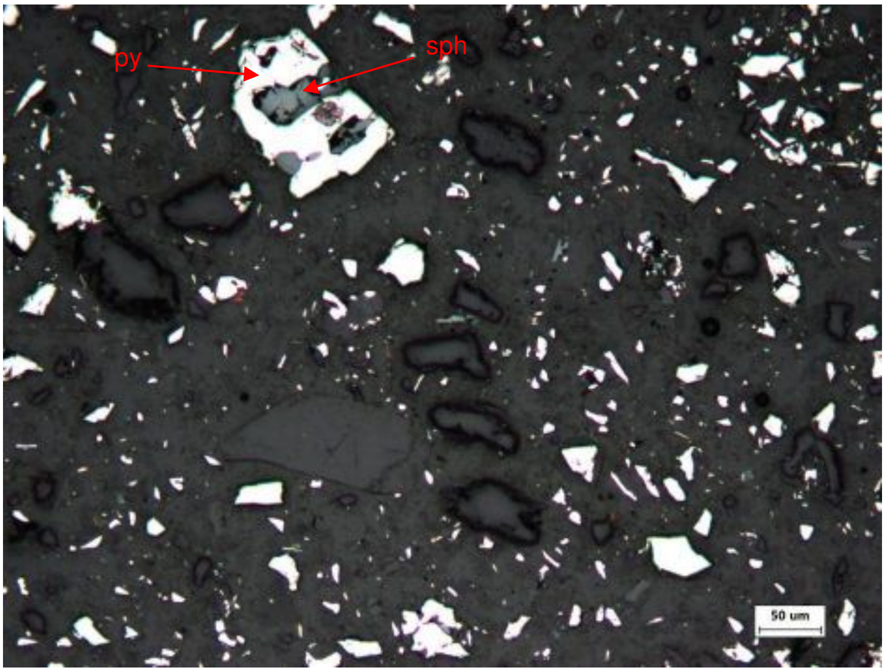


Figure 3: Overview of June 29/05 Combined OD Composite Tails

Plane-polarized reflected light (PPRL) photomicrograph showing bimodal size distribution of pyrite (py) and a sphalerite (sph)-pyrite binary grain (red arrows).

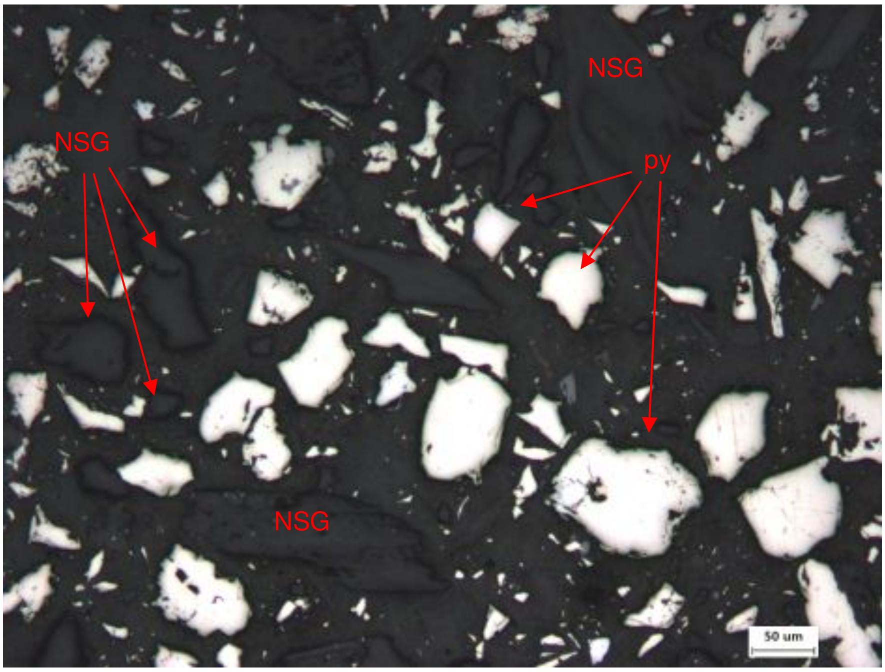


Figure 4: Overview of Combined Ro Cl Sc Tailings Solids

PPRL photomicrograph showing relatively coarse-grained pyrite (py) and non-sulphide gangue (NSG).

Appendix A – Photomicrographs June 29/05 Combined OD Composite Tails

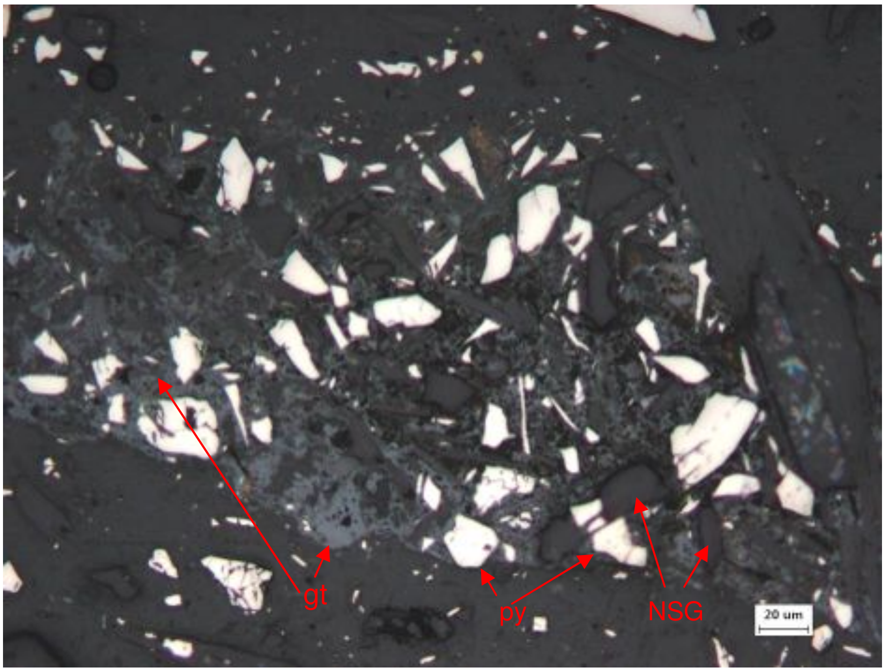


Figure 5: June 29/05 Combined OD Composite Tails

PPRL photomicrograph showing an agglomeration of pyrite (py) and non-sulphide gangue (NSG) cemented together by goethite (gt).

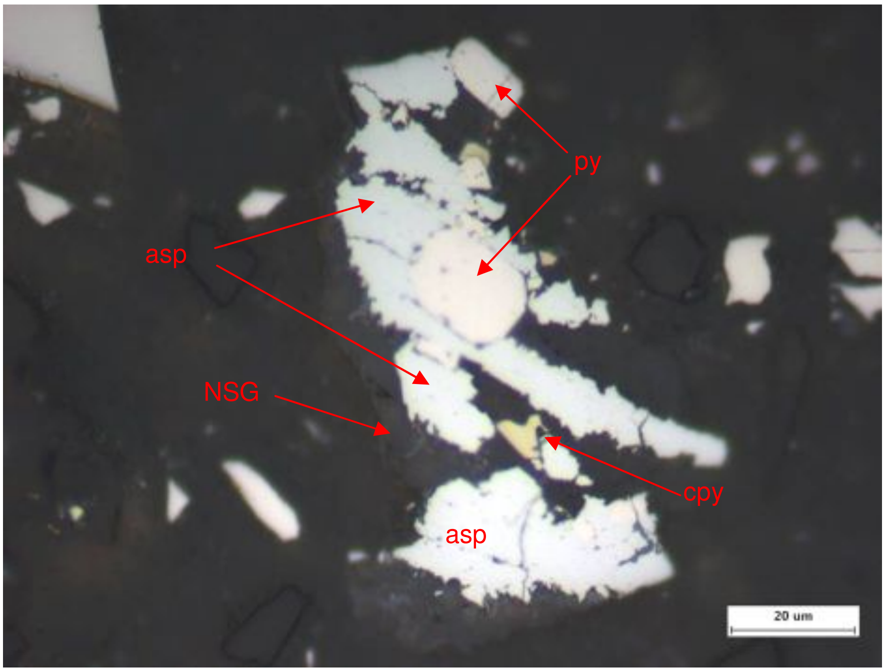


Figure 6: June 29/05 Combined OD Composite Tails

PPRL photomicrograph showing a complex particle of pyrite (py) and chalcopyrite (cpy) surrounded by a rim of non-sulphide gangue (NSG).

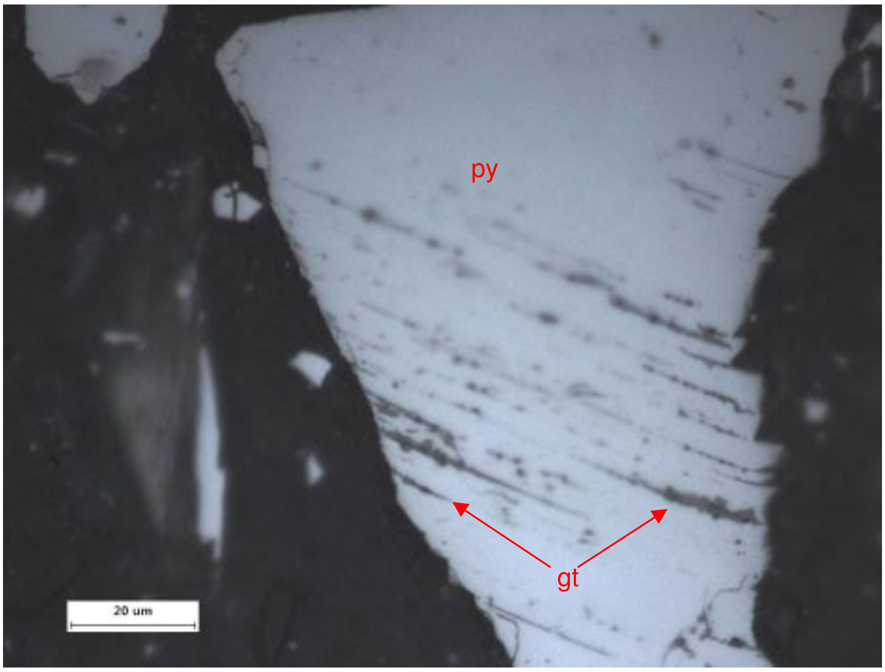


Figure 7: June 29/05 Combined OD Composite Tails

PPRL photomicrograph showing goethite (gt) forming along crystallographic planes in pyrite (py) due to oxidation.

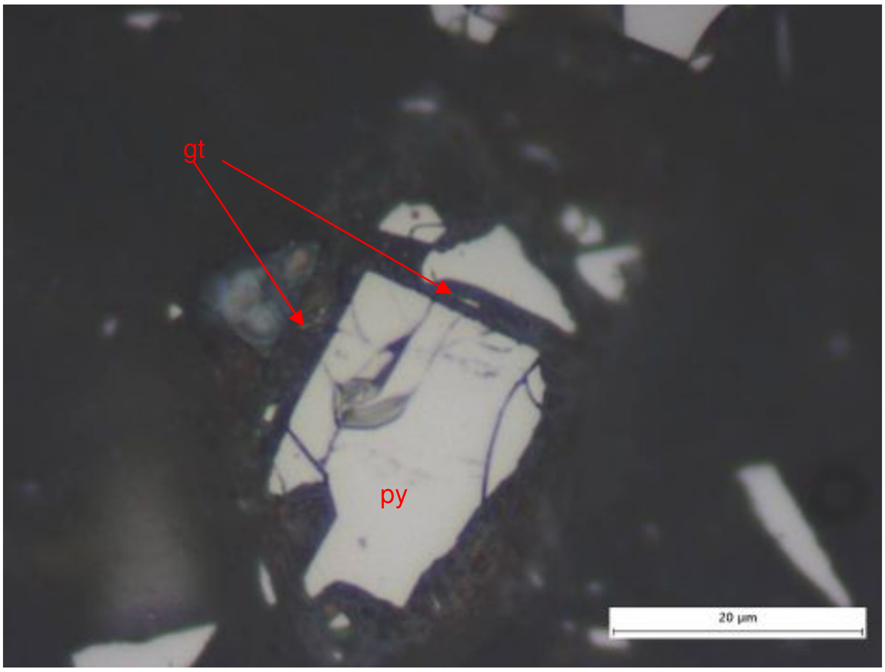


Figure 8: June 29/05 Combined OD Composite Tails

PPRL photomicrograph showing goethite (gt) forming along oxidized cracks in pyrite (py) and on the outer edges of the pyrite.

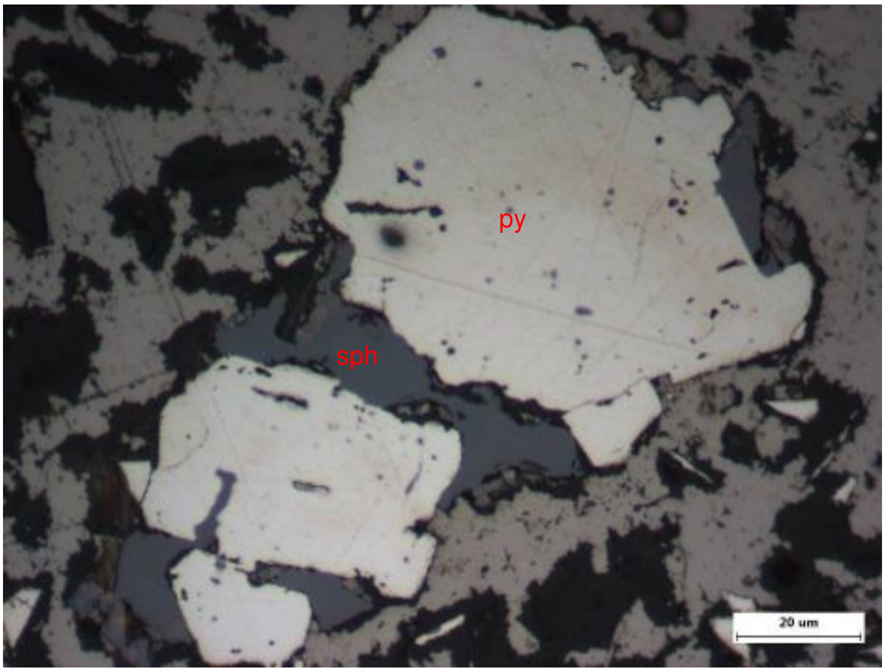


Figure 9: June 29/05 Combined OD Composite Tails

PPRL photomicrograph showing binary particle of pyrite (py) and sphalerite (sph).

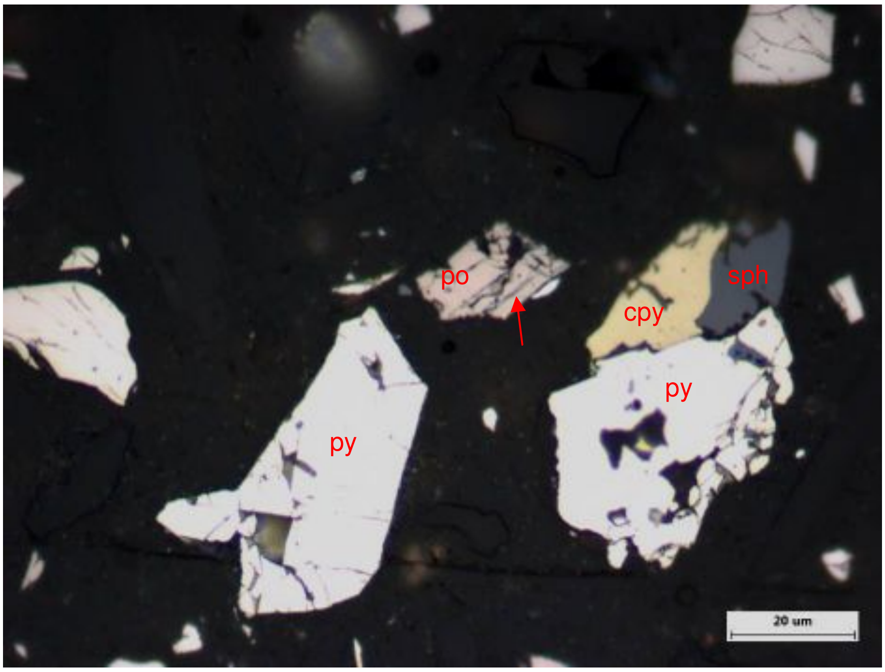


Figure 10: June 29/05 Combined OD Composite Tails

PPRL photomicrograph showing a ternary particle of pyrite (py), chalcopyrite (cp) and sphalerite (sph); and liberated grains of pyrrhotite (po) and pyrite (py). Note that pyrrhotite shows signs of oxidation along crystallographic grain boundaries to goethite (indicated by red arrow).

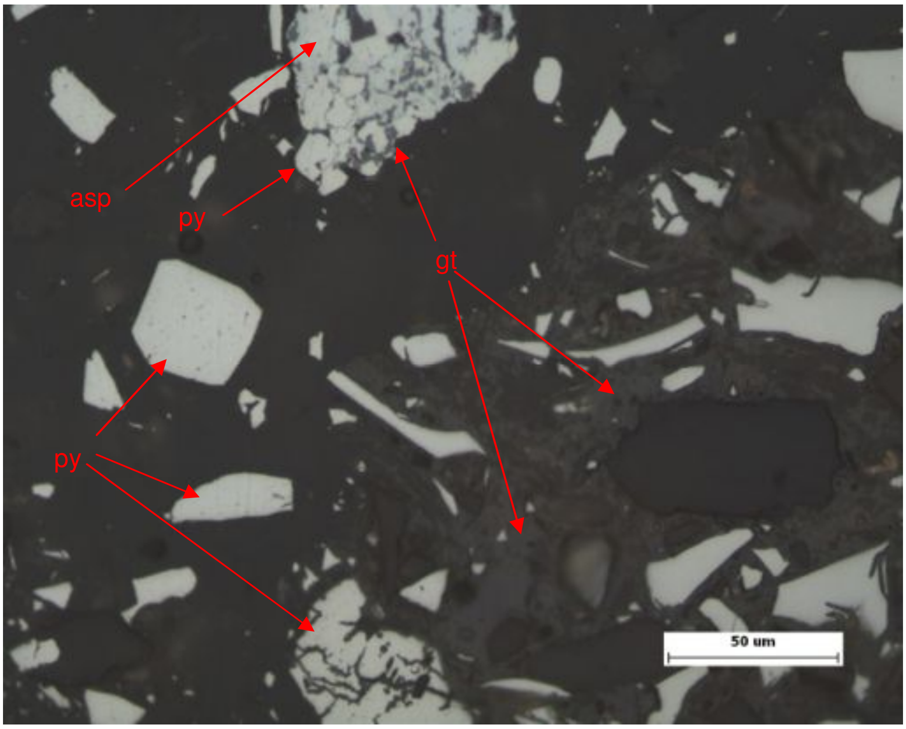


Figure 11. June 29/05 Combined OD Composite Tails

PPRL photomicrograph showing a binary pyrite-arsenopyrite (asp) particle (top, centre) showing oxidation to goethite (gt). Goethite agglomerate enclosing oxidized pyrite grains (bottom, right).

Appendix B – Photomicrographs Combined Ro Cl Sc Tailings Solids

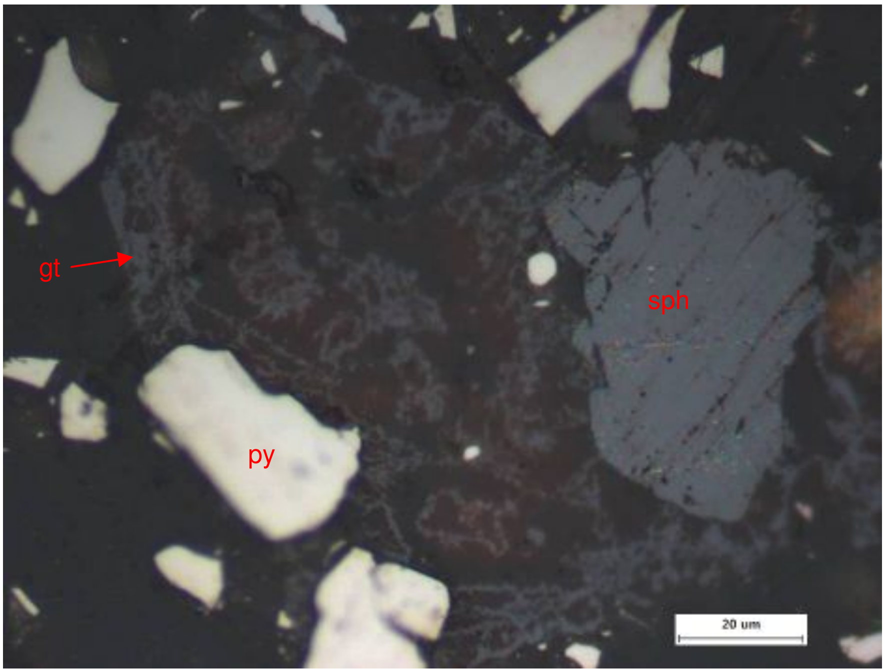


Figure 12: Combined Ro Cl Sc Tailings Solids

PPRL photomicrograph of complex particle containing sphalerite (sph), pyrite (py) and goethite (gt).

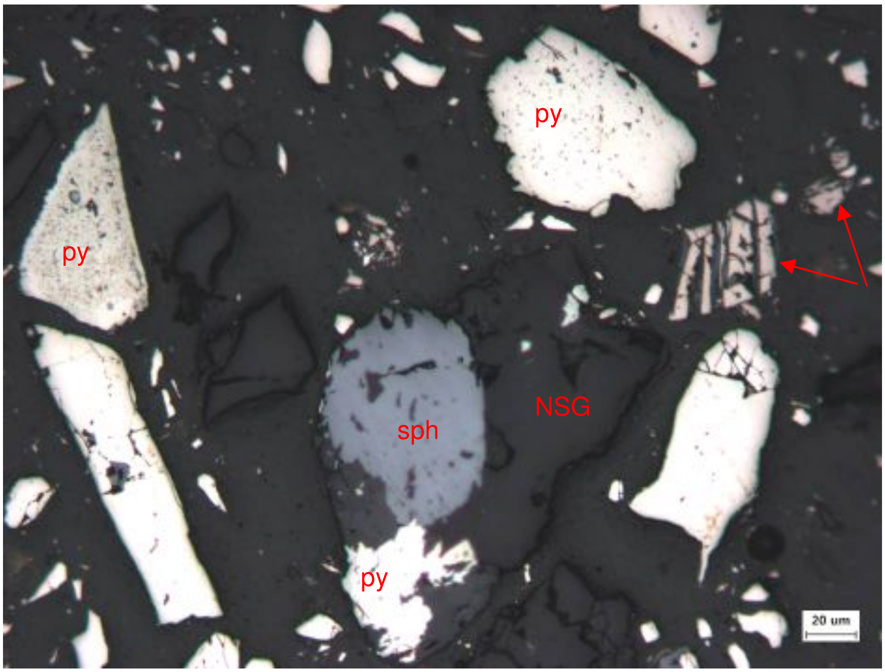


Figure 13: Combined Ro Cl Sc Tailings Solids

PPRL photomicrograph showing ternary particle of sphalerite (sph), pyrite (py) and non-sulphide gangue (NSG) surrounded by liberated pyrite and porous pyrite (py). The red arrows denote oxidized pyrrhotite which is also shown in high magnification below.

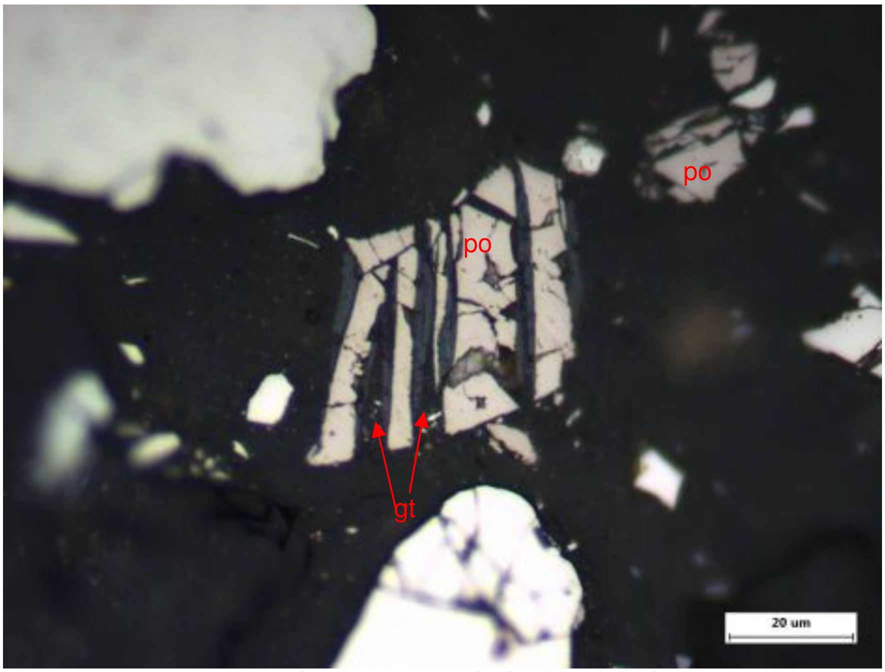


Figure 14: Combined Ro Cl Sc Tailings Solids

PPRL photomicrograph of a fractured grain of pyrrhotite (po) with goethite (gt) oxidation along the crystallographic grain boundaries.

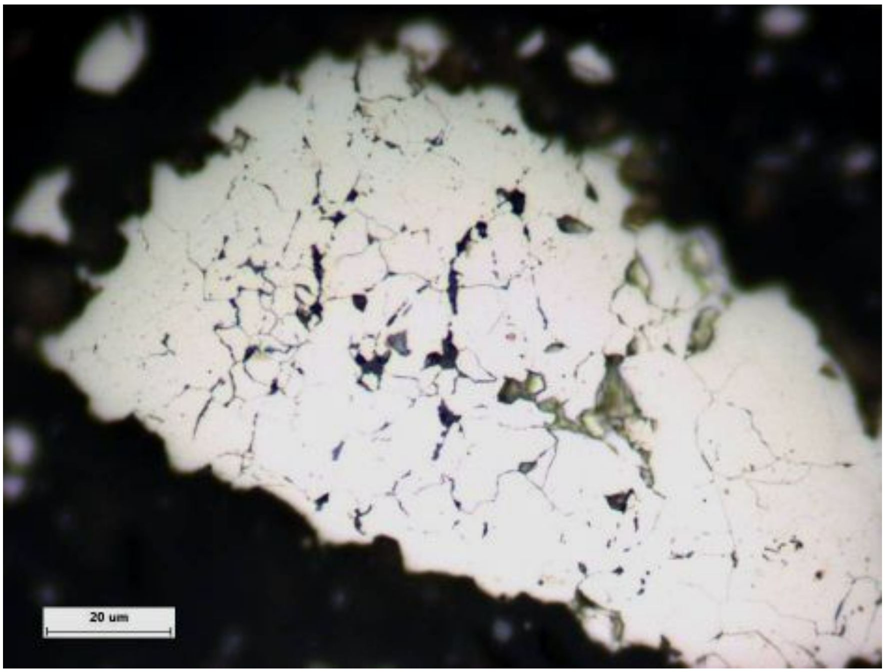


Figure 15: Combined Ro Cl Sc Tailings Solids

PPRL photomicrograph of granular pyrite which will be more susceptible to oxidation due to its high surface area.

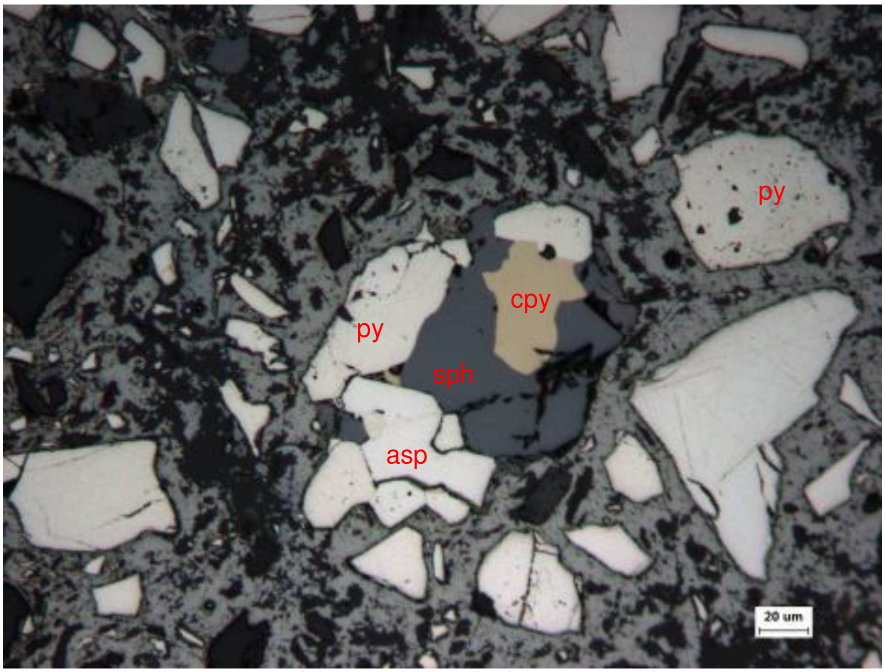


Figure 16: Combined Ro Cl Sc Tailings Solids

PPRL photomicrograph showing quaternary particle comprised of sphalerite (sph), chalcopyrite (cpy), pyrite (py) and arsenopyrite (asp). A porous grain of pyrite (py) lies to the upper right.

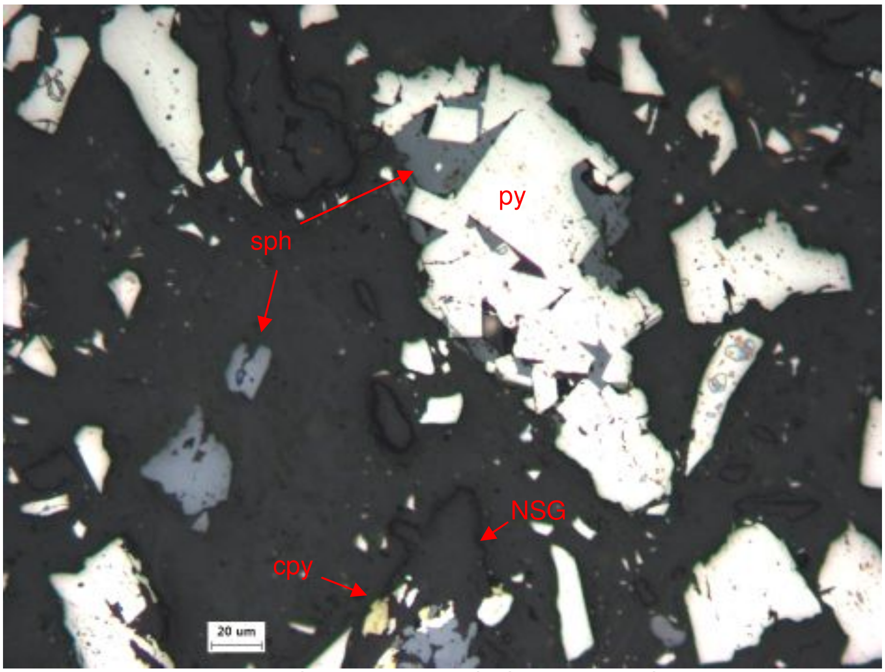


Figure 17: Combined Ro Cl Sc Tailings Solids

PPRL photomicrograph showing various associations of sphalerite.

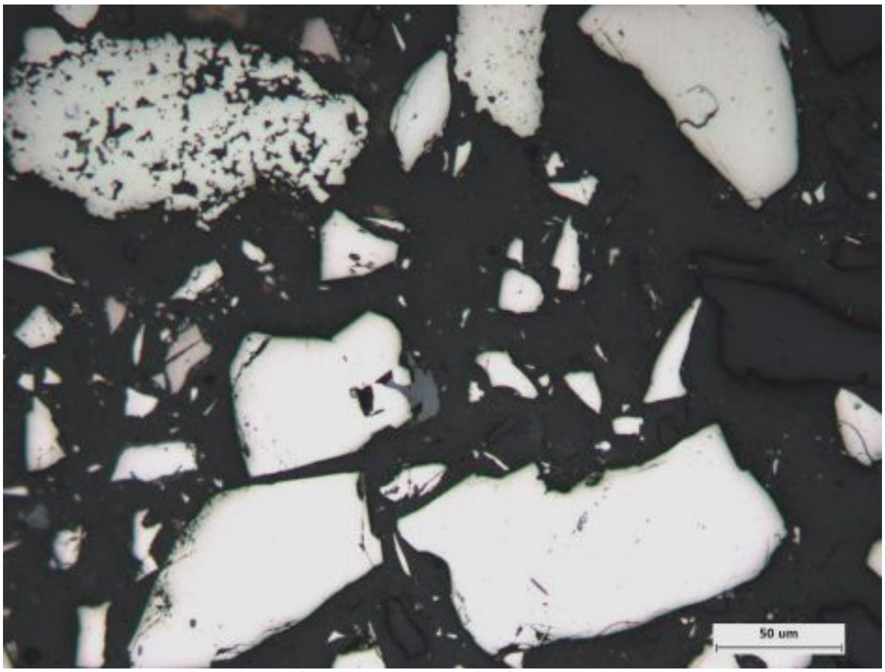


Figure 18: Combined Ro Cl Sc Tailings Solids

PPRL photomicrograph showing typical occurrences of pyrite in this sample.

Appendix B: Final Acid Base Accounting Results

Mod ABA
(Price 1997)

Parameter	**Units**	**Combined Wolverine D Composite Tails Final Washed Solids**	**Combined Lynx D Composite Tails Final Washed Solids**
Paste pH	units	7.05	6.45
Fizz Rate	---	2	2
Sample	weight(g)	1.96	2.00
HCl added	mL	62.00	44.00
HCl	Normality	0.10	0.10
NaOH	Normality	0.10	0.10
NaOH to	pH=8.3 mL	33.40	28.30
Final pH	units	1.65	1.77
NP	t $CaCO_3$/1000 t	73.00	39.2
AP	t $CaCO_3$/1000 t	534	906
Net NP	t $CaCO_3$/1000 t	-461	-867
NP/AP	ratio	0.14	0.04
S	%	18.6	27.1
Insoluble SO_4	%	< 0.01	< 0.01
$S^=$	%	17.1	29.0
C(t)	%	1.912	0.865
CO_3	%	2.426	0.895

LIMS #10480-NOV06

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Modified ABA

Project : PO#100453

February-24-12

Yukon Zinc Corporation
Attn : Mary Mioska

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Vancouver, Ontario
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Phone: 604-682-5474 ext246
Fax:pdf, excel

Date Rec. :	23 January 2012
LR Report:	**CA11273-JAN12**
Reference:	Hum Cell Shutdown - Washed Solids
Copy:	#1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	**3: Analysis Approval Date**	**4: Analysis Approval Time**	**5: June 29/05 Combined OD Composite Tails**	**6: Combined RO + Cl Sc Tailings Solids**
Paste pH [units]	14-Feb-12	13:38	5.65	7.06
Fizz Rate [---]	14-Feb-12	13:38	1	2
Sample weight [g]	14-Feb-12	13:38	2.04	2.05
HCl added [mL]	14-Feb-12	13:38	24.30	48.90
HCl [Normality]	14-Feb-12	13:38	0.10	0.10
NaOH [Normality]	14-Feb-12	13:38	0.10	0.10
NaOH to [pH=8.3 mL]	14-Feb-12	13:38	19.63	29.82
Final pH [units]	14-Feb-12	13:38	1.65	1.62
NP [t CaCO3/1000 t]	14-Feb-12	13:38	11.5	46.5
AP [t CaCO3/1000 t]	23-Feb-12	09:51	725	862
Net NP [t CaCO3/1000 t]	23-Feb-12	09:51	-714	-816
NP/AP [ratio]	23-Feb-12	09:51	0.02	0.05
Sulphur (total) [%]	17-Feb-12	14:37	23.2	27.6
Acid Leachable SO4-S [%]	23-Feb-12	09:50	< 0.01	< 0.01
Sulphide [%]	23-Feb-12	09:50	23.2	27.6
Carbon (total) [%]	17-Feb-12	14:37	0.727	1.22
Carbonate [%]	22-Feb-12	14:12	0.533	1.29

Brian Graham B.Sc.
Project Specialist
Environmental Services, Analytical

OnLine LIMS

Appendix C: Final ICP-MS Results

Solids ICP-MS by Aqua Regia

Parameter	Units	Combined Wolverine D Composite Tails Final Washed Solids	Combined Lynx D Composite Tails Final Washed Solids
Hg	g/t	---	---
Ag	µg/g	86	59
Al	µg/g	8400	2100
As	µg/g	1200	3700
Ba	µg/g	57	32
Be	µg/g	0.2	< 0.1
Bi	µg/g	18	4.9
B	µg/g		
Ca	µg/g	22000	18000
Cd	µg/g	75	100
Co	µg/g	40	32
Cr	µg/g	91	110
Cu	µg/g	1100	850
Fe	µg/g	200000	300000
K	µg/g	3100	1200
Li	µg/g	4.2	0.1
Mg	µg/g	14000	3700
Mn	µg/g	600	590
Mo	µg/g	28	47
Na	µg/g	100	55
Ni	µg/g	60	66
Pb	µg/g	4500	4600
P	µg/g		
Sb	µg/g	290	200
Se	µg/g	530	430
Sn	µg/g	9	14
Sr	µg/g	52	36
Ti	µg/g	62	39
Tl	µg/g	12	23
U	µg/g	6.5	3.9
V	µg/g	34	26
Y	µg/g	10	6.2
Zn	µg/g	8300	11000

LIMS #10481-NOV06

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Project : Metals - on wahsed solids

Monday, February 20, 2012

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V6C 2B3, Canada

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Fax:pdf, excel

Date Rec. : 23 January 2012
LR Report: **CA11275-JAN12**
Reference: Hum Cell Shutdown

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	**3: Analysis Approval Date**	**4: Analysis Approval Time**	**5: June 29/05 Combined OD Composite Tails**	**6: Combined RO + Cl Sc Tailings Solids**
Sample Date & Time			Date:N/A	Date:N/A
Mercury [µg/g]	14-Feb-12	10:19	3.9	5.5
Silver [µg/g]	15-Feb-12	13:42	56	63
Aluminum [µg/g]	14-Feb-12	14:31	31000	24000
Arsenic [µg/g]	15-Feb-12	13:42	2600	2900
Barium [µg/g]	15-Feb-12	13:42	3900	1900
Beryllium [µg/g]	15-Feb-12	13:42	1.4	1.2
Bismuth [µg/g]	15-Feb-12	13:42	9.8	10
Calcium [µg/g]	14-Feb-12	14:31	4500	11000
Cadmium [µg/g]	15-Feb-12	13:42	53	130
Cobalt [µg/g]	15-Feb-12	13:42	29	33
Chromium [µg/g]	15-Feb-12	13:42	440	430
Copper [µg/g]	15-Feb-12	13:42	640	960
Iron [µg/g]	14-Feb-12	14:31	350000	350000
Potassium [µg/g]	14-Feb-12	14:31	13000	11000
Lithium [µg/g]	15-Feb-12	13:42	29	23
Magnesium [µg/g]	14-Feb-12	14:31	8600	10000
Manganese [µg/g]	15-Feb-12	13:42	470	730
Molybdenum [µg/g]	15-Feb-12	13:42	36	36
Sodium [µg/g]	14-Feb-12	14:31	400	290
Nickel [µg/g]	15-Feb-12	13:42	45	54
Phosphorus [µg/g]	14-Feb-12	14:32	410	330
Lead [µg/g]	15-Feb-12	13:42	4100	4300
Antimony [µg/g]	15-Feb-12	13:42	280	280
Selenium [µg/g]	15-Feb-12	13:42	370	470
Tin [µg/g]	15-Feb-12	13:42	21	20
Strontium [µg/g]	15-Feb-12	13:42	37	49
Titanium [µg/g]	14-Feb-12	14:32	550	450
Thallium [µg/g]	15-Feb-12	13:42	36	34
Uranium [µg/g]	15-Feb-12	13:43	6.4	6.5
Vanadium [µg/g]	15-Feb-12	13:43	240	200
Yttrium [µg/g]	15-Feb-12	13:43	9.8	10
Zinc [µg/g]	15-Feb-12	13:43	6800	17000

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Project Specialist
Environmental Services, Analytical

Appendix D: Final Shake Flask Extraction Test Results

Final Wash - DI Leach 3:1 Ratio as per Price (1997)

Sample ID	**Units**	**MMER**[1]	**Combined Wolverine D Composite Tails - Final Solids**	**Combined Lynx D Composite Tails - Final Solids**
Sample	weight(g)		1095	1069
Volume mL	D.I. H_2O		3000	3000
Initial pH	units	6.0 to 9.5	6.7	6.7
Final pH	units	6.0 to 9.5	7.09	6.94
F	mg/L		0.19	0.16
pH	units	6.0 to 9.5	7.05	7.24
Alkalinity	mg/L as $CaCO_3$		51	41
Acidity	mg/L as $CaCO_3$		116	40
Conductivity	uS/cm		2300	2260
Cl	mg/L		3.6	< 2
SO_4	mg/L		1500	1500
NO_3	as N mg/L		< 0.5	0.09
NH_3+NH_4	as N mg/L		0.1	< 0.1
Thiosalts	as S_2O_3 mg/L		80	40
CN(T)	mg/L	1.00	< 0.01	< 0.01
CNO	mg/L		< 1	< 1
CNS	mg/L		< 2	< 2
Hg	µg/L		< 0.1	< 0.1
Ag	mg/L		< 0.0003	< 0.0003
Al	mg/L		< 0.01	< 0.01
As	mg/L	0.50	0.008	< 0.005
Ba	mg/L		0.0331	0.0345
Be	mg/L		0.0008	< 0.0004
Bi	mg/L		0.0005	0.0003
B	mg/L		0.020	0.023
Ca	mg/L		611	614
Cd	mg/L		0.361	0.288
Co	mg/L		0.0614	0.0602
Cr	mg/L		< 0.003	< 0.003
Cu	mg/L	0.30	0.003	0.004
Fe	mg/L		< 0.01	< 0.01
Li	mg/L		0.005	0.004
K	mg/L		0.84	1.97
Mg	mg/L		20.7	22.7
Mn	mg/L		22.3	5.20
Mo	mg/L		0.0008	0.0008
Na	mg/L		0.42	0.72
Ni	mg/L	0.50	0.151	0.131
P	mg/L		< 0.01	0.03
Pb	mg/L	0.20	0.0530	0.0167
Sb	mg/L		< 0.01	0.01
Se	mg/L		0.28	0.45
Si	mg/L		0.97	0.62
Sn	mg/L		0.005	0.004
Sr	mg/L		1.19	0.896
Ti	mg/L		< 0.001	< 0.001
Tl	mg/L		0.007	< 0.001
U	mg/L		0.0008	0.0010
V	mg/L		0.004	0.004
Zn	mg/L	0.50	**33.2**	**17.0**

LIMS #10080-NOV06

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Monday, February 20, 2012

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Canada, V6C 2B3
Phone: 604-682-5474 ext246, Fax:pdf, excel

Date Rec. : 23 January 2012
LR Report: **CA11274-JAN12**
Reference: Hum Cell Shutdown - Final Wash

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	**3: Analysis Approval Date**	**4: Analysis Approval Time**	**5: June 29/05 Combined OD Composite Tails Final Wash**	**6: Combined RO + Cl Sc Tailings Solids Final Wash**
Sample [weight(g)]	03-Feb-12	11:24	1000	1000
Volume D.I. Water [mL]	03-Feb-12	11:24	3000	3000
Initial pH [units]	03-Feb-12	11:24	5.29	6.53
Final pH [units]	03-Feb-12	11:24	5.41	7.05
pH [no unit]	06-Feb-12	14:21	6.51	6.94
Alkalinity [mg/L as CaCO3]	06-Feb-12	14:21	16	17
Acidity [mg/L as CaCO3]	06-Feb-12	14:21	522	37
Conductivity [µS/cm]	06-Feb-12	14:21	2960	2050
Fluoride [mg/L]	07-Feb-12	10:37	< 0.06	0.08
Chloride [mg/L]	03-Feb-12	15:56	< 2	< 2
Sulphate [mg/L]	03-Feb-12	15:56	2200	1300
Cyanide (total) [mg/L]	03-Feb-12	14:50	< 0.01	< 0.01
Cyanate [mg/L]	03-Feb-12	09:52	< 1	< 1
Thiocyanate [mg/L]	06-Feb-12	11:19	< 0.2	< 0.2
Thiosalts (total) [as S2O3 mg/L]	15-Feb-12	21:40	<10	<10
Ammonia+Ammonium (N) [mg/L]	02-Feb-12	13:55	0.1	0.2
Nitrate (as N) [mg/L]	03-Feb-12	16:22	< 0.05	< 0.05
Mercury [mg/L]	02-Feb-12	17:16	< 0.0001	0.0003
Silver [mg/L]	07-Feb-12	13:54	0.00041	0.00005
Aluminum [mg/L]	07-Feb-12	13:54	0.0004	0.0008
Arsenic [mg/L]	07-Feb-12	13:54	0.112	0.0064
Barium [mg/L]	07-Feb-12	13:54	0.0387	0.0293
Beryllium [mg/L]	07-Feb-12	13:54	< 0.00002	< 0.00002
Bismuth [mg/L]	07-Feb-12	13:54	< 0.00001	< 0.00001
Boron [mg/L]	07-Feb-12	13:54	0.0323	0.0086
Calcium [mg/L]	03-Feb-12	14:53	573	539
Cadmium [mg/L]	07-Feb-12	13:54	2.10	1.21
Cobalt [mg/L]	07-Feb-12	13:54	0.136	0.00872
Chromium [mg/L]	07-Feb-12	13:54	< 0.0005	< 0.0005
Copper [mg/L]	07-Feb-12	13:54	0.376	0.0136
Iron [mg/L]	03-Feb-12	14:53	0.012	< 0.003
Lithium [mg/L]	07-Feb-12	13:54	0.002	< 0.001

Analysis	3: Analysis Approval Date	4: Analysis Approval Time	5: June 29/05 Combined OD Composite Tails Final Wash	6: Combined RO + Cl Sc Tailings Solids Final Wash
Potassium [mg/L]	03-Feb-12	14:53	1.50	0.798
Magnesium [mg/L]	03-Feb-12	14:53	62.4	4.38
Manganese [mg/L]	07-Feb-12	13:54	27.7	2.08
Molybdenum [mg/L]	07-Feb-12	13:54	0.00012	0.00329
Sodium [mg/L]	03-Feb-12	14:53	5.17	4.01
Nickel [mg/L]	07-Feb-12	13:54	0.630	0.0237
Phosphorus [mg/L]	03-Feb-12	14:53	< 0.009	0.012
Lead [mg/L]	07-Feb-12	13:54	0.0569	0.00965
Selenium [mg/L]	07-Feb-12	13:54	2.95	0.193
Silicon [mg/L]	03-Feb-12	14:53	6.51	1.06
Tin [mg/L]	07-Feb-12	13:54	0.00006	0.00035
Strontium [mg/L]	03-Feb-12	14:53	1.21	0.568
Titanium [mg/L]	07-Feb-12	13:54	0.0008	0.0003
Thallium [mg/L]	07-Feb-12	13:54	0.0165	0.0129
Uranium [mg/L]	07-Feb-12	13:54	0.000159	0.000085
Vanadium [mg/L]	07-Feb-12	13:54	0.00006	0.00014
Zinc [mg/L]	03-Feb-12	14:53	328	37.7

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