KLOHN-CRIPPEN

April 16, 1998

Echo Bay Mines Ltd.
Lupin Operation
c/o Echo Bay Mines Hanger
9818 Edmonton International Airport
Edmonton, Alberta
T5J 2T2

Mr. David B. Hohnstein
Manager, Environmental Affairs
Lupin, NWT

Dear Mr. Hohnstein:

Final Report on Kinetic Testing of Sulfide-rich Material from Ulu

Enclosed please find four copies of the final report on humidity-cell testing of ore and prospective mine waste for the Ulu Project. Incorporating the comments and suggestions you made on the draft report, we trust that this final version of the report will meet with your approval. We thank you for the opportunity to work on the interesting project and we look forward to providing you with our service again soon.

Yours truly,

KLOHN-CRIPPEN CONSULTANTS LTD.

John Y. T. Kwong.

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ECHO BAY MINES LTD.

ULU PROJECT

Kinetic Testing of Sulfide-Rich Material from Ulu

PM 7534 02

APRIL 1998

EXECUTIVE SUMMARY

To facilitate further mine development at the Ulu site, Echo Bay Mines Limited - Lupin Operation has retained Klohn-Crippen Consultants to design and conduct a kinetic test program to investigate the possibility of acid rock drainage (ARD) generation and metal leaching from stockpiling ore at Ulu for transport by winter-road to Lupin for processing. The test program involves humidity-cell testing of composites of an ore and a waste rock at both 4°C and 22°C, a prospective tailings sample at 22°C as well as field-column testing of two duplicate ore subsamples. Grain size effects, temperature control of reaction rates and the influence of flushing events on leachate chemistry are considered in the interpretation of test results.

From the weathering of the Ulu composites under different settings, it is evident that temperature affects the rate of sulfide oxidation more than that of depletion of neutralization potential (NP) in a sample. Since NP depletion has invariably occurred faster than sulfide oxidation, only materials with a neutralization potential ratio (NPR) of greater than 3 will not lead to net acid generation with prolonged weathering at 22°C. Under colder conditions, the NPR required to eliminate the possibility of ARD can be as high as 7. However, in the latter case, the amount of acid released on an annual basis is so low that it should not cause any significant impact.

A lower average reaction temperature and a lower frequency of flushing events account for the relatively low sulfide oxidation and metal leaching rates observed with the field-column testing of the Ulu ore compared to the humidity-cell testing results. Metal leaching with the Ulu waste rock is largely insignificant but variable amounts of As and Zn can be leached from the Ulu ore depending on the grain size of the test sample, the ambient temperature for reaction and the frequency of flushing. Based on the kinetic test results, it is estimated that stockpiling of coarse ore at the Ulu site up to 50 years will not lead to net acid generation or intense metal leaching. To avoid unnecessary metal leaching problems, however, it is recommended that ore temporarily stockpiled at the Ulu site should not be pulverized to less than 1.5 mm in diameter.

Further work recommended to complement the current investigation include: (1) a two-year extension of the field-testing to establish a long-term weathering trend; and (2) testing of samples collected from the deeper parts of the Ulu deposit to rectify the fact that all samples tested to date have been collected near the surface; the orebody and the associated waste rock may change in composition with depth.

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1. INTRODUCTION

1.1 Project Background

The Ulu deposit is an Archean epigenetic lode-gold occurrence located within the High Lake greenstone belt of the north-central Slave Province. The Ulu property is located 45 km north of the Arctic Circle and 135 km north of the Lupin Mine in the Mackenzie Mining District, Northwest Territories (Figure 1). Echo Bay Mines - Lupin Operation (EBM-Lupin) acquired the property from BHP Minerals Canada Ltd. in 1995, intending to develop it to provide ore for milling at the Lupin Mine. The tentative mine plan involves stockpiling ore materials at the Ulu site year-round and transporting them to the Lupin Mine when winter roads are operational. Waste rock excavated to reach the orebody is to be used for the construction of ore pads for temporary ore storage and camp pads at the Ulu site.

At Ulu, gold mineralization is hosted by discordant quartz veins in mafic metavolcanics and, less commonly, also in metagabbro and metasediments. A preliminary acid rock drainage (ARD) assessment involving field reconnaissance and geochemical static testing led to two tentative conclusions (Klohn-Crippen Consultants Ltd., 1996):

1) Temporary stockpiling of ore on the surface at the Ulu site up to four years may not lead to net acid generation.
2) A less conservative neutralization potential ratio (NPR) than those recommended by the regulatory agencies (3 to 1 according to the United State Environmental Protection Agency and 4 to 1 according to the British Columbia Acid Rock Drainage Guidelines (Price and Errington, 1995)) may be applicable to discriminate potentially acid-generating from non-acid generating waste rock in the project area.

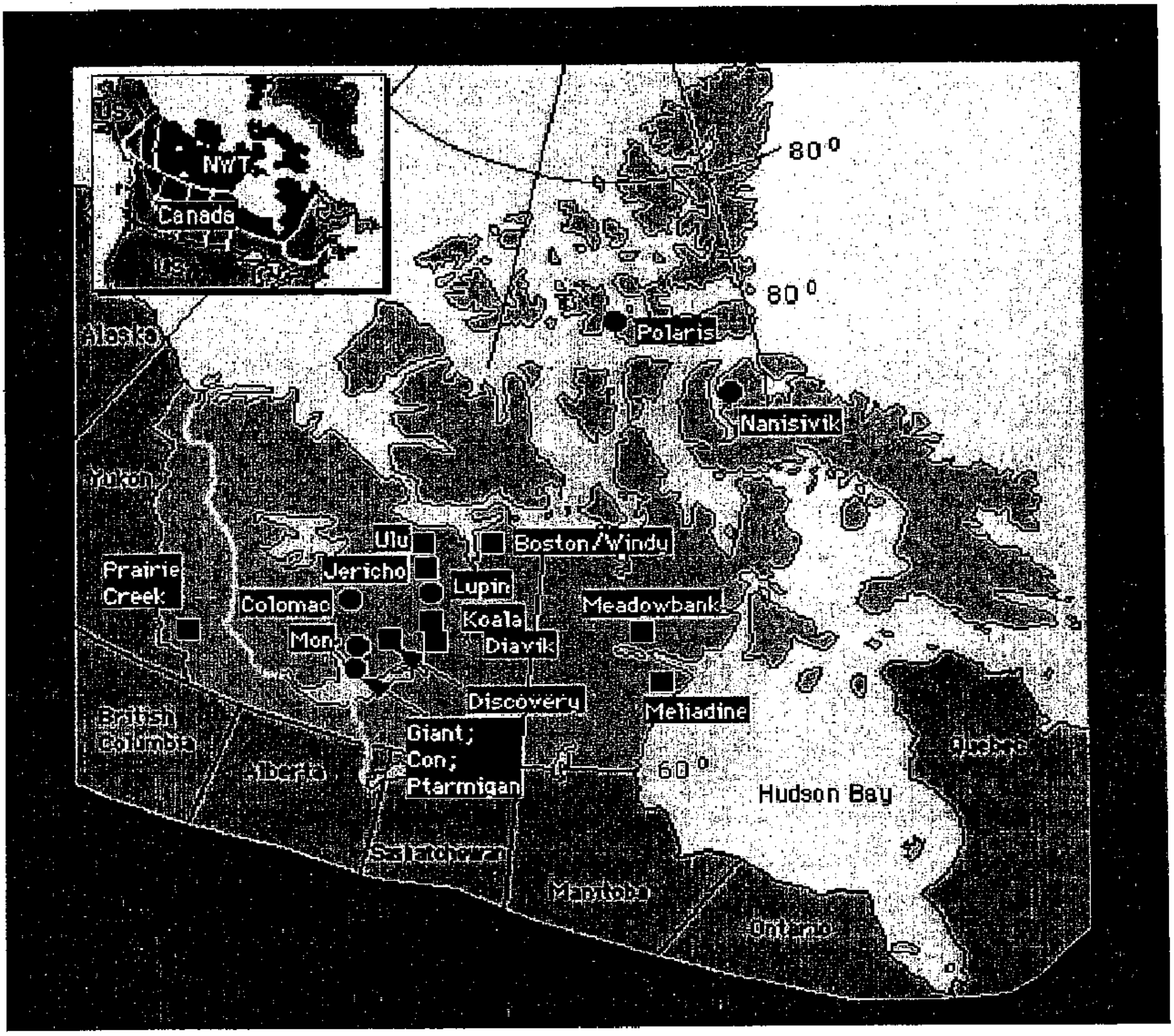


Figure 1 Location of the Ulu property with respect to Lupin Mine

These contentions, however, require validation by kinetic testing. Furthermore, geochemical kinetic tests will help to identify potential metal contamination problems early in the mining phase so that appropriate remedial schemes can be devised to reduce or eliminate the environmental risks. Thus, EBM-Lupin has retained Klohn-Crippen Consultants to design and conduct a kinetic test program with three primary goals as follows:

1) To validate ARD predictions based on geochemical static test data;
2) To demonstrate, where appropriate, that the local climatic conditions justify less conservative criteria for classifying potentially acid-generating material; and,
3) To identify potential metal leaching problems associated with the Ulu Project, if any.

1.2 Scope of Work

In consultation with environmental personnel at EBM-Lupin, a simulated weathering program involving humidity-cell testing of sulfide-rich (>1% total-S) material from Ulu under two temperature settings in the laboratory and under field conditions was designed. Both the laboratory and field columns have been run for 40 weeks. This report describes the details of the test work, documents the data obtained and discusses their implications. Where appropriate, supplementary data collection as the Ulu Project progresses is suggested.

2. METHODOLOGY

The detailed setup of laboratory humidity cells and field columns are described in the next two sections. All test materials used in the investigation originated from the Flood Zone of the Ulu deposit, where most recent exploration has been focused and where initial mining development will probably commence. The ore sample was made up of the +1.5 mm fraction of a 44 kg composite grading 0.25 oz/t Au and crushed to -6 mesh. The original sample was collected by EBM-Lupin geologists at the 25 m Level of the V5/V6 system. The tailings sample consisted of the -1.5 mm fraction of the same sample, which accounted for about 16% by weight of the composite. The waste rock subjected to kinetic testing was comprised of two parts by weight of Ulu-ARD-1 and one part by weight of Ulu-ARD-3, both of which were basalt and previously collected for preliminary ARD assessment from the Ulu site (Klohn-Crippen Consultants Ltd., 1996). All the test samples were fully characterized with respect to their geochemical composition (major and trace elements) and acid-base-accounting properties before and after the testing. The mineralogy of the test samples was also determined by petrographic examination prior to weathering.

2.1 Laboratory Humidity-Cell Testing

Two sets of humidity-cell experiments were conducted in the laboratory to assess the weathering behaviour of geologic materials from Ulu.

For weathering at room temperature (22 ± 2°C), a 2-kg subsample of each of the prospective ore, waste rock and tailings from Ulu was placed in a custom-made cylindrical cell as shown in Figure 2. Following an initial flush with 500 mL of deionized distilled water, the cell contents were subjected to enhanced weathering by pumping humid air through the cells. The test samples were flushed weekly with of de-ionized distilled water. The duration of flushing was about an hour for the ore and waste rock cells and two hours for the tailings cell. The weekly leachates were analyzed for pH, conductivity, Eh, sulfate, acidity, alkalinity and dissolved metals. To reduce the analytical costs, the weekly leachates were combined every other week after Weeks 20 prior to submission for analysis. The final rinse was conducted 10 weeks after the termination of humidity-cell testing to determine the influence of antecedent drying on leachate chemistry.

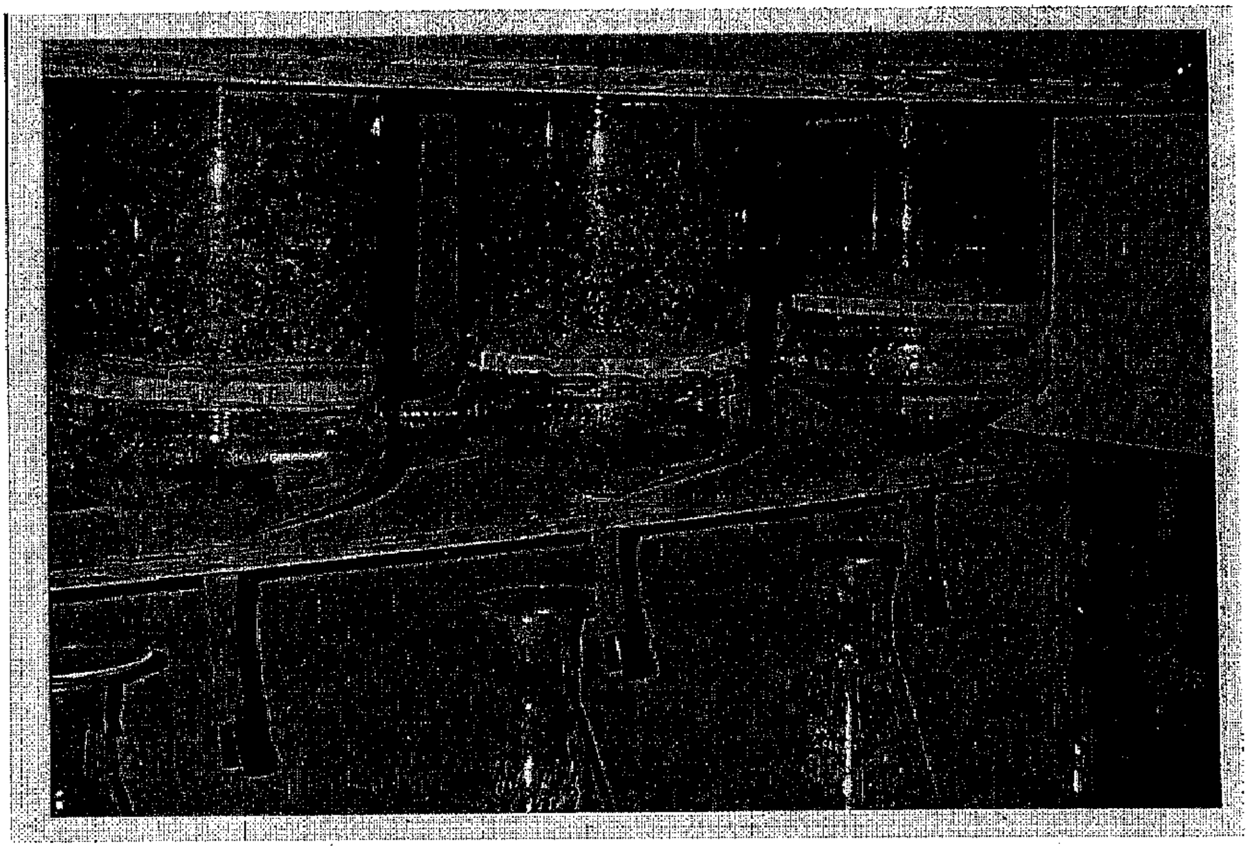


Figure 2 **A photograph showing the room-temperature humidity cell setup.**

For low temperature (4 ± 1°C) weathering, a duplicate cell each of Ulu ore and waste rock was set up and run inside a refrigerator. The frequency of leachate collection and analysis was the same as that of the room-temperature weathering experiment. The room-temperature experiment represents the worst-case scenario for weathering of the Ulu material. A comparison of the results of the two sets of humidity-cell experiments will demonstrate the influence of temperature on acid generation and metal leaching.

2.2 Field Column Setup

To validate predictions based on laboratory test results and to assess the geochemical stability of prospective Ulu ore stockpiles under field conditions, two field columns each containing a 15-kg subsample of the ore composite was installed in an open area near the termination of the winter road at Lupin. Each field column consisted of two staggered 18-L plastic pails. The upper pail with a perforated bottom contained the 15-kg test sample and the lower pail served as a leachate collector. The system was held upright in a slot in a broad-base wood frame made up of two pallets tied together with iron wire. Instructions on column maintenance and leachate collection (Appendix II) were communicated to EBM-Lupin environmental personnel who were responsible for the respective tasks.

3. RESULTS AND INTERPRETATION

The raw data on pre- and post-weathering material characterization and the leachate chemistry for each of the laboratory and field columns are given in Appendix III. Salient observations pertaining to the Ulu ore, waste rock and tailings are summarized below:

3.1 Material Characterization

The geochemical properties of the test samples, including major and trace element composition and the acid-base accounting (ABA) characteristics, were determined both prior to and after the humidity-cell testing. Owing to the inherent limitation of petrographic examinations (i.e. large margin of error for quantitative analysis), the mineralogy of the test composite was assessed only prior to the testing.

3.1.1 Mineralogy

The mineralogy of the test composites are summarized in Table 1 while the detailed petrographic descriptions are given in Appendix III. Since the ore and tailings samples represent the different size fractions of the same bulk sample, it is not surprising to find the two composites having a similar mineralogical composition. However, there are significant differences in mineralogy between the ore and waste rock composites. The ore composite contains more quartz and biotite and less hornblende and plagioclase than the waste rock. Although the total sulfide content of the two composites is similar (i.e. within the error of visual estimates), pyrrhotite and arsenopyrite are the dominant sulfide minerals in the ore composite while pyrite predominates in the waste rock tested. All sulfides are fresh and carbonate is rare in all of the test composites.

Table 1 **Mineralogy of the Ulu ore, waste rock and prospective tailings used in humidity-cell testing**

Ulu ore	*Ulu waste rock*	*Prospective tailings*
25% quartz	15% quartz	22% quartz
20% plagioclase	28% plagioclase	25% plagioclase
1% K-feldspar	40% hornblende	1% K-feldspar
28% hornblende	5% biotite	28% hornblende
12% biotite	trace sericite	14% biotite
4% sphene	2% epidote	trace pyroxene, garnet
5% ilmenite	trace chlorite	trace epidote
0.5% carbonate	2% magnetite	2% sphene
2% pyrrhotite	3% ilmenite	2% ilmenite
2% arsenopyrite	2% rutile + sphene	0.5% carbonate
0.5% pyrite	2.5% pyrite	2% pyrrhotite
trace chalcopyrite	0.5% pyrrhotite	2% arsenopyrite
		1% pyrite
		trace chalcopyrite

3.1.2 Geochemistry

The ABA characteristics and the major and trace element composition of the test samples prior to and after the humidity-cell testing are compared in Table 2. The ABA data confirms the overall low carbonate content and the freshness of the sulfide minerals in the test samples. However, the tailings appears to contain more carbonates than the coarser-grained ore and waste rock composites. The abundance of hornblende in the waste rock composite is supported by the relative enrichment in Al_2O_3, CaO and MgO content and the paucity of arsenopyrite by the low As content for the waste rock. The gold mineralization is apparently associated with silicic and potassic alteration (in the form of quartz, biotite and K-feldspar) as reflected by the relative enrichment of K_2O and SiO_2 in the ore and tailings composites. The latter composites, as mentioned before, are derived from the same bulk ore sample.

Changes in geochemical composition as a result of the simulated weathering are, however, generally within the measurement errors of the analytical methods used in determining the various parameters. Thus, the consequence of weathering is better assessed by the evolving leachate chemistry than by changes in the geochemical composition of the test samples. A repeat analysis of the test samples suggests that the discrepant As analyses for the Ulu ore and waste rock samples (Table 2) are largely due to sample heterogeneity with respect to As distribution.

Table 2 A comparison of pre- and post-test sample characterization data

a) ABA data

Sample #	Paste pH	%Total S	Sulfate-S	Acid Pot.	Neut. Pot	NNP	NP/AP	Carb-NP
			%	kg/t CaCO3				kg/t CaCO3
B1, Ulu ore								
Pre-test	8.70	1.14	<0.01	35	32	-3	0.9	6
Post-test @4 deg.C	9.21	1.14	<0.01	35	31	-4	0.9	5
Post test @ room T	8.97	1.22	<0.01	38	25	-13	0.7	5
B2, Ulu waste rock								
Pre-test	9.32	1.17	<0.01	36	28	-8	0.8	4
Post-test @4 deg.C	9.31	1.19	<0.01	37	28	-9	0.8	6
Post test @ room T	9.16	1.17	<0.01	36	25	-11	0.7	4
B3, Prospective tails								
Pre-test	8.12	1.63	<0.01	51	49	-2	1.0	9
Post test @ room T	8.56	1.55	<0.01	48	45	-3	0.9	8

b) Geochemistry

Sample #	% Al2O3	% CaO	% Cr2O3	%Fe2O3	% K2O	% MgO	% MnO2	% Na2O	% P2O5	% SiO2	% TiO2	% LOI	Total %
B1, Ulu ore													
Pre-test	11.98	6.54	<0.01	15.77	1.34	3.07	0.21	2.30	0.21	55.05	1.88	1.39	99.74
Post-test @4 deg.C	11.70	6.54	<0.01	15.98	1.33	3.23	0.21	2.39	0.20	54.60	1.87	0.72	98.77
Post-test @ room T	11.58	6.58	<0.01	15.82	1.40	3.38	0.20	2.19	0.18	54.81	1.87	0.67	98.68
B2, Ulu waste rock													
Pre-test	13.34	8.24	<0.01	14.80	0.79	5.46	0.21	2.33	0.17	50.56	1.46	1.57	98.93
Post-test @4 deg.C	13.16	8.40	<0.01	14.96	0.69	5.56	0.22	2.49	0.16	50.43	1.44	1.56	99.07
Post-test @ room T	12.99	8.17	<0.01	15.01	0.74	5.58	0.22	2.56	0.19	50.22	1.47	1.65	98.80
B3, Prospective tails													
Pre-test	10.48	5.91	<0.01	15.30	1.46	2.94	0.20	2.17	0.18	56.36	1.66	2.00	98.66
Post-test @ room T	10.78	6.04	<0.01	15.71	1.35	2.94	0.20	1.97	0.19	56.45	1.69	1.28	98.65
	ppm Ag	ppm As	ppm Ba	ppm Cd	ppm Co	ppm Cr	ppm Cu	% Fe	ppm Ni	ppm Pb	ppm Sr	ppm V	ppm Zn
B1, Ulu ore													
Pre-test	<0.2	7780	90	<0.5	31	38	60	4.71	11	2	8	119	86
Post-test @4 deg.C	<1	9590	100	10	35	50	60	5.37	20	<5	10	120	65
Post-test @ room T	<1	9870	100	10	35	60	75	5.64	12	5	10	140	90
B2, Ulu waste rock													
Pre-test	<0.2	556	70	<0.5	37	59	103	4.58	36	<2	20	120	44
Post-test @4 deg.C	<1	90	80	<5	35	60	110	4.71	40	<5	20	120	40
Post-test @ room T	<1	90	80	<5	40	80	125	4.89	37	<5	20	120	40
B3, Prospective tails													
Pre-test	0.8	>10000	90	<0.5	37	47	75	5.77	13	6	12	132	84
Post-test @ room T	<1	10670	100	10	35	50	80	6.03	14	10	5	120	90

3.2 Leachate Chemistry

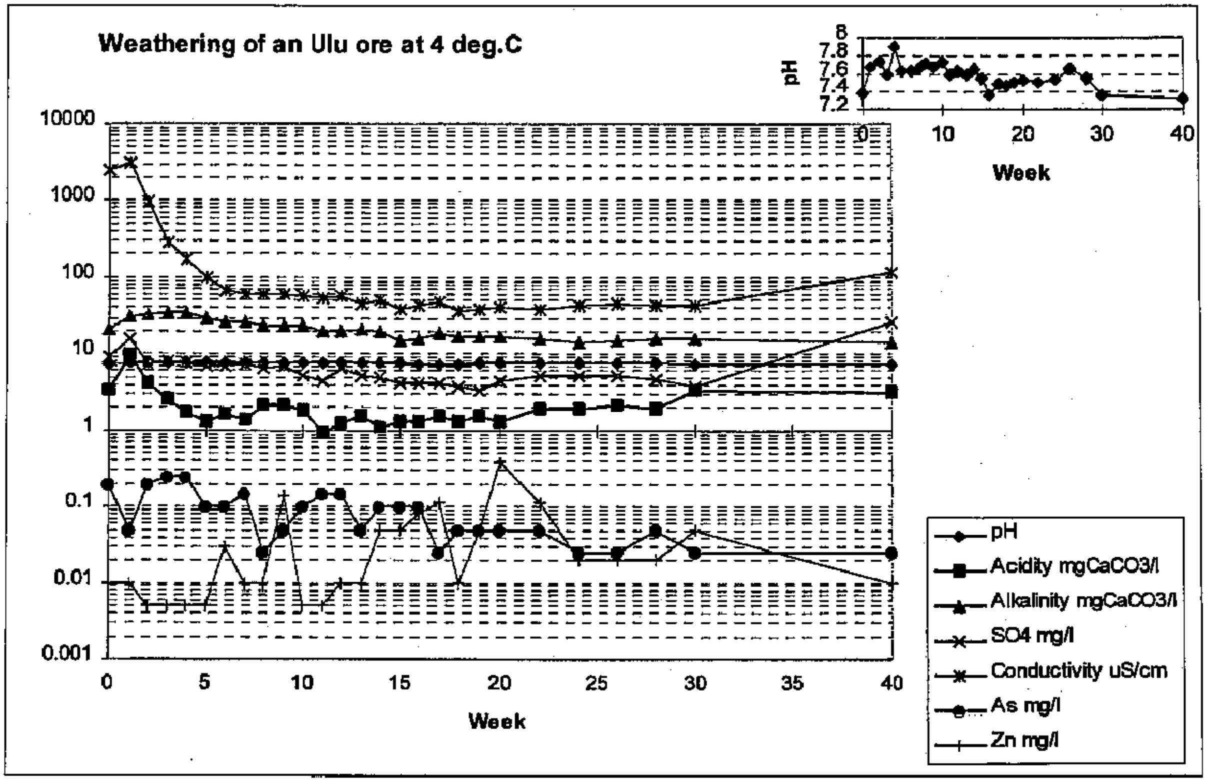
The humidity-cell test results are described below according to sample types. The kinetic data derived under different experimental conditions are also summarized and compared at the end of each presentation.

3.2.1 Weathering of Ulu Ore

The Ulu ore composite chosen for detailed study has been tested under three sets of conditions: laboratory humidity-cell testing at 4°C and at room temperature (22°C) and column leaching under field conditions. The time series of selected parameters measured from the leachate (pH, acidity, alkalinity, sulfate, conductivity, dissolved As and Zn) and the derived production rates for sulfate, dissolved As and Zn and the cumulative sulfate and alkali production for each scenario are depicted with corresponding figures.

Low temperature weathering at 4°C: The leachate pH has remained near neutral at a value of 7.6 ± 0.3 throughout the testing and the measured alkalinity has always exceeded acidity (Figure 3a). The dissolved sulfate concentration appears to follow a decreasing trend with time except for the final leachate of Week 40. The sulfate increase suggests the formation of efflorescence during the long antecedent drying period between Weeks 30 and 40. The efflorescence is dissolved during the final rinse which also gives rise to higher acidity and conductivity readings at Week 40. The overall sulfate release rate on a per mass basis, however, shows a prominent decreasing trend with time (Figure 3b). This reflects a continuously decreasing sulfide oxidation rate, possibly caused by coating of the reacting sulfides with oxidation products like iron oxyhydroxide.

For the leaching of trace elements, only the profiles for As and Zn are shown in Figure 3 because other trace elements were mostly undetectable except for rare excursions which could have resulted from analytical error. Both the measured dissolved As concentration and the derived As release rate decrease with the progress of the testing, suggesting a diminishing arsenopyrite oxidation rate with time. On the other hand, both the dissolved Zn content and the calculated Zn release rate appear to increase with the progress of the experiment except during the final rinse at Week 40. Given the low initial Zn content of the test sample, the apparent increase in Zn leaching could be a cumulative effect of laboratory contamination. Alternatively, if the Zn occurred as sphalerite embedded in other sulfides with a higher electrode potential (e.g., pyrite and chalcopyrite), preferential Zn leaching could have taken place as a result of galvanic interactions (Kwong, 1995). The observed decrease in Zn release during the final rinse again suggests coating of the source mineral with secondary oxidation products during the long antecedent drying period (10 weeks).



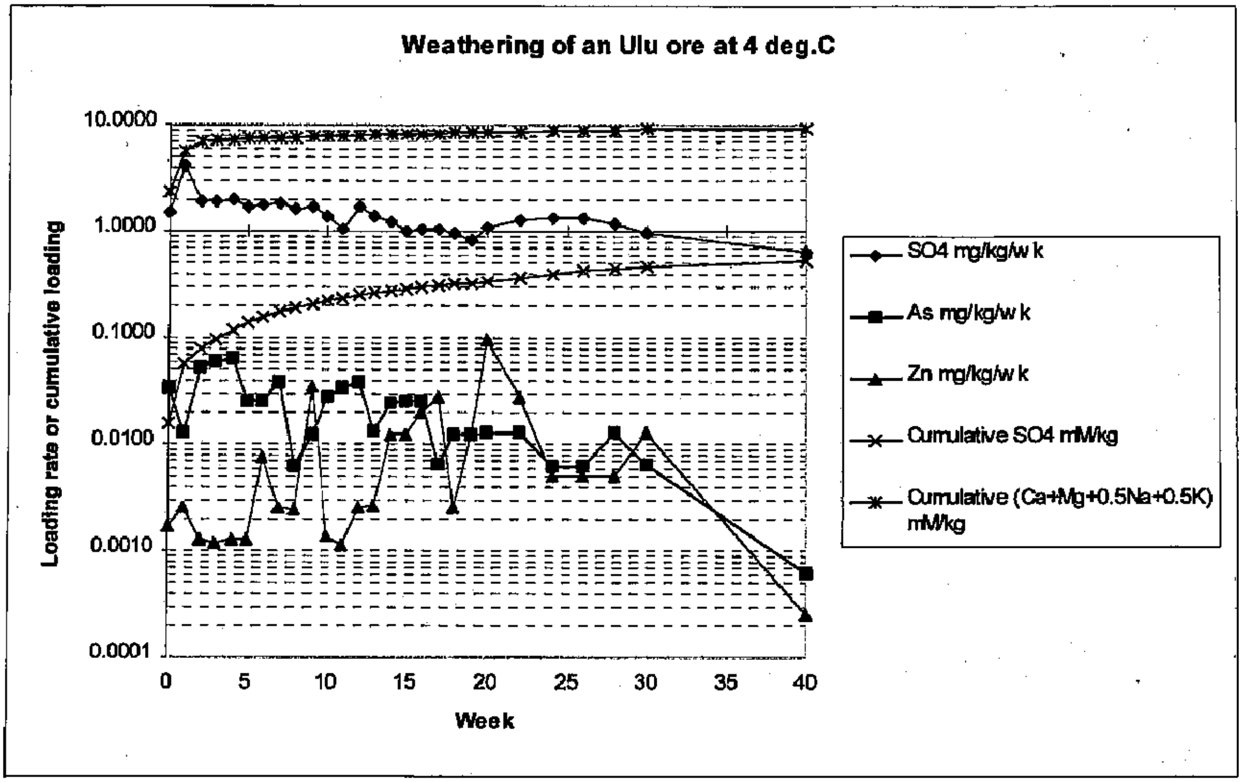


Figure 3 Time series of selected parameters determined during humidity-cell testing of an Ulu ore at 4°C.

Weathering at room temperature (22°C): The overall appearance of the time series for leachates collected in the room temperature experiment (Figure 4) is similar but not identical to that of the low temperature experiment. The leachate pH has remained near neutral at a value of about 7.4 ± 0.3. The dissolved sulfate concentrations initially follows a decreasing trend but reverses course after Week 26. The reason for the sudden change in sulfate release is not clear. However, the increase in sulfate concentration is accompanied by increases in measured acidity and conductivity (Figure 4a) and is therefore unlikely due to measurement errors. Nonetheless, the decrease in sulfate production rate derived from the final rinse data collected at Week 41 (Figure 4b) still supports the formation of efflorescence material during the long antecedent drying period (11 weeks).

While the net values are higher compared to those obtained in the low temperature experiment, both the leachate As concentration and the As release rate on a per mass basis decreases with the progress of the weathering simulation. On the other hand, dissolved Zn appears to follow a slowly increasing trend although the reduced release rate during the final rinse reflects coating effects with prolonged antecedent drying.

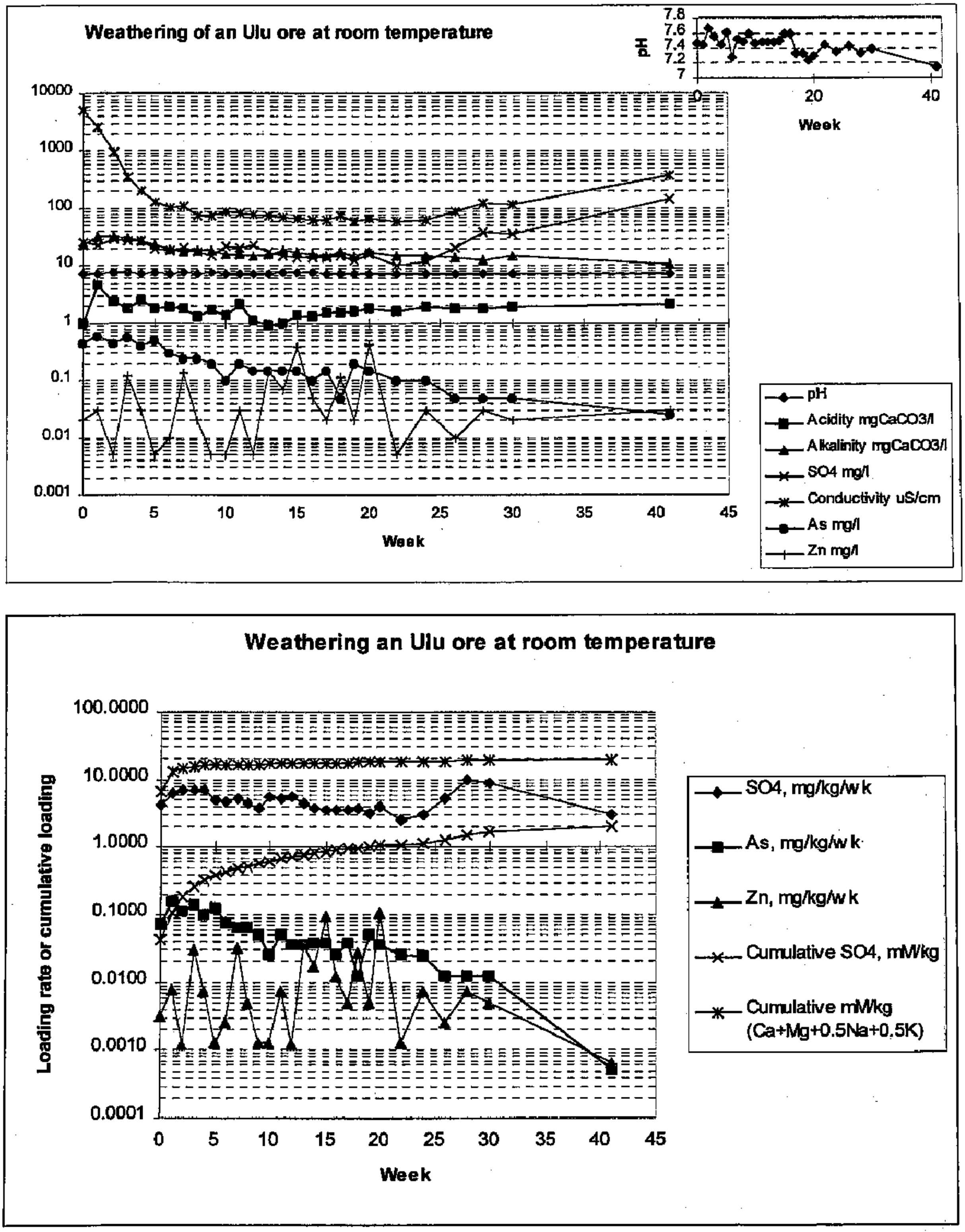


Figure 4 Time series of selected parameters determined during humidity-cell testing of an Ulu ore at room temperature

Column leaching under field conditions: The leachate chemistry of the two duplicate field columns are depicted in Figure 5. Since the site conditions are such that the ground remains frozen eight months of the year, it has been possible only to collect three leachate samples from each of the field columns during the thaw period from June to September. As shown in Figure 5, the two sets of leachate samples have very similar composition except possibly for the dissolved Zn concentrations, which are all close to the analytical detection limit. The leachate samples are all characterized by a near-neutral pH value of 7.6 ± 0.2 and a measured alkalinity exceeding acidity. They also show anomalous conductivity measurements ranging from 2000 to 9000 μS/cm. Correspondingly high dissolved Na concentrations (360 to 1630 mg/l) are noted in the leachate analyses (Appendix III). Apparently, salt water has been used as drilling fluid in drilling the Ulu portal for bulk ore sampling (David Hohnstein, personal communication, December, 1997). The observed high dissolved Na and conductivity in the leachate samples thus result from the leaching of adsorbed salt in the ore composite instead of in-situ weathering of the constituent minerals. A comparison with the leachate chemistry of the laboratory cells shows that the adsorbed salt is essentially leached within about five flushing events for the laboratory cells; the salt contaminant is however not completely removed in three flushing events for the field columns.

Since there are only three data points for each parameter depicted in Figure 5 and the volume of leachate collected in each sampling event is different, no apparent trends for temporal changes in leachate chemistry can be established. However, a close examination of the calculated loading rates suggests that the dissolved sulfate, As and Zn release rates on a per mass basis are considerably higher between August and September than during the rest of the year. In other words, the bulk of the sulfide oxidation could have occurred during the short summer months when the test samples are totally thawed and the air temperature is presumably at its peak.

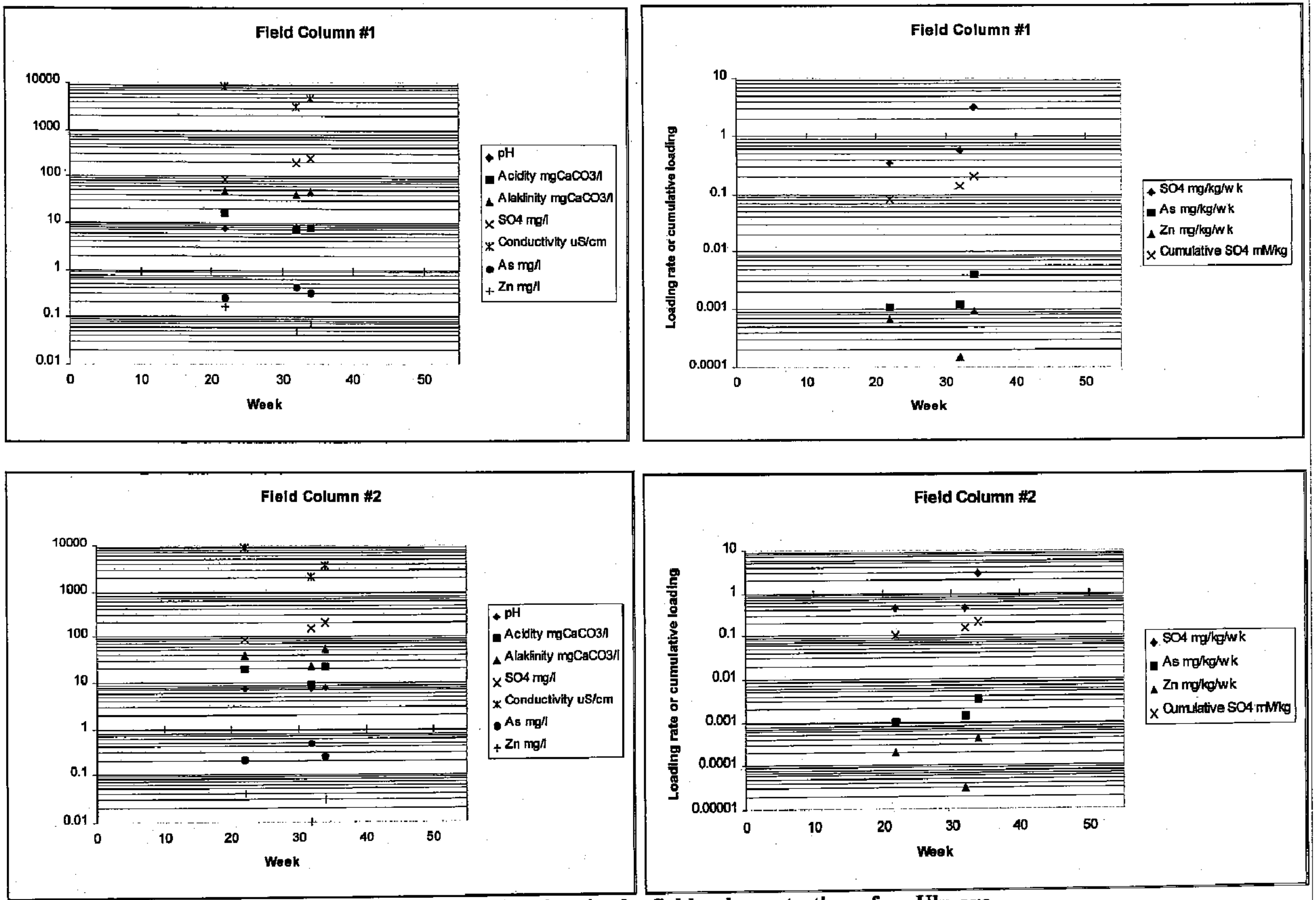


Figure 5 Variation of selected parameters with time in the field-column testing of an Ulu ore.

Comparing the results of weathering of the Ulu ore under different conditions: The consequences of weathering the Ulu ore for the three scenarios described above are compared in Table 3. For the humidity-cell testing in the laboratory, the sulfide-S depletion rate is calculated based on the average sulfate release rate measured between Weeks 10 and 30. Since the sulfate production rates appear to slowly decrease with time (Figures 3a and 4a), this may result in an underestimate of the time required to deplete all the sulfides. For the field columns, the sulfide-S depletion rate is obtained by dividing the cumulative sulfate release to date (assumed to be the yearly production) by 52 weeks. The neutralization potential (NP) depletion rate is calculated from the total weekly release, on a molar basis, of Ca+Mg+0.5Na+0.5K. The factor of 0.5 is used for Na and K because the two alkali metals can compensate only for half of the acid produced by the complete oxidation of one mole of sulfide-S. Since the ore composite has apparently been contaminated with salt water, the average of the NP depletion rates measured from Weeks 10 to 30 (when all the remnant salts have been leached) is used to estimate the time required for complete depletion of the NP available in the ore composite. The estimated time represents the lag time for net acid generation because the sample NP will be totally depleted prior to the complete oxidation of the sulfides. Since the field columns still contain remnant salts, similar calculations cannot be made for the weathering of non-sulfide minerals under field conditions.

Table 3 **A comparison of the results of weathering of an Ulu ore under different conditions**

	Humidity cell at 4°C	Humidity cell at 22°C	Field Columns #1 / #2
S depletion rate (mM/kg/week)	0.012	0.052	0.004 / 0.004
NP depletion rate (mM $CaCO_3$/kg/week)	0.060	0.116	not calculated due to remnant salt
Time for total S depletion (years)	563	132	1707 / 1726
Time for total NP depletion (years)	102	53	not calculated
As loading rate (mg/kg/week)	0.001 - 0.063 decrease with time	0.001 - 0.153 decrease with time	0.001 - 0.004 / 0.001 - 0.003
Zn loading rate (mg/kg/week)	0.0002 - 0.0961 erratic	0.0006 - 0.1061 erratic	0.0002 - 0.0009 / 0.0002 - 0.0004

From the data presented in Table 5, it is evident that the sulfides contained in the Ulu ore tested oxidize four times as fast at room temperature as at 4°C, which is in turn three times faster than sulfide oxidation under field conditions. Even at room temperature with 100% humidity and weekly flushing, the test sample will not give rise to net acid generation in at least 50 years. For the release of both As and Zn from the test composite, temperature does not appear to affect the overall loading rate as much as the removal of oxidation products by frequent flushing.

3.2.2 Weathering of Ulu Waste Rock

Subsamples of the Ulu waste rock composite was subjected to humidity-cell testing in the laboratory under low (4°C) and room temperature (22°C) conditions. The time series for the same set of parameters as described above for the weathering of the Ulu ore are depicted in Figures 6 and 7, respectively. Salient observations are summarized below:

Low-temperature weathering (4°C): The leachate pH has remained steady at values of 7.6 ± 0.2 from Week 1 and the measured alkalinity has always exceeded acidity (Figure 6a). The dissolved sulfate concentration appears to decrease with the progress of the experiment except during the final rinse, concomitant with a slight increase in the acidity and conductivity measurements. The noted increase in acidity, dissolved sulfate and conductivity reflects storage of soluble sulfide oxidation products during the antecedent 10-week drying period. The calculated sulfate release rate, however, has definitely followed a decreasing trend throughout the testing (Figure 6b). The waste rock sample contains relatively little As (556 ppm) such that dissolved As has not been detected in most of the leachate samples. In the As time series depicted in Figure 6, concentrations corresponding to half the detection limit for As has been used if As is non-detectable in the leachate analysis. The Zn content of the waste rock is also low (40 ppm). Dissolved Zn concentrations measured in the leachate analysis are either below detection limit (0.01 mg/L) or generally below 0.1 mg/L. The anomalous value of 23 mg/L noted on Week 17 is probably a measurement error, or due to contamination introduced in the laboratory.

Room-temperature weathering (22°C): The leachate pH has generally remained near-neutral with values of 7.3 ± 0.2 (Figure 7a and Appendix III). Observations made on the dissolved sulfate concentration, acidity, conductivity, sulfate production rate for the cold temperature weathering also apply to the room temperature weathering results. However, the amount of sulfate released during the room-temperature weathering is higher than that obtained in the low-temperature experiment. While dissolved As is mostly undetectable, the dissolved Zn concentrations are generally higher than those measured in the low temperature experiment. The measurements are generally erratic and do not follow any definable trend.

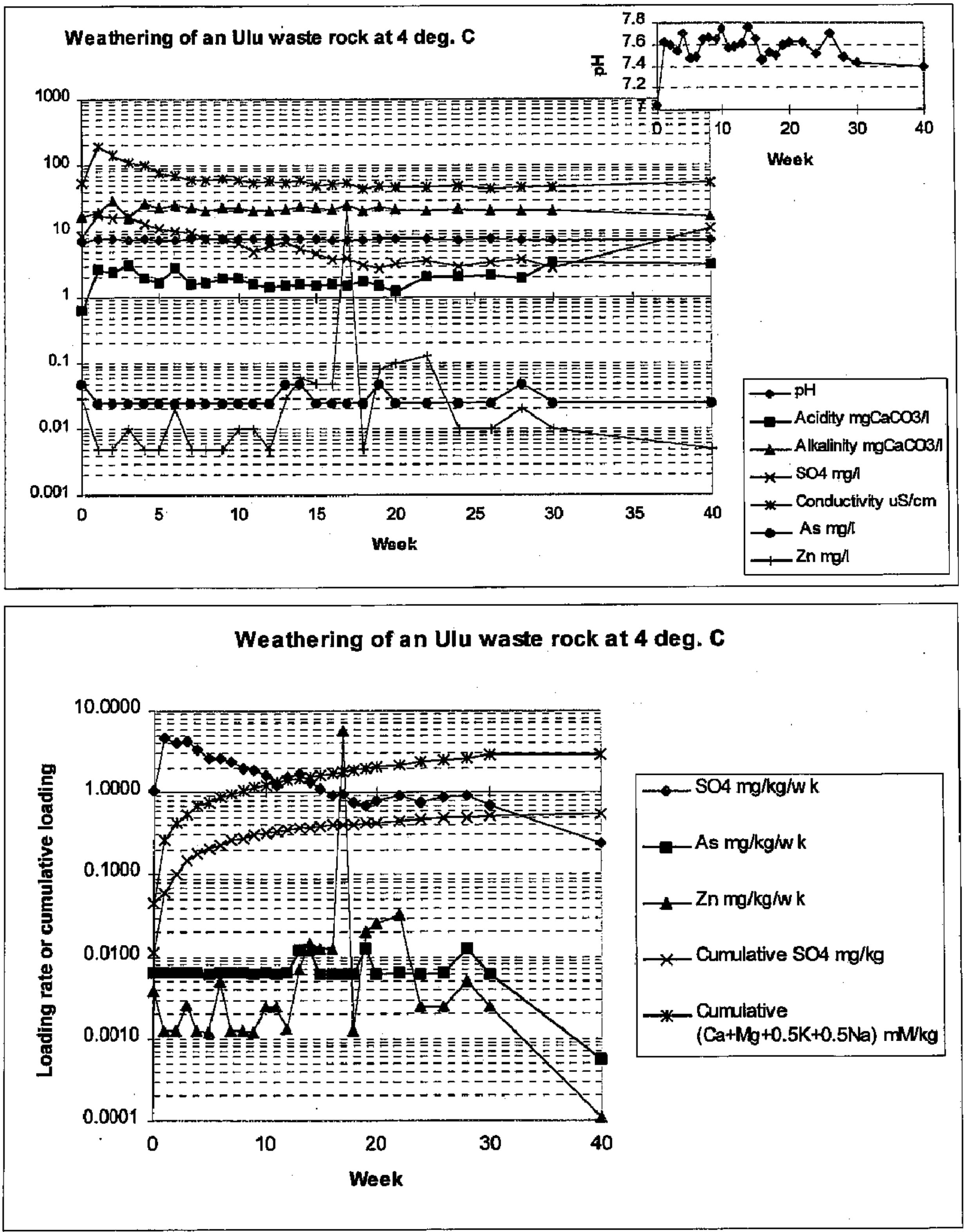


Figure 6 Time series of selected parameters determined during humidity-cell testing of an Ulu waste rock at 4°C.

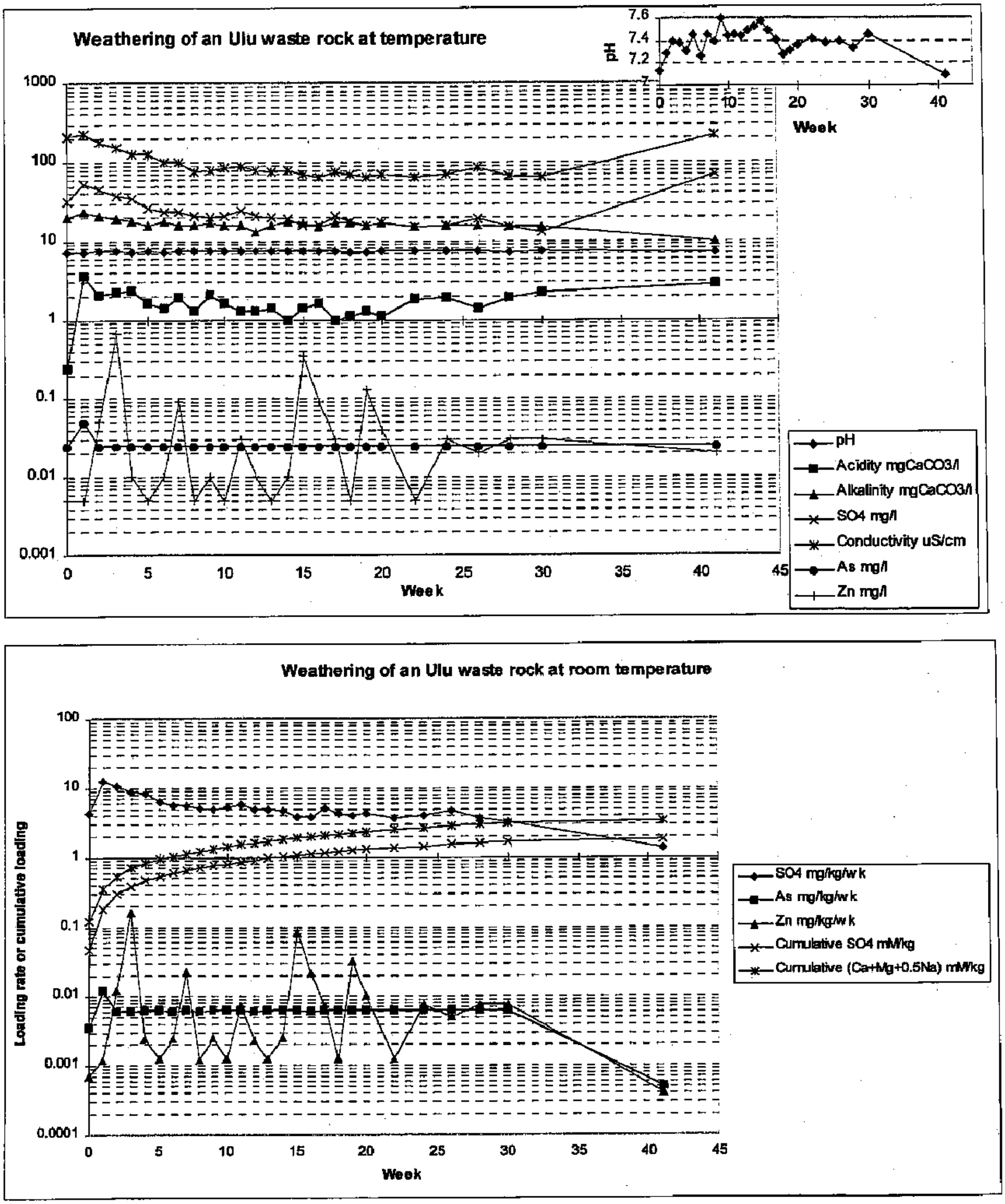


Figure 7 Time series of selected parameters determined during humidity-cell testing of an Ulu waste rock at room temperature.

Comparison of the consequences of weathering at different temperatures: The deductions on sulfate oxidation and NP depletion rates for the weathering of the Ulu waste rock under the two temperature conditions are compared in Table 4. Although the waste rock composite does not appear to contain any salt contamination, to be consistent, the same methodology as described above for the Ulu ore is used to calculate the relevant data on release rates and depletion times. Since no significant release of trace elements has been detected in the waste rock leachates, loading rate data are omitted.

Table 4 **A comparison of the results of weathering of an Ulu waste rock under different conditions**

	Low temperature (4°C)	Room temperature (22°C)
S depletion rate (mM/kg/wk)	0.010	0.044
NP depletion rate (mM $CaCO_3$/kg/wk)	0.079	0.087
Time for complete S depletion (yr)	698	159
Time for total NP depletion (yr)	68	62

Similar to what has been observed in the weathering of Ulu ore samples, temperature does not greatly affect the NP depletion rate but the sulfide-S depletion rate at room temperature is four times as high as that obtained at 4°C. On a molar basis, NP depletion proceeds faster than sulfide oxidation under both temperature conditions. Thus, although the waste rock composite has a neutralization potential ratio (NPR, = NP/MPA) of about 1, sustained weathering will eventually lead to net acid generation. This will occur in about 60 years with weathering at room temperature and about 70 years at 4°C.

3.2.3 Weathering of Prospective Ulu Tailings

Humidity-cell testing of prospective Ulu tailings has been conducted only at room temperature to serve as the worse case scenario for weathering of geological materials from the Ulu deposit. The test sample represents the fine-grained portion (<1.5 mm) of the bulk ore composite. Its geochemical and mineralogical composition is thus very similar to that of the Ulu ore subsamples subjected to kinetic testing under varied conditions as described above. The major differences are that the tailings contains slightly more total S (1.6 versus 1.1%) and has a higher NP (9 versus 6 kg/t $CaCO_3$) than the ore subsamples tested.

The time series for selected parameters measured and derived in the humidity-cell testing of the prospective tailings sample are depicted in Figure 8. The leachate pH is slightly basic with values generally measured at 8.0 ± 0.3 and the net difference between the corresponding alkalinity and acidity measurements is much higher than that observed in the weathering of the Ulu ore at room temperature. After consistent decreases in the first five weeks, the sulfate concentration measured in the leachates appear to increase with further weathering culminating in a significant jump during the final rinse (Figure 8 a). The sulfate production rate also follows the same trend (Figure 8b). Apparently, the fine grain size of the test sample has led to the retention of intergranular moisture that has sustained significant sulfide oxidation during the non-flushing period of Weeks 30 to 41.

The time variation curves for acidity and conductivity generally mimic that of dissolved sulfate. The apparently low acidity measurement in Week 2 (<0.1 mg $CaCO_3$ /L) is compatible with the measured pH of 8.4, which reflects the reactivity of the acid-neutralizing minerals during the early stage of the weathering experiment.

The leaching of As appears to decrease slightly with the progress of the weathering while Zn leaching appears to be slightly enhanced with time. Similar to that observed in the weathering of Ulu ore and waste rock, the Zn measurements are generally more erratic than the As measurements.

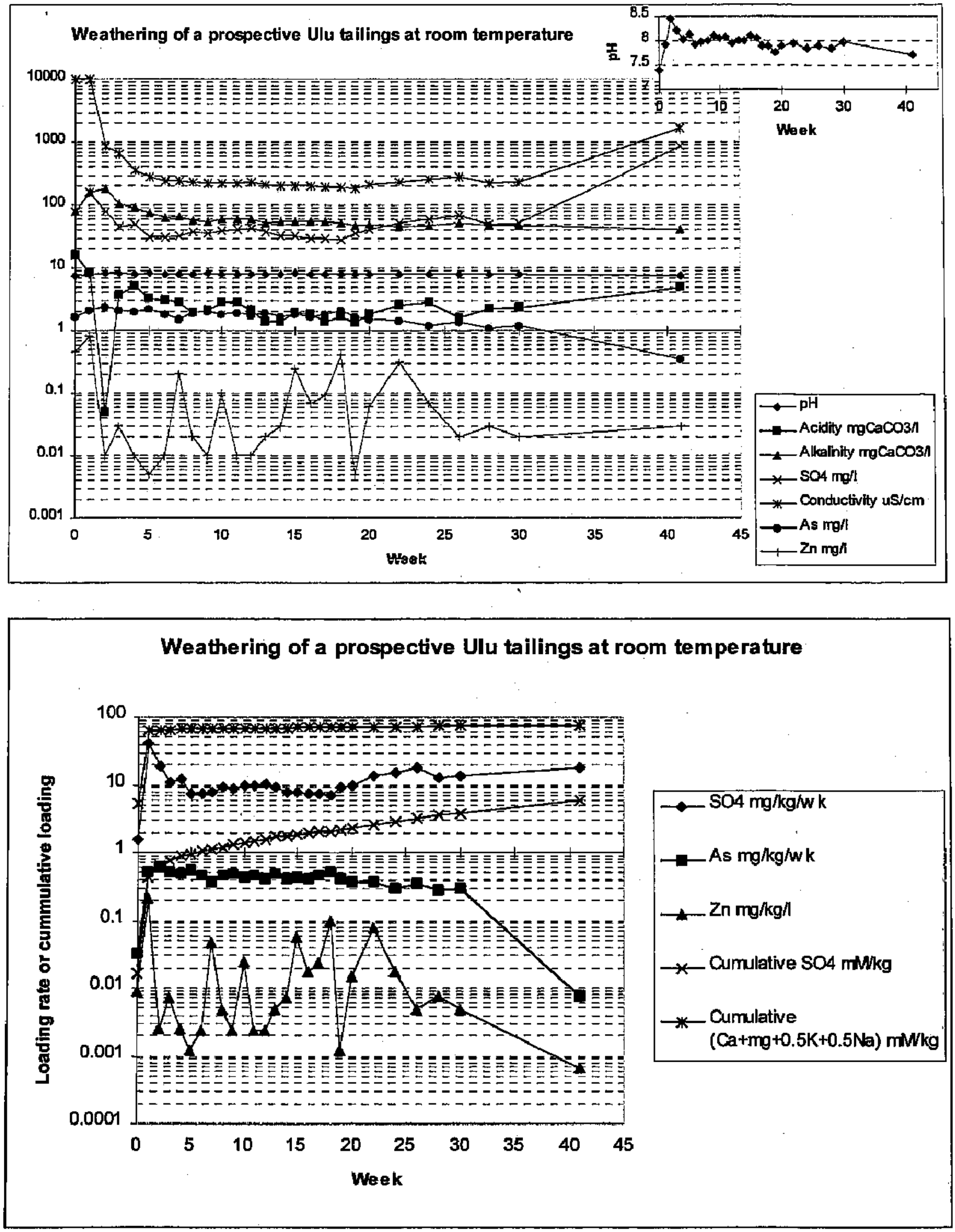


Figure 8 **Time series of selected parameters measured or derived in the humidity-cell testing of a prospective Ulu tailings sample at room temperature.**

Rate-related data derived from the weathering of the tailings sample are summarized in Table 5. Compared to the weathering of Ulu ore under the same conditions, the sulfate depletion rate is twice as fast and the NP depletion rate nearly three times faster. Thus, even though the tailings contains more sulfides and has a higher NP than the Ulu ore, it takes less time for the tailings to exhaust its sulfide content and NP than the coarser-grained ore. It is estimated that net acid generation will occur in about 30 years if the tailings is subjected to weathering at room temperature. The calculated As loading rates are at least four times higher than those calculated for the Ulu ore while the erratic Zn release rates are only about two time higher. Evidently, grain size plays a significant role in mineral weathering and the associated metal leaching.

Table 5 **Deduced rate data from the weathering of an Ulu tailings at room temperature**

Sulfide-S depletion rate (mM/kg/wk)	0.119
NP depletion rate (mM $CaCO_3$/kg/wk)	0.305
Time required for total S depletion (yr)	82
Time for complete NP depletion (yr)	31
As loading rate (mg/kg/wk)	0.28 - 0.61
Zn loading rate (mg/kg/wk)	0.001 - 0.209

4. DISCUSSION

The kinetic test program for the Ulu Project described above has been designed to elucidate the climatic controls on mineral weathering and metal leaching. Based on the acquired data, two important environmental issues related to the proposed ore stockpiling at the Ulu site can be addressed. These topics are briefly discussed below. Recommendations for further work to complement the current investigation are also made.

4.1 Climatic controls of mineral weathering

From the perspective of acid rock drainage prediction, the most important aspects of mineral weathering are sulfide oxidation and alkali removal. Sulfide oxidation can lead to acid generation if the sulfides are iron-rich or have a metal to sulfur ratio of less than one (Kwong, 1993). The sulfide oxidation rate can be estimated directly from the sulfate production rate if a test sample does not contain any soluble sulfate minerals. This is the case for the Ulu test samples. From the humidity-cell testing of the ore and waste rock composites, it is evident that the contained sulfide minerals oxidized about four times faster at room temperature than at 4°C. The different sulfide mineralogy in the test samples (mainly pyrrhotite and arsenopyrite in the ore and pyrite in the waste rock) does not seem to affect the sulfate production rate. Evidenced by significant changes in leachate chemistry during the final rinse, however, the length of antecedent drying period greatly affects the overall sulfide oxidation rate. Generally speaking, a longer antecedent drying period will allow a greater accumulation of oxidation products, resulting in higher concentrations of dissolved constituents in the leachate. Nevertheless, the overall oxidation rate on a per mass basis is reduced with a longer antecedent period between flushing events unless sufficient intergranular moisture is maintained to sustain rigorous oxidation. It is due to the dual effects of an overall lower mean temperature and less frequent flushing that the weathering of the Ulu ore in the field columns has given rise to a much lower sulfide oxidation rate compared to controlled weathering in the laboratory.

The acid neutralization process essentially involves the replacement of alkali (e.g. Na, K) and alkali earth (e.g. Mg, Ca) elements occurring in an acid-neutralizing mineral by hydrogen with or without concomitant complete dissolution of a solid and/or evolution of a gaseous phase. Thus, the release rate of alkali and alkali earth metals expressed in terms of equivalent moles of calcite (i.e., Ca+Mg+0.5Na+0.5K) during weathering can be used to represent the rate of NP depletion in a test sample. Both the laboratory humidity-cell testing of the Ulu ore and waste rock and field-column testing of the Ulu ore indicate that the NP depletion rate is higher than the sulfide oxidation rate. In addition, temperature appears to have a less dominant effect on NP depletion than on sulfide oxidation. At room temperature, the NP depletion rate is slightly less than threefold the sulfide oxidation rate. Thus, only geologic materials with an NPR of equal to or greater than 3 will not give rise to acid rock drainage upon weathering. Under colder conditions, an NPR of about 7 is required. However, in the latter case, the amount of acid generated is so small (e.g., 0.2 moles of H_2SO_4 per tonne of rock per year for the weathering of the Ulu ore under field conditions) that it will not have a significant environmental impact or that it can readily be remedied.

4.2 Environmental Issues Related to Ore Stockpiling at Ulu

The possible formation of acid rock drainage and metal leaching are two important environmental issues of concern for ore stockpiling at the Ulu site. Both the laboratory and field weathering results have shown that the lag time for net acid generation with natural weathering of the Ulu material is long. Even for the worst case of weathering the relatively sulfide-rich tailings at room temperature with frequent flushing, the material will not turn acid in 30 years. Thus, temporal storage of the ore material on site for a few years waiting for transport to Lupin for processing should not pose a problem as far as acid generation is concerned.

The results of leachate analysis show that no potentially deleterious trace elements are leached from the weathering of the Ulu waste rock under any of the test conditions. Dissolved As and Zn, however, have been detected from the weathering of the Ulu ore composite. The leaching rates for both elements are extremely low under the field conditions (averaged about 0.002 mg/kg/wk for As and <0.0009 mg/kg/wk for Zn). Nevertheless, because of the possibility of enhanced leaching of these trace elements from pulverized materials particularly at higher temperatures (Table 5), it is recommended that the ore should not be pulverized to <1.5 mm for stockpiling on site or for transport to Lupin. This will help to prevent potential metal leaching problems from occurring at the Ulu site or from accidental spillage during transport.

4.3 Recommended Further Work

While the current study has furnished valuable data on the acid generation and metal leaching potential of the Ulu materials under different conditions, there are two apparent short-comings that require further complementary work for ratification. These are briefly discussed below:

1) The field-column testing has been operated for one complete cycle of changing seasons yielding three data points, which are insufficient to define any long-term trend. In addition, the leachate volume has not been measured accurately during two of the three sampling events. Thus the resultant loading rates calculated are only rough estimates. Since the operation of the test column does not require much maintenance and the costs associated with the subsequent leachate analyses are relatively low, it is recommended that the field-column testing be extended for at least two more years.

2) The kinetic test work described in this report has been conducted with samples collected from the upper levels of the Ulu deposit. If the composition of either the orebody or the associated waste rock changes with depth, then more samples must be collected and tested accordingly.

5. CONCLUSIONS

The kinetic test program with selected Ulu ore, waste rock and prospective tailings composites under different conditions have been conducted to facilitate further mine development at the Ulu site and substantiate conclusions on acid generation and metal leaching potential drawn previously based on field observations and static geochemical analyses. The results of the current test work lead to the following conclusions:

1) Given the low sulfide oxidation and metal leaching rates occurring under field conditions, stockpiling of coarse ore at the Ulu site up to 50 years is unlikely to give rise to acid drainage or intensive metal leaching.

2) Temperature affects the rate of sulfide oxidation to a greater extent than the rate of depletion of neutralization potential in a sample. Since the latter occurs faster than the former under all conditions for the weathering of test composites from Ulu, only geologic materials with a neutralizing potential ratio of greater than 3 will not lead to net acid generation with prolonged weathering at room temperature. Under colder conditions, the ratio required can be as high as 7. However, in this latter case, the annual production of acid is too small to cause any significant impact.

3) The relatively low sulfide oxidation and metal leaching rates observed in the field-column testing of the Ulu ore compared to those observed in the humidity-cell experiments are the results of both a lower average annual temperature and a lower frequency of flushing events occurring at the site.

4) Metal leaching with the Ulu waste rock tested is insignificant but variable amounts of As and Zn may be leached from the ore composite depending on grain size, the ambient temperature and the frequency of flushing. To avoid unnecessary metal leaching problems, it is recommended that ore stockpiled at the Ulu site or for winter-road transport to Lupin should be as coarse as practical. They should definitely not be pulverized to generate a large proportion of grains finer than 1.5 mm in diameter.

5) Since insufficient data have been collected from the field columns to establish long-term trends and that kinetic testing has been conducted only with samples collected from the shallow parts of the Ulu deposit, it is recommended that the field testing program be extended for another two years and more samples be collected from the deeper parts of the deposit for complementary testing as the Ulu Project progresses.

Yours truly,

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APPENDIX I

Glossary

APPENDIX I

GLOSSARY

Antecedent drying period: Time elapsed prior to flushing of the weathering products.

Archean: Early Precambrian, describing the age of the oldest rocks of the Precambrian.

Arsenopyrite: A tin-white metallic mineral with a chemical formula of $FeAsS$.

Concomitant: Occurring at the same time.

Discordant: A term used to describe an igneous contact that cuts across the bedding or foliation of adjacent rocks.

Efflorescence: Surface encrustation produced by evaporation.

Epigenetic: That formed near the surface of the earth.

Excursion: A deviation from the norm.

Galvanic sulfide oxidation: Preferential oxidative dissolution of a sulfide mineral resulting from the formation of a galvanic cell between two sulfide minerals with differing electrode potentials.

Iron oxyhydroxide: A precipitate containing iron oxide and an hydroxyl (OH) ion.

Lode: A tabular deposit of valuable mineral(s) between definite boundaries.

Mafic: Composed mainly of the magnesian rock-forming silicates.

Metagabbro: A metamorphosed, coarse-grained dark igneous rock.

Pyrrhotite: A magnetic iron sulfide with the general formula of $Fe_{1-x}S$ where x varies from 0 to 0.2.

APPENDIX II

Test Procedures and Sampling Protocols

INTERNATIONAL METALLURGICAL AND ENVIRONMENTAL INC.

Modified Acid Base Accounting

OBJECTIVES:

* to determine the balance between acid producing and acid consuming components of a mine waste.

PRINCIPLES OF TEST:

The fundamental principles of the modified acid base accounting procedure are essentially the same as for the standard procedure, and involve: (1) determination of the neutralization potential (NP) of a sample and (2) calculation of the acid potential (AP) of the sample. The difference between the two values, the net neutralization potential (Net NP), allows classification of the sample as potentially acid consuming or producing. A positive value for the Net NP indicates that the sample is a net consumer of acid. To facilitate comparison of values, NP, AP, and Net NP are all expressed in units of tonnes $CaCO_3$ equivalent per 1000 tonnes.

In the modified method, the neutralization potential is determined by treating a sample with excess standardized hydrochloric acid at ambient, or slightly above (25-30 C) ambient temperatures for 24 hours. Acid is added as required during the acid-treatment stage to maintain sufficient acidity for reaction. After treatment, the unconsumed acid is titrated with standardized base to pH 8.3 to allow calculation of the calcium carbonate equivalent of the acid consumed. The sample is analyzed for total sulphur and sulphate sulphur, and sulphide sulphur is calculated by difference. AP is determined from the calculated sulphide sulphur analysis, assuming (1) total conversion of sulphide to sulphate, and (2) production of 4 moles H+ per mole of pyrite oxidized. In some cases, other sulphur species might be determined.

The modified acid base accounting test is still under development, although the test as described herein has been in use essentially since 1986.

A. Reagents

1. Distilled and deionized water.

2. Certified grade, 1.0 N hydrochloric acid, for standardization of bases.

3. Certified grade, 1.0 N sodium hydroxide for standardization of acids.

4. *0.1 N hydrochloric acid* - using a 100 ml burette, dispense 16.5 ml of concentrated HCl into a 2000 ml volumetric flask and bulk to the mark with deionized water.

5. *0.5 N hydrochloric acid* - using a 250 ml burette, dispense 82.5 ml of concentrated HCl into a 2000 ml volumetric flask and bulk to the mark with deionized water.

6. *0.1 N sodium hydroxide* - measure 8.0 grams of granular NaOH into a plastic weighing boat and transfer the NaOH into a 1000 ml beaker containing 500 ml of deionized water. Place on magnetic stirrer until

dissolved. Transfer into a 2000 ml volumetric flask and bulk to volume with deionized water.

7. *0.5 N sodium hydroxide* - measure 40 grams of granular NaOH into a plastic cup and transfer the NaOH into a 1000 ml beaker containing 500 ml of deionized water. Place on a magnetic stirrer until dissolved. Transfer into a 2000 ml volumetric flask and bulk to volume with deionized water.

NOTE: granular NaOH should only be handled and measured with a plastic spatula and weighing boat. Take extra care not to allow contact with metal.

8. *Phenolphthalein Indicator* - dissolve 0.5g. Phenolphthalein in 50 ml. ethyl or isopropyl alcohol and bulk to 100 ml. with distilled water.

B <u>Reagent Standardization Method</u>:

-Pipette 20 ml of 0.1 N HCl (4.) into a 50 ml beaker. Add 4 to 5 drops phenolphthalein indicator and place on a magnetic stirrer. Titrate with a certified 1.0 N NaOH standard solution from a conditioned 50 ml burette until the endpoint (from a clear to a pink color) is reached. <u>Approximately</u> 2 ml. (lets say 2.1 ml NaOH was used for the example equation).
Duplicate this step to standardize the 0.5 N HCl (5.). The endpoint should take approximately 10 ml of the certified 1.0 N NaOH standard solution.

-Pipette 20 ml of 0.1 N NaOH (6.) into a 50 ml beaker. Add 4 to 5 drops phenolphthalein indicator and place on a magnetic stirrer. Titrate with a certified 1.0 N HCl standard solution from a conditioned 50 ml burette until the endpoint (from a pink to a clear solution) is reached. <u>Approximately</u> 2 ml.
Duplicate this step to standardize the 0.5 N NaOH (7.). The endpoint should take approximately 10 ml of the certified 1.0 N HCl standard solution.

Normality (NaOH/HCl) : V(base) X N(base) = V(acid) X N(acid)
e.g.: 20 ml of ? N HCl ,2.1 ml of 1.0 N NaOH was used. Then;

(2.1 ml NaOH)(1.0 N NaOH) = (20 ml HCl)(? N HCl)

$$\text{Therefore: ? N HCl} = \frac{(2.1\ \text{ml})(1.0\ \text{N})}{20\ \text{ml}}$$

NOTE: Record Normality to 3 decimal places.

C. <u>Procedure</u>

a) Weigh 2.00 grams of sample into a 250 ml Nalgene wide mouth bottle, and add 40 ml (using a 100 ml burette) of 0.1 N standardized HCl.

b) Cover with a film of saran wrap and secure with a punctured lid.

c) Agitate the contents for 24 hours by placing on a mechanical shaker.

d) After 6 hours check the pH of the pulp.

d.i) If the pH of the pulp is below 1.0 at this point, the sample must be rerun starting with a smaller amount of 0.1 N HCl.

d.ii) If the pH of the pulp is above 1.3 at this point, carefully add 0.5 N HCl until the pH drops to 1.2-1.25. Return it to the shaker and continue shaking for the remainder of the test period.

NOTE: The Normality of the hydrochloric acid added at this point should be of the same strength originally added. However, the volume of the bottles may not accommodate the added amount of HCl , therefore, you can use 0.5 N HCl at this point as long as it is accounted for in the final equation.

d.iii) If the pH of the pulp is between 1.0 and 1.3 return it to the shaker and continue for the remainder of the test period.

e) At the end of the shaking period, check the pulp pH. If the total volume and strength of acid was appropriate, the end pH will be in the range 1.0 - 1.5. If the pH is above this range, the amount of acid added is judged to be insufficient for the reaction. If the pH is below the range, the amount of acid added is judged to be too high, causing over- reaction. In either case, repeat the test using the next higher or lower volume or strength of HCl as required.

f) If the pH is within the 1.0-1.5 range titrate the contents using 0.5 N NaOH until a pH of 8.3 is reached. Titrate with NaOH until a *constant reading* of 8.3 remains for at least 30 seconds.

NOTE: The Normality of the sodium hydroxide added at this point should be of the same strength originally added. However, if additional acid of 0.5 N was added at the 6 hour mark then it is best to titrate with 0.5 N NaOH at this point as long as it is accounted for in the final equation.

h) All samples must be run in duplicate.

i) The NBM-1 CANMET standard is run with each set of samples to insure the accuracy of the procedure.

D. Calculations:

1. The neutralization potential, NP, of the sample given by:

$$NP = \frac{50a\,[x - (b/a)y]}{c}$$

where: NP = neutralization potential in tonnes $CaCO_3$ equivalent per 1000 tonnes of material
a = normality of HCl
b = normality of NaOH
c = sample weight in grams
x = volume of HCl added in ml
y = volume of NaOH added to pH 8.3 in ml

2. Different concentrations :

2.1) e.g. If you started with 40 ml 0.1 HCl and 6 ml of 0.489 N HCl was added at the 6 hour mark then the following calculation would be used to determine:

<u>a</u>: $\frac{0.489\ \text{N}}{5} = 0.098\ \text{N}$

$$\frac{0.098\ \text{N} + 0.1\ \text{N}}{2} = \underline{0.099\ \text{N HCl}}$$

<u>x</u>: 6 ml X 5 = 30 ml

$$40\ \text{ml} + 30\ \text{ml} = \underline{70\ \text{ml of .099N HCl}}$$

2.2) e.g. con't At the end of the test period 8.6 ml of 0.498 N NaOH was added, then the following calculation would be used to determine:

<u>y</u>: 8.6 ml X 5 = 43 ml

<u>b</u>: 0.498 N / 5 = 0.100 N NaOH

Therefore, the NP would be:

$$\frac{50(0.099\ \text{N})[70\ \text{ml} - (0.100\ \text{N} / 0.099)\ 43\ \text{ml}]}{2.00\ \text{grams}} = 65.75$$

3. The acid potential , AP, of the sample in tonnes $CaCO_3$ equivalent per 1000 tonnes, is given by:

AP = Percent sulphide sulphur X 31.25

where sulphide sulphur = total sulphur - sulphate sulphur

4. The net neutralization potential, Net NP, in tonnes $CaCO_3$ equivalent per 1000 tonnes of material is given by:

Net NP = NP - AP

E. Interpretation of Results

Interpretation of the Net NP value requires judgment, since although a negative value indicates the theoretical potential of a sample to produce ARD, some samples with this classification are not confirmed as acid producers in kinetic testing or in actual field experience. Of course, this does not imply the ARD will not be produced at some future time. Similarly, samples with positive Net NP values might, under specific circumstances, produce ARD.

Although the Net NP value does provide a good first indication of ARD potential, it is recommended that an interpretation based on the simple arithmetic difference between the NP and AP values should be used with caution. For example, A sample with a Net NP value of +10 derived from a sample having a high sulphide content and correspondingly high acid consuming ability, might have a greater potential to produce acid in the long term compared with a sample which also has a Net NP value of +10 but which has a very low sulphide content. Establishment of an absolute guideline in this regard is not possible. It has been suggested that the ratio between NP and AP values might provide a more reliable guideline for classification of samples, with suggestions that NP should exceed AP by at least 3 to 1 to ensure classification of a sample as non-acid producing. This might be over-conservative, and a classification based on an increasing NP/AP ratio for an increasing sulphide content might be more useful. In general, test results should be assessed within the context of each specific application and with consideration of other available predictive tools.

REFERENCES

1. Coastech Research, Modified Acid Base Accounting, *AMD Prediction Procedures*, Vancouver, B.C. July (1990).

Remark: This procedure is a modification of Coastech Research method (Modified Acid Base Accounting, July 1990)

INTERNATIONAL METALLURGICAL AND ENVIRONMENTAL INC.

Carbonate Analysis

The following procedure is used for the determination of carbonate content.

Glassware Cleaning Procedure

All glassware must be cleaned with 10% HCl. DI water rinsed and acetone dried.

Preparation of CO2 Free Water

1) Boil DI Water for 15 Minutes
2) Transfer to a 2 Litre flask with the tube containing glass wool and CO_2 removing agent Ascarite II. Rapid cooling can be accomplished by running cold water over flask or putting into an ice bath.

Preparation of Reagents

0.1N HCl:(Pipette) 8.25 ml concentrated HCl into 1000 ml flask and bring to the mark with CO_2 Free water.

0.6N HCl: (Pipette) 50 ml concentrated HCl into 1000 ml flask and bring to the mark with CO_2 Free water.

0.1N NaOH: weigh 4gm of NaOH into 1000 ml flask and bring to the mark with CO_2 Free water.

40% Potassium Hydroxide:	40% in 100 ml flask , weigh 40.0 gms.
	40% in 300 ml flask , weigh 120.0 gms.
	40% in 200 ml flask , weigh 80.0 gms.

15% $BaCl_2$ Solution: weigh 150 grams $BaCl_2$ crystals into 1000 ml flask and bring to the mark with CO_2 Free water.

Indicator: dissolve 0.5 gms of Phenolphthalein in 50 ml Iso Propyl alcohol and add 50 ml CO_2 Free water.

Procedure:

1) Weigh out 1.0 to 5.0 grams of sample into a flat bottom flask.

2) Into a 1 Litre filtering flask Pipette exactly 50 ml of 0.1N NaOH and then add 4 to 5 drops of indicator. The indicator will turn the solution pink when added.

3) Connect a separatory funnel to the flat bottom flask and the filtering flask so a vacuum can be established between both flasks. Evacuate the system for about 5 minutes. Don't forget to close the stop cock to maintain a vacuum throughout the test.

4) Add 50 ml of 0.6N HCl (using a graduate cylinder) to the separatory funnel and slowly add to the flat bottom flask. (i.e., add three drops then shake, add 3 drops then shake etc.). Stop flow when a few drops remain in the bottom of the separatory funnel.

5) After contact for a few minutes, shake every 2 min. for 10 minutes.

6) Connect the top of the separatory funnel to the Gas Washing Tower containing 40% KOH and very slowly draw in CO_2 free air until the vacuum is destroyed. This should take about 10 minutes. Shake flasks for about 10 minutes.

7) Disconnect filter flask:
   - Rinse down sides with CO_2 free water.
   - Add 10 ml of $BaCl_2$ solution to the filter flask.
   - Titrate with 0.1N HCl until indicator becomes colorless.

NOTE: A reagent blank must be carried through the entire operation.

*****If titer is less than 5 ml re-run on a lower sample weight.**

*****Also re-run on a lower weight if solution turns milky when $BaCl_2$ solution is added.**

CALCULATIONS:

$$\frac{(\text{Blank titer, ml} - \text{Sample titer, ml}) \times \text{Normality of HCl} \times 5}{\text{Weight of sample(grams)}} = \text{Calcium carbonate equivalent, \%}$$

Standardize 0.1 N HCl against standard 1.00 Normality NaOH solution and check 0.1 N NaOH against standard 1.00 Normality HCl solution.

Reagent Standardization Method:

-Pipette 20 ml of 0.10 N HCl into a 50 ml beaker. Add 4 to 5 drops phenolphthalein indicator and place on a magnetic stirrer. Titrate with a certified 1.0 N NaOH standard solution from a conditioned 50 ml burette until the endpoint (from a clear to a pink color) is reached. Approximately 2 ml. (lets say 2.1 ml NaOH was used for the example equation).

-Pipette 20 ml of 0.1 N NaOH into a 50 ml beaker. Add 4 to 5 drops phenolphthalein indicator and place on a magnetic stirrer. Titrate with a certified 1.0 N HCl standard solution from a conditioned 50 ml burette until the endpoint (from a pink to a clear solution) is reached. Approximately 2 ml.

Normality (NaOH/HCl) : V(base) X N(base) = V(acid) X N(acid)

e.g.: 20 ml of ? N HCl ,2.1 ml of 1.0 N NaOH was used. Then;

(2.1 ml NaOH)(1.0 N NaOH) = (20 ml HCl)(? N HCl)

$$\text{Therefore: ? N HCl} = \frac{(2.1\ \text{ml})(1.0\ \text{N})}{20\ \text{ml}}$$

NOTE: Record Normality to 3 decimal places.

INTERNATIONAL METALLURGICAL AND ENVIRONMENTAL INC.

GRAVIMETRIC DETERMINATION OF SULPHUR

REAGENTS:

1) SATURATED NITRIC ACID-POTASSIUM CHLORATE SOLUTION.

Prepare a saturated solution by carefully adding, with constant stirring, potassium chlorate to reagent grade nitric acid.

2) BROMINE-ACETIC ACID SOLUTION.

Prepare a 1:1 (volume/volume) solution of bromine and acetic acid.

3) POTASSIUM CHLORATE.

Reagent grade potassium chlorate.

4) HYDROCHLORIC ACID.

Reagent grade concentrated hydrochloric acid.

5) BARIUM CHLORIDE SOLUTION.

Ten percent weight/volume solution of barium chloride and distilled water.

PROCEDURE:

1) Weigh a suitable weight of sample into a 400 ml short form beaker.

2) Add 20 ml saturated HNO3-KCLO3 solution. Cover and place on low hot plate for 5 minutes. Transfer to a medium hot place and boil until all nitrous fumes have been evolved. Use bromine when necessary.

3) Cool, add 10 ml concentrated HCl. Digest on a medium hot plate for 10 minutes.

4) Remove cover glasses and take to dryness on a low hot plate. Add 10 ml concentrated HCl and take to dryness a second time.

5) Add 5 ml HCl, 40-50 ml distilled water, and a small amount of filter pulp. Cover and boil until all soluble salts are in solution.

6) Filter through a 15 cm Whatman #42 filter paper, receiving the filtrate in 600 ml beakers. Wash two times with hot 1% HCl and 8 times with hot distilled water. Scrub the inside of the beakers with a rubber policeman.

7) Bulk the filtrate to 300 ml with distilled water, bring to a boil, add with constant stirring 25 ml of 10% BaCl2.

8) Allow the precipitate to stand in a warm place for at least 2 hours, preferably overnight.

9) Filter through a 15 cm Whatman #42 filter paper, scrub the inside of the beaker with a rubber policeman and wash 2 times with 1% hot HCl and 8 times with distilled water.

10) Transfer the filter paper containing the precipitate to a clay crucible. Char the filter paper without igniting it in the front of the muffle furnace. Move the crucibles to the rear of the muffle and heat to 900 Celcius for 30 minutes.

11) Cool in a dessicator and weigh as barium sulphate.

CALCULATION

$$\% \text{ SULPHUR} = \frac{(\text{WEIGHT } BaSO_4)\ (.1373)}{\text{SAMPLE WEIGHT}}\ 100\%$$

QUALITY CONTROL.

Include at least 1 certified reference standard with each run.

Run 1 duplicate sample for every 10 samples.

REFERENCES

1. Brenda Mines Limited, Peachland, B.C. Canada. (1994).

Remark: This procedure is a modification of Brenda Mines Limited method as modified by International Metallurgical and Environmental Inc. Kelowna, B.C. Canada. (1995).

INTERNATIONAL METALLURGICAL AND ENVIRONMENTAL INC.

Sulphate analysis by Turbidmetric Method

INTRODUCTION:

Sulphate, in the form of SO_4, is widely distributed in nature and may be present in natural water in concentrations ranging from a few to a thousand mg/L.
Mine drainage wastes can produce large amounts of sulphate due to oxidation of pyrites. Sodium and magnesium sulphate exert a cathartic action.

The sulphate ion is brought into solution by digestion and is then precipitated with barium chloride ($BaCl_2$) to form a barium sulphate ($BaSO_4$) crystal of uniform size.
Light absorbance of the barium sulphate suspension is measured and the sulphate concentration is determined by comparison of the reading to those of the standards.

INTERFERENCE'S:

Color or suspended solids in large amounts will interfere. Make determinations at room temperature.

REAGENTS:

1. Hydrochloric acid - concentrated reagent grade HCl.
2. Conditioning Reagent - Dissolve 150.0 g. Sodium Chloride (NaCl) in 600ml. deionized water. Add 100 ml. Glycerol ($C_3H_5(OH)_3$), 60 ml. Hydrochloric acid (HCl), 200 ml. isopropyl alcohol (CH_3CHOH), and bring to volume in a 1000 ml. volumetric flask.
3. Stock Sodium Sulphate Solution: 4000 mg/l- Dissolve 1.4786 g Sodium Sulphate (Na_2SO_4) in deionized water. Transfer to a 250 ml volumetric flask, and dilute to volume with deionized water.
4. Barium Chloride - Reagent grade ($BaCl_2$) crystal

STANDARD PREPARATION:

4000 mg/l Stock sodium sulphate solution:

1.) 400 mg/l standard : Pipette 20 ml of stock solution into a 200 volumetric flask and bulk to volume.
2.) 100 mg/l standard : Pipette 50 ml of the 400 mg/l standard into a 200 volumetric flask and bulk to volume.

Process a blank by measuring 100 ml deionized water into a 125 ml. erlenmeyer flask.

100 mg/l standard
(125 ml. erlenmeyer flasks)

2.0 mg/l SO_4- 50:1 dilution = 2 ml to 100
5.0 mg/l SO_4 - 20:1 dilution = 5 ml to 100
10.0 mg/l SO_4 - 10:1 dilution = 10 ml to 100
20.0 mg/l SO_4 - 5:1 dilution = 20 ml to 100

400 mg/l standard
(125 ml. erlenmeyer flasks)

40.0 mg/l SO_4 - 10:1 dilution = 10 ml to 100

PROCEDURE:

a) Weigh 1.0 gram of sample into a (acid washed) 100/150 ml beaker. Samples known to contain a high concentration SO_4 use a 0.250 gram sample.

b) Add 47.5 ml deionized water and 2.5 ml HCl to each beaker. Also process a reagent blank with each run.

c) Cover with (acid washed) watch glass. Place on hot plate and simmer for about 1 hour. Stir periodically.

d) If color forms during step c, add filter pulp and the color should lessen.

e) Remove from hot plate and wash off watch glasses.

f) Add 1 drop of floc, and allow to cool for about 5 minutes.

g) Filter the solutions through 12.5 cm # 5 Whatman filter papers into 125 ml. erlenmeyer flasks. (for solutions that will be diluted, filter into 100 ml flasks.).Wash the filter paper 3 to 4 times with hot deionized water.

h) Let samples cool, then bulk to 100 ml. For dilution samples: pipette desired amount into 125 ml. erlenmeyer flask and bulk to 100 using a graduated cylinder.

i) Add 5 ml. of the conditioning reagent. While sample is being stirred, add 0.5g. of Barium Chloride ($BaCl_2$), and continue to stir for 2 minutes. Allow to stand for a further 8 minutes. Swirl and read turbidity on the turbidimeter. It is important for the accuracy of the results, that the speed of the magnetic stirrer, and the measurement of time remain constant throughout the entire run.

CALCULATIONS:

a) Calculate the linear regression equation of the standards.
b) Calculate the concentration (mg/l) of the sample.
c) Calculate the % Sulphate in the sample.
d) Calculate the % Sulphur in the sulphate.

A) *LINEAR REGRESSION EQUATION*:

-call up Microsoft excel program.
-file
-open
-C:\data\ssdata\ SO4.XLS
-enter standards in column A.
-enter corresponding NTU readings in column B.

Note: the chart at the right should re-adjust to the numbers you enter.

-tools
-data analysis
-regression, ok
-input / input y -highlight column A.
input x -highlight column B.
-output / output range - put cursor in selection box then click on Summary Output on the spread sheet, A12 should appear in selection box.
-residuals / residuals - make sure this activated.
- keypunch **ok**, this will update the calculations according to the new data..

Slope = x Variable on spread sheet
Intercept = intercept on spread sheet
Standard Error = Standard Error on spread sheet
r = Multiple R on spread sheet

After your equation has been determined, enter the date of your test onto the chart and then print a copy. At this time you can computer calculate the concentrations and % SO_4 of your samples by going to sheet 2.

B) *CALCULATE THE CONCENTRATION OF THE SAMPLE*:

mg/l SO_4 = NTU (X) SLOPE (+) INTERCEPT

C) *CALCULATE THE PERCENT SULPHATE IN THE SAMPLE*:

% SO_4 = mg/l SO_4(bulked Volume / Sample weight / 10,000)

D) *CALCULATE THE PERCENT SULPHUR IN THE SULPHATE*:

% S = % SO_4 (X) 0.3338

In excel, your linear regression spread sheet and chart are found on sheet 1. Now go to sheet 2.

-Enter your sample #s in column A (heading Sample) and the corresponding NTU numbers in column B (heading abs). If no dilution was done enter 1 in column C.

Column D gives you your results in mg/l. Column E gives you your results in % SO_4 as indicated and Column F gives you your results in %S as indicated.

NOTE: If there is a change in the weight or bulked volume from 1.0g/100ml. then the results showing in columns E and F are wrong. The formula would have to be updated.

QUALITY CONTROL:

With each run:
- 1 calibration blank to indicate zero.
- 1 reagent blank to monitor glassware contamination.
- duplicate samples (every 10 samples) to monitor precision
- 1 or 2 standard checks with each run.

REFERENCES

1. Clesceri, Lenore S, Arnold E. Greenberg, & R. Rhodes Trusssell ed. 1989 *Standard Methods,* 17th Edition. pp.4:207-4:208.

2. Brenda Mines Limited, Peachland, B.C. Canada. (1994)

Remark: This procedure is a modification of Brenda Mines limited method (adapted from Standard Methods, 17th Edition) as modified by International Metallurgical and Environmental Inc. Kelowna, B.C. Canada. (1995).

QUALITY ASSURANCE AND QUALITY CONTROL

International Metallurgical and Environmental Inc. subscribes to the rigourous use of certified standards and dupicate analysis to assure the quality of reported results.

The result of analysis of certified standard materials are reported with the sample analysis.

Duplicate analysis of approximately 5 to 8 percent of the recieved samples has been conducted to provide a confirmation of the quality of sample preparation and sample handling at International Metallurgical and Environmental Inc. This analysis is reported as "check samples" and are reported with the appended data.

The measured value of the neutralization potential of a sample is known to be a function of the acid digestion used in the 24 hour test, and its determination variable to the point that overall rock characterization is affected. Neutralization potentials are conducted in duplicated and results are averaged to provide a measure of the neutralization potential. Discrepancies of 10 percent between the measured neutralization potentials of a sample will result in the test work being repeated.

International Metallurgical and Environmental Inc. is a registered member of the Environmental Data Quality Assurance Program - Ministry of Environment, Province of British Columbia.

INTERNATIONAL METALLURGICAL AND ENVIRONMENTAL INC.
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Humidity Cell Procedure

OBJECTIVES

To provide a stable environment to observe the oxidation and leaching of various chemical species from an ore, waste rock, tailings or sludge sample.

PRINCIPLES OF TEST

The humidity cell test provides an opportunity to determine the rate of release of metals and oxidation products as a function of time from a specific sample. The basic test is supported by a wide variety of analysis and chemical measurement of the leachates from the test, most of which is specific to a particular project. However common elements of the test include measurement of pH, sulphate, alkalinity and acidity and some level of detailed metal analysis.

The term humidity cell is derived from the elevation and control of humidity in the tested rock samples to mimic sub-terrainian humidity levels. The sample is regularly washed with a distilled water wash to remove and recover soluble species from solids. Solids which are washed from the cell by the flush water are recovered in the decanting of the leachate and returned to the upper surface of the cell during the following flushing cycle one week later.

The scale of humidity test work can be varied and very large scale tests can be completed using custom apparatus and specific methodologies.

HUMIDITY CELL SET-UP

The standard bench scale humidity cell uses a 125 mm diameter glass humidity cell, a support deck and filter media. New filter media and support deck are used with each new humidity cell test. All apparatus should be acid washed, rinsed with distilled water and air dried. The cell is then placed in the support rack and support deck and filter media placed in the cell.

Sample material is weighed and added to the cell in a manner as to not segregate the material in terms of particle size distribution. The cell can be filled to within 3 cm of the top of the cell. Sample weight is recorded to 0.1 grams. In the event that the sample is wet, a separate sample is taken for moisture determination and the humidity cell solid weight is determined by calculation.

The humidity cell is connected to the humidifier and covered with an acid washed glass lid.

HUMIDITY CELL OPERATION

The cell is typically flushed with a volume of distilled water each week during the first 20 weeks of operation and leachates analyzed for a number of metals and chemical parameters. The volume and schedule of water flushing are determined by the requirements of the project. Other project specific operation items may include temperature control, sample pre-treatment via acid leaching, or inoculation of samples using active biological cultures.

The most common flush volume for a 2 kg humidity cell sample is 500 mls of distilled water. The exact volume is measured using a volumetric flask. A portion of the flush water is added to the collection flask and the residual solids are re-suspended and washed back into the humidity cell. The collection flask is then placed to recover the leachate from the cell and the balance of the flush water is slowly added to the entire surface of the humidity cell sample. The draining of the sample is continued for approximately 1 hour and the leachate sample removed. The humidity cell is then covered and left till the next flush cycle.

The leachates are analyzed for the following parameters:

pH
mV
conductivity
sulphate
alkalinity
acidity
ICP metal scan

INTERNATIONAL METALLURGICAL AND ENVIRONMENT INC.

Acidity- Titrimetric Method pH 8.3

Introduction:

Acidity of a water sample is its quantitative capacity to react with a strong base to a designated pH. The measured value may vary significantly with the endpoint pH used in the determination. Acidity is a measure of the aggregate property of water and can be interpreted in terms of specific substances only when the chemical composition of the sample is known. The measurement provides an indication of corrosiveness which in turn can provide insight into water quality.

Sample Preparation:

Collect samples in polyethylene or borosilicate glass bottles and store at a low temperature. Fill bottles completely and cap tightly. Because waste samples may be subject to microbial action and to loss or gain of $C0_2$ or other gases when exposed to air, analyse samples without delay, preferably within 1 d. If biological activity is suspected analyse within 6 h. Avoid sample agitation and prolonged exposure to air. Do not filter, dilute, concentrate, or alter sample. Carry out acidity on the as-is, received sample.

Interferences:

Suspended matter present in the sample, or precipitates formed during the titration may cause sluggish electrode response. This is overcome by allowing 15-20 second pauses between titrant additions and by drop by drop titrant additions near the end point. Chlorine should be neutralised with $Na_2S_20_3$.

Apparatus:

1. 50 ml beakers
2. 10 ml burette
3. 50 ml graduated cylinder
4. Magnetic stirrer and Teflon stir bars
5. Any commercial pH meter and glass electrode

Reagents:

1. 0.1N Sodium Hydroxide: Dissolve 4.0 g. of NAOH in 1.0 L of distilled water. Standardise by titrating against 1N certified Hydrochloric acid.

2. 1 N Hydrochloric acid: (certified 1 N solution)

   Note: With regards to the HCl and NaOH, one of these reagents must be a certified grade and is used to calibrate the other reagent.

Reagent Calibration:

Titrate 20 mls of 0.1N HCl made from the certified 1N HCl, against the 0.1N NaOH, using a 10 ml burette and a magnetic stirrer. Titrate from a pink to clear color using phenolphthalein indicator.

Normality NaOH: V(base) X N(base) = V(acid) X N(acid)

Method:

1. Measure 40 mls of sample into a clean 50ml beaker.
2. While stirring sample, titrate to pH 8.3 and record volume of NaOH titrant used to attain that pH. As the end point is approached make smaller additions of alkali and be sure that pH equilibrium is reached before making the next addition.

Calculations:

$$\text{Acidity (mg CaCO}_3\text{/L)} = \frac{\text{(ml NaOH titrant used) X (normality of NaOH) X 50000}}{\text{ml of sample}}$$

Report as: "The acidity to pH ______=______mg $CaCO_3$/L." If a negative value is obtained, determine the alkalinity of the sample.

INTERNATIONAL METALLURGICAL AND ENVIRONMENT INC.

Alkalinity-Titration Method pH 4.5

Introduction:

Alkalinity of a water is its acid-neutralising capacity- the sum of all titrable bases. The measured value will vary significantly with the end-point pH used. Alkalinity is primarily a function of carbonate, bicarbonate, and hydroxide concentrations, but may also include contributions from borates, phosphates, and silicates.
We use a titration method for determining Alkalinity. The hydroxyl ions present from the hydrolysis or dissociation of solutes react with additions of a standard acid to an end-point pH.

Sample Preparation:

Do not filter, dilute, concentrate, or alter sample. Carry out alkalinity on the as-is, received sample.

Interferences:

Do not let samples sit exposed to air for long periods, as this may increase the alkalinity.

Apparatus:

1. 50 ml beakers
2. 10 ml burette
3. 50 ml graduated cylinder
4. Magnetic stirrer and stir bar

Reagents:

1. 0.02N Hydrochloric acid: Made from a certified 1 N solution. Place 20 ml of 1 N HCl in clean 1 L volumetric flask and bulk to 1 L with de ionized water.

2. 0.02 N Sodium Hydroxide: Dissolve 0.8g of certified grade sodium hydroxide in a 1L flask and bulk with distilled water.

3. Bromocresol Green Indicator: Dissolve 0.10g Bromocresol Green in distilled water and transfer to a clean 100 ml flask and bulk with distilled water.

   Note: With regards to the HCl and NAOH, one of these reagents must be certified grade and is used to calibrate the other reagent.

4. Phenolphthalein Indicator: Dissolve 0.5g Phenolphthalein in 50 ml ethyl or isopropyl alcohol and bulk to 100 ml with distilled water.

nstructions for Field Column Maintenance and Leachate Collection

. Column Maintencance

ach field column is consisted of two staggered 18-litre plastic pails. The upper pail with a perforated bottom ontains 15 kg waste rock and the lower pail serves as a leachate collector. The system is held upright in a slot n the broad-base wood frame made up of two palettes.

nspect monthly during the dry season and during each sampling event in the wet season the physical integrity f the columns. Either pail can be replaced if serious disintegration is observed. Just ensure that the eplacement pail(s) is(are) thoroughly cleaned prior to be used.

nsure also during each inspection that the field columns are well supported in the wood-frame base such that ey will not topple over in strong wind.

. Leachate Collection

s soon as spring freshet starts, collect the leachate in each column weekly* following the steps given below:

.) Pull out the waste rock (upper) container in the column assembly and sit it on a clean plastic sheet.
.) Decant the leachate in the collector (lower) pail into a clean, plastic sampling container; measure** its volume, pH, conductivity and temperature; filter it through a 0.45 μm cellulose acetate filter, ship subsample (minimum 200ml, preferably 500 ml) together with a data record sheet (sample attached) to John Kwong at Klohn-Crippen Consultants, Calgary.
.) With a rubber policemen or spatula and using a minimum amount of water (<20 ml), return all the fine solids collected in the lower pail and the filter paper to the upper pail.
.) Re-assemble the column system and put it back in the wood-frame support.

ote:

* Sampling frequency is, to a large extent, dependent on precipitation. After a heavy rainfall, a sampling ampaign may have to be initiated immediately. During dry spells, leachate sampling may be stretched to monthly basis. A minimum of 200 ml filtrate is required for chemical analysis.

** If measurements are to be made in the laboratory, ensure that they are done within a couple of hours afte ollection. Extra care should be taken in decanting the leachate in the collector pail into the sampling containe o avoid excessive loss of fine particles that came through with the leachate to the collector pail.

Field Column Leachate Collection Record

Date of collection: ______________________________

Volume of leachate: ________________________ ml.

Leachate pH ________________

Eh ________________ mV

Temperature ________________ deg. C

Conductivity ________________ μS/cm

Measurements made in _____ field or _____ laboratory (Check 1)

ime elapsed since collection if measurements were made in the laboratory _________ hrs.

Date of shipment* to Klohn Crippen: ______________________________

*Shipment can be made on a monthly basis. Just keep the sample(s) in a refrigerator (≈ 4 deg. C) prior to shipment.

APPENDIX III

Original Laboratory Reports

Harris
EXPLORATION
SERVICES
MINERALOGY AND GEOCHEMISTRY

534 ELLIS STREET, NORTH VANCOUVER, B.C., CANADA V7H 2G6
TELEPHONE (604) 929-5867

Report for: I. M. & E. Inc.,
13 - 2550 Acland Rd.,
KELOWNA, B.C.
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Report 97-28

April 3, 1997

MINERALOGICAL EXAMINATION OF SAMPLES FROM THE LUPIN PROJECT

Introduction:

3 samples, labelled as below, were submitted by Chris Werbicki. Small portions of each were prepared as polished thin sections.

Sample	Slide No.
Lupin B1 Ulu Ore	97-2223
Lupin B2 Ulu Waste	97-2224
Lupin B3 Tailings	97-2225

Summary:

All three samples are made up of fine-grained crystalline metamorphic rocks of amphibolitic and/or metasedimentary/metatuffaceous aspect. These are composed of quartz, plagioclase, hornblende and biotite, in various proportions, with accessory sphene, ilmenite and sulfides. Total sulfide contents are estimated as about 5% in B1 and B3, and about 3% in B2.

The sulfides consist of pyrrhotite, arsenopyrite and pyrite in various proportions. They typically occur as individual disseminated grains, 10 - 200 microns in size, in the fine-grained host rock. Sulfides and host rock are homogenous, unfractured, and strikingly fresh in all cases.

Carbonate contents in these samples are low (maximum 0.5%) so they will have negligible self-buffering capacity.

Individual petrographic descriptions are attached.

JF Harris

J.F. Harris Ph.D.

SAMPLE: LUPIN B1: ULU ORE (Slide 97-2223)

Estimated mode

Quartz	25
Plagioclase	20
K-feldspar	1
Hornblende	28
Biotite	12
Sphene	4
Ilmenite	5
Carbonate	0.5
Pyrrhotite	2
Arsenopyrite	2
Pyrite	0.5
Chalcopyrite	trace

This sample consists of rock fragments 0.2 - 6.0 mm in size.

These are varigranular (but dominantly fine-grained) intergrowths of quartz, plagioclase, hornblende and biotite in various proportions, having the aspect of metamorphic amphibolites or metasediments.

The prevalent grain size of these fresh, unfractured, unfoliated to weakly foliated rocks is in the 20 - 200 micron range, but there are occasional variants consisting of segregations of hornblende and/or quartz in which the grain size is in the 0.5 - 1.0 mm range.

Fine-grained sphene and ilmenite are prominent accessories, as even disseminations and wispy concentrations.

Carbonate is rare, being seen as a few, sporadic, small clumps, and as a partial alteration of coarse amphibole.

Sulfides consist dominantly of pyrrhotite and arsenopyrite, as individual disseminated grains 20 - 200 microns in size. They occur strongly concentrated in a relatively few specific rock fragments - mostly biotite-bearing quartzo-feldspathic variants. The majority of the amphibole-rich fragments are essentially devoid of sulfides.

The sulfides appear completely fresh.

SAMPLE: LUPIN B2: ULU WASTE (Slide 97-2224)

Estimated mode

Quartz	15
Plagioclase	28
Hornblende	40
Biotite	5
Sericite	trace
Epidote	2
Chlorite	trace
Magnetite	2
Ilmenite	3
Rutile) Sphene)	2
Pyrite	2.5
Pyrrhotite	0.5

This sample is made up of rock fragments in a dominant size range of 0.2 - 3.0 mm.

The lithologies represented are of a generally similar type (equigranular metamorphic amphibolites) to those noted in the previous sample, but there are some systematic differences.

The proportion of biotite-rich variants is much lower, and most of the constituent fragments are intergrowths of varigranular hornblende with plagioclase and/or quartz. Epidote is a sporadic accessory not seen in sample B1, as is magnetite.

Carbonate appears to be absent.

Sulfides are present in roughly similar (or only slightly lower) total abundance as in the ore sample (B1), but they differ in consisting dominantly of pyrite, plus minor accessory pyrrhotite - arsenopyrite being essentially absent.

The sulfides occur as random disseminations of individual grains. In the case of the pyrrhotite these are anhedral, and typically range in size from 10 - 200 microns. In the case of the dominant pyrite, the form of the grains is cubic subhedral, and grain size ranges up to 0.5 mm. There is also a single rock fragment in which the pyrite occurs as peripheral segregations of coalescent grains up to several mm in size.

All sulfides appear fresh.

SAMPLE: LUPIN B3: TAILINGS (Slide 97-2225)

Estimated mode

Quartz	22
Plagioclase	25
K-feldspar	1
Hornblende	28
Biotite	14
Pyroxene	trace
Garnet	trace
Epidote	trace
Sphene	2
Ilmenite	2
Carbonate	0.5
Pyrrhotite	2
Arsenopyrite	2
Pyrite	1
Chalcopyrite	trace

This sample consists of rock fragments and disaggregated mineral grains ranging from 10 microns up to 1 mm or so in size.

Dominant constituents are quartz, plagioclase, hornblende and biotite, with accessory sphene, ilmenite and sulfides, and the sample clearly represents comminuted rock of similar types to those making up sample B1.

Carbonate is of low abundance, occurring as sporadic, small, fine-grained flecks and pockets, and as one or two liberated fragments of sparry aspect.

Sulfides consist of arsenopyrite, pyrrhotite and pyrite, as discrete, mutually unassociated grains in the size range 10 - 200 microns. Rare aggregated clusters of slightly larger size are also seen.

The sulfides typically appear fresh, and the silicate host rock clean and free of limonite staining.

International Metallurgical and Environmental Inc.
Acid-Base Accounting
(Pre-humidity-cell testing)

Project : Klohn Crippen
Mine: Lupin
Date: Feb 5, 1997

Sample	Paste pH	Total S %	S as SO_4^{-2} %	Acid Pot. kg/t $CaCO_3$	Neut. Pot. kg/t $CaCO_3$	Net Neut. Pot kg/t $CaCO_3$	NP: AP Ratio	CO_2 kg/t $CaCO_3$
B1 ULU Ore	8.70	1.14	<.01	35	32	-3	0.9	6
B2 ULU Waste	9.32	1.17	<.01	36	28	-8	0.8	4
B3 Tailings	8.12	1.63	<.01	51	49	-2	1.0	9
B4 OC8	7.97	1.02	0.01	32	13	-19	0.4	2
B5 ULU Waste XD1	9.61	0.29	<.01	9	30	21	3.4	11

Sample	Paste pH	Total S %	S as SO_4^{-2} %	Acid Pot. kg/t $CaCO_3$	Neut. Pot. kg/t $CaCO_3$	Net Neut. Pot kg/t $CaCO_3$	NP: AP Ratio	CO_2 kg/t $CaCO_3$
Check Samples								
B2 ULU Waste			<.01					
B5 ULU Waste XD1								12

Certified Reference Material	Measured Value	Reference Value
Std. UTS-4	1.86 % S	1.80 % S
Std. UTS-1	2.92 % SO_4	2.65 % SO_4
Std. NBM - 1	53 kg/t $CaCO_3$	52 kg/t $CaCO_3$

International Metallurgical and Environmental Inc.
Acid-Base Accounting
(Post humidity-cell testing)

Project : Klohn Crippen
Mine: Lupin
Date: Dec 2, 1997

Sample	Paste pH	Total S %	S as SO_4^{-2} %	Acid Pot. kg/t $CaCO_3$	Neut. Pot. kg/t $CaCO_3$	Net Neut. Pot kg/t $CaCO_3$	NP: AP Ratio	CO_2 kg/t $CaCO_3$
B1 ULU Ore	8.97	1.22	<0.01	38	25	-13	0.7	5
B2 ULU Waste	9.16	1.17	<0.01	36	25	-11	0.7	4
B3 Tailings	8.56	1.55	<0.01	48	45	-3	0.9	8
B1 @4C	9.31	1.19	<0.01	37	28	-9	0.8	6
B2 @4C	9.21	1.14	<0.01	35	31	-4	0.9	5

Sample	Paste pH	Total S %	S as SO_4^{-2} %	Acid Pot. kg/t $CaCO_3$	Neut. Pot. kg/t $CaCO_3$	Net Neut. Pot kg/t $CaCO_3$	NP: AP Ratio	CO_2 kg/t $CaCO_3$
Check Samples								
B1 ULU Ore								5
B2 ULU Waste		1.17	<0.01					
B3 Tailings								8
B1 @ 4C								6
B2 @ 4C								5

Certified Reference Material	Measured Value	Reference Value
Std. CZN-1	29.5 % S	30.2 % S
Std. LS2	0.09 % SO_4	0.10 % SO_4
Std. NBM - 1	54 kg/t $CaCO_3$	52 kg/t $CaCO_3$

International Metallurgical and Environmental Inc.
ICP Analysis

(Pre humidity-cell testing)

Project: Klohn Crippen
Mine: Lupin
Date: Feb 5,1997

Sample	Ag ppm	Al %	As ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Ga ppm	Hg ppm	K %	La ppm	Mg %	Mn ppm	Mo ppm
B1 ULU Ore	<0.2	1.53	7780	90	<0.5	<2	1.03	<0.5	31	38	60	4.71	<10	<1	0.67	10	0.68	395	1
B2 ULU Waste	<0.2	1.52	556	70	<0.5	<2	1.07	<0.5	37	59	103	4.58	<10	<1	0.29	10	1.16	345	1
B3 Tailings	0.8	1.66	>10000	90	<0.5	<2	1.17	<0.5	37	47	75	5.77	<10	<1	0.68	10	0.75	470	<1
B4 OC8	<0.2	2.9	2220	20	<0.5	<2	0.23	<0.5	17	83	45	9.16	<10	<1	0.16	20	1.41	410	1
B5 ULU Waste XD1	<0.2	1.26	76	130	<0.5	<2	1.21	<0.5	23	60	109	2.56	<10	<1	0.56	<10	0.65	245	1

International Metallurgical and Environmental Inc.
ICP Analysis

Project: Klohn Crippen
Mine: Lupin
Date: Feb 5,1997

Sample	Na %	Ni ppm	P ppm	Pb ppm	Sb ppm	Sc ppm	Sr %	Ti %	Tl ppm	U ppm	V ppm	W ppm	Zn ppm
B1 ULU Ore	0.07	11	690	2	<2	10	8	0.14	<10	10	119	10	86
B2 ULU Waste	0.04	36	630	<2	<2	8	20	0.17	<10	<10	120	<10	44
B3 Tailings	0.28	13	620	6	<2	10	12	0.14	<10	<10	132	20	84
B4 OC8	<0.01	50	450	8	<2	3	13	0.02	<10	10	35	<10	52
B5 ULU Waste XD1	0.04	33	450	<2	<2	6	12	0.13	<10	<10	58	<10	76

International Metallurgical and Environmental Inc.
Sample Analysis Summary

Project: Klohn Crippen
Mine: Lupin
Date: Feb 5, 1997

Sample	Al_2O_3 %	CaO %	Cr_2O_3 %	Fe_2O_3 %	K_2O %	MgO %	MnO %	Na_2O %	P_2O_5 %	SiO_2 %	TiO_2 %	LOI %	Total %
B1 ULU Ore	11.98	6.54	<0.01	15.77	1.34	3.07	0.21	2.3	0.21	55.05	1.88	1.39	99.74
B2 ULU Waste	13.34	8.24	<0.01	14.80	0.79	5.46	0.21	2.33	0.17	50.56	1.46	1.57	98.93
B3 Tailings	10.48	5.91	<0.01	15.30	1.46	2.94	0.20	2.17	0.18	56.36	1.66	2.00	98.66

International Metallurgical and Environmental Inc.
ICP Analysis

(Post humidity - cell testing)

Project: Klohn Crippen
Mine: Lupin
Date: Dec 2,1997

Sample	Ag ppm	Al %	As ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Hg ppm	K %	Mg %	Mn ppm	Mo ppm
B 1	<1	1.66	9870	100	<5	<10	1.09	10	35	60	75	5.64	<10	0.67	0.75	510	<5
B 2	<1	1.43	90	80	<5	<10	1.04	<5	40	80	125	4.89	<10	0.27	1.11	440	5
B 3	<1	1.56	10670	100	<5	<10	1.07	10	35	50	80	6.03	<10	0.66	0.72	530	<5
B 1 @4C	<1	1.55	9590	100	<5	<10	1.06	10	35	50	60	5.37	<10	0.62	0.72	470	<5
B 2 @4C	<1	1.42	90	80	<5	<10	1.07	<5	35	60	110	4.71	<10	0.26	1.11	430	<5

International Metallurgical and Environmental Inc.
ICP Analysis

Project: Klohn Crippen
Mine: Lupin
Date: Dec 2,1997

Sample	Na %	Ni ppm	P ppm	Pb ppm	Sb ppm	Sc ppm	Sr ppm	Ti %	Tl ppm	U ppm	V ppm	W ppm	Zn ppm
B 1	0.12	12	1000	5	<10	5	10	0.26	<20	<20	140	<20	90
B 2	0.10	37	900	<5	10	5	20	0.23	<20	<20	120	<20	40
B 3	0.10	14	900	10	<10	5	5	0.25	<20	<20	120	<20	90
B 1 @4C	0.11	20	900	<5	<10	5	10	0.26	<20	<20	120	<20	65
B 2 @4C	0.10	40	900	<5	<10	5	20	0.23	<20	<20	120	<20	40

International Metallurgical and Environmental Inc.
Sample Analysis Summary

Project: Klohn Crippen
Mine: Lupin
Date: December 17,1997

Sample	Al_2O_3 %	CaO %	Cr_2O_3 %	Fe_2O_3 %	K_2O %	MgO %	MnO %	Na_2O %	P_2O_5 %	SiO_2 %	TiO_2 %	LOI %	Total %
B1	11.58	6.58	<0.01	15.82	1.40	3.38	0.20	2.19	0.18	54.81	1.87	0.67	98.68
B2	12.99	8.17	<0.01	15.01	0.74	5.58	0.22	2.56	0.19	50.22	1.47	1.65	98.80
B3	10.78	6.04	<0.01	15.71	1.35	2.99	0.20	1.97	0.19	56.45	1.69	1.28	98.65
B 1 @ 4°C	11.70	6.54	<0.01	15.98	1.33	3.23	0.21	2.39	0.20	54.60	1.87	0.72	98.77
B 2 @ 4°C	13.16	8.40	<0.01	14.96	0.69	5.56	0.22	2.49	0.16	50.43	1.44	1.56	99.07

International Metallurgical and Environmental Inc.
Humidity Cell Test Data

Project Name: Lupin
Test Sample: B1 @ 4 C
Sample Weight: 2001.5g
Start Date: Feb 25, 1997

Cycle	Days	Weight Added (g)	Weight Rec. (g)	pH	Acidity (mg $CaCO_3$/l)	Alkalinity (mg $CaCO_3$/l)	SO_4 (mg/l)	Conductivity (µmhos)	Redox Potential (mV)
0	0	500	334	7.39	3.4	21	9	2510	121
1	7	500	506	7.67	9.7	31	16	3200	114
2	14	500	517	7.73	4.1	32	7.4	960	108
3	21	500	479	7.60	2.6	34	8.0	290	96
4	28	500	507	7.90	1.7	35	7.7	175	167
5	35	500	502	7.64	1.3	30	6.7	100	140
6	42	500	502	7.63	1.6	26	7.0	68	132
7	49	500	499	7.65	1.4	26	7.3	61	124
8	56	500	494	7.72	2.1	24	6.5	60	160
9	63	500	496	7.67	2.2	23	6.9	61	115
10	70	500	543	7.74	1.8	23	5.1	58	132
11	77	500	457	7.60	0.94	20	4.5	53	104
12	84	500	506	7.63	1.2	20	6.6	56	108
13	91	500	528	7.58	1.5	21	5.2	46	120
14	98	500	491	7.66	1.1	20	5.0	51	125
15	105	500	497	7.54	1.3	15	4.1	39	138
16	112	500	500	7.36	1.3	16	4.1	43	N/A
17	119	500	505	7.48	1.5	19	4.1	47	151
18	126	500	497	7.46	1.3	17	3.8	36	127
19	133	500	496	7.51	1.5	17	3.3	39	156
20	140	500	506	7.52	1.3	17	4.3	40	166
22	154	1000	1000	7.51	1.9	16	5.1	38	107
24	168	1000	1004	7.52	1.9	14	5.2	44	221
26	182	1000	1001	7.66	2.1	15	5.3	46	228
28	196	1000	1009	7.54	1.9	16	4.7	44	139
30	210	1000	1007	7.37	3.4	16	3.8	43	197
40	280	500	500	7.32	3.1	14	26	120	167

International Metallurgical and Environmental Inc.
Humidity Cell Test Data

Project Name: Lupin
Test Sample: B1 @ 4 C
Sample Weight: 2001.5g
Start Date: Feb 25, 1997

Cycle	Days	Ag mg/l	Al mg/l	As mg/l	Ba mg/l	Be mg/l	Ca mg/l	Cd mg/l	Co mg/l	Cr mg/l	Cu mg/l	Fe mg/l	K mg/l	Mg mg/l	Mn mg/l	Mo mg/l	Na mg/l	Ni mg/l	P mg/l	Pb mg/l	Sb mg/l	Sr mg/l	Ti mg/l	V mg/l	Zn mg/l
0	0	<0.01	<1	0.20	<0.1	<0.001	31	0.003	<0.02	<0.02	0.01	<1	15	3.4	0.07	<0.01	590	<0.01	<1	<0.05	0.05	0.07	<1	<0.01	0.01
1	7	<0.01	<1	0.05	<0.1	<0.001	49	0.004	<0.02	<0.02	<0.01	<1	15	6.20	1.10	0.01	550	<0.01	<1	<0.05	<0.05	0.14	<1	<0.01	0.01
2	14	<0.01	<1	0.20	<0.1	<0.001	13.0	<0.001	<0.02	<0.02	<0.01	<1	5	2.0	0.45	<0.01	175	<0.01	<1	<0.05	<0.05	0.03	<1	<0.01	<0.01
3	21	<0.01	<1	0.25	<0.1	<0.001	5.5	0.003	<0.02	<0.02	<0.01	<1	<5	1.05	0.16	<0.01	43	0.01	<1	0.10	<0.05	<0.01	<1	<0.01	<0.01
4	28	<0.01	<1	0.25	<0.1	<0.001	5.0	<0.001	<0.02	<0.02	<0.01	<1	<5	<0.05	0.14	<0.01	24	<0.01	<1	<0.05	<0.05	0.03	<1	<0.01	<0.01
5	35	<0.01	<1	0.10	<0.1	<0.001	4.5	<0.001	<0.02	<0.02	<0.01	<1	<5	<0.05	0.14	<0.01	11	<0.01	<1	0.05	<0.05	0.01	<1	<0.01	<0.01
6	42	<0.01	<1	0.10	<0.1	<0.001	6.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.14	<0.01	7	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.03
7	49	<0.01	<1	0.15	<0.1	<0.001	6.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.17	<0.01	5	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.01
8	56	<0.01	<1	<0.05	<0.1	<0.001	7.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.21	<0.01	4	<0.01	<1	<0.05	<0.05	0.06	<1	<0.01	0.01
9	63	<0.01	<1	0.05	<0.1	<0.001	7.5	<0.001	<0.02	<0.02	<0.01	<1	<5	1.10	0.22	<0.01	3	0.01	<1	<0.05	<0.05	0.04	<1	<0.01	0.14
10	70	<0.01	<1	0.10	<0.1	<0.001	7.5	0.022	<0.02	<0.02	<0.01	<1	<5	1.05	0.20	<0.01	2	<0.01	<1	0.65	<0.05	<0.01	<1	<0.01	<0.01
11	77	<0.01	<1	0.15	<0.1	<0.001	7.5	<0.001	<0.02	<0.02	<0.01	<1	<5	<0.05	0.16	<0.01	2	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	<0.01
12	84	<0.01	<1	0.15	<0.1	<0.001	9.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.22	0.02	2	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.01
13	91	<0.01	<1	0.05	<0.1	<0.001	7.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.18	<0.01	2	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.01
14	98	<0.01	<1	0.10	<0.1	<0.001	8.5	<0.001	<0.02	<0.02	<0.01	<1	<5	<0.05	0.18	<0.01	2	0.02	<1	<0.05	<0.05	0.01	<1	<0.01	0.05
15	105	<0.01	<1	0.10	<0.1	<0.001	7.0	0.01	<0.02	<0.02	<0.01	<1	<5	<0.05	0.18	<0.01	1	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.05
16	112	<0.01	<1	0.10	<0.1	<0.001	7.5	<0.001	<0.02	<0.02	<0.01	<1	<5	<0.05	0.18	<0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.08
17	119	<0.01	<1	<0.05	<0.1	<0.001	7.5	0.003	<0.02	<0.02	<0.01	<1	<5	<0.05	0.19	<0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.11
18	126	<0.01	<1	0.05	<0.1	<0.001	6.5	<0.001	<0.02	<0.02	<0.01	<1	<5	<0.05	0.17	<0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.01
19	133	<0.01	<1	0.05	<0.1	<0.001	6.0	<0.001	<0.02	<0.02	<0.01	<1	<5	<0.05	0.17	<0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.05
20	140	<0.01	<1	0.05	<0.1	<0.001	7.5	0.002	<0.02	<0.02	<0.01	<1	<5	<0.05	0.18	<0.01	1	0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.38
22	154	<0.01	<1	0.05	<0.1	<0.001	6.5	0.007	<0.02	<0.02	<0.01	<1	<5	<0.05	0.18	<0.01	1	<0.01	<1	0.10	<0.05	<0.01	<1	<0.01	0.11
24	168	<0.01	1	<0.05	<0.1	<0.001	7.5	<0.001	<0.02	<0.02	<0.01	<1	<5	<0.05	0.17	0.03	<1	<0.01	<1	<0.05	<0.05	0.02	<1	<0.01	0.02
26	182	<0.01	<1	<0.05	<0.1	<0.001	8.0	<0.001	<0.02	<0.02	<0.01	<1	<5	<0.05	0.19	<0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.02
28	196	<0.01	<1	0.05	<0.1	<0.001	7.0	<0.001	<0.02	<0.02	0.14	<1	<5	<0.05	0.15	<0.01	<1	<0.01	<1	0.05	<0.05	<0.01	<1	<0.01	0.02
30	210	<0.01	<1	<0.05	<0.1	<0.001	7.0	<0.001	<0.02	<0.02	0.01	<1	<5	<0.05	0.16	<0.01	<1	<0.01	<1	<0.05	<0.05	0.02	<1	<0.01	0.05
Final Rinse	280	<0.01	<1	<0.05	<0.1	<0.001	13.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.32	<0.01	1	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.01

International Metallurgical and Environmental Inc.
Humidity Cell Test Data

Project Name: Lupin
Test Sample: B1 @ room temp.
Sample Weight: 2001.3g
Start Date: Feb 18, 1997

Cycle	Days	Ag mg/l	Al mg/l	As mg/l	Ba mg/l	Be mg/l	Ca mg/l	Cd mg/l	Co mg/l	Cr mg/l	Cu mg/l	Fe mg/l	K mg/l	Mg mg/l	Mn mg/l	Mo mg/l	Na mg/l	Ni mg/l	P mg/l	Pb mg/l	Sb mg/l	Sr mg/l	Ti mg/l	V mg/l	Zn mg/l
0	0	<0.01	<1	0.45	<0.1	<0.001	110	<0.001	<0.02	<0.02	<0.01	<1	20	10.0	0.71	<0.01	850	<0.01	<1	0.05	<0.05	0.27	<1	<0.01	0.02
1	7	<0.01	<1	0.60	<0.1	<0.001	47	0.001	<0.02	<0.02	<0.01	<1	15	6.70	0.85	<0.01	540	<0.01	<1	<0.05	0.05	0.13	<1	<0.01	0.03
2	14	<0.01	<1	0.45	<0.1	<0.001	15.0	0.007	<0.02	<0.02	<0.01	<1	5	2.1	0.27	0.01	160	0.01	<1	<0.05	<0.05	0.03	<1	<0.01	<0.01
3	21	<0.01	<1	0.55	<0.1	<0.001	7.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.15	<0.01	62	0.01	<1	<0.05	<0.05	0.02	<1	<0.01	0.12
4	28	<0.01	<1	0.40	<0.1	<0.001	6.5	0.002	<0.02	<0.02	0.01	<1	<5	1.05	0.12	<0.01	25	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.03
5	35	<0.01	<1	0.50	<0.1	<0.001	8.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.05	0.15	<0.01	16	<0.01	<1	<0.05	0.05	0.06	<1	<0.01	<0.01
6	42	<0.01	<1	0.30	<0.1	<0.001	7.5	0.002	<0.02	<0.02	<0.01	<1	<5	1.10	0.13	<0.01	8	<0.01	<1	0.05	0.05	<0.01	<1	<0.01	0.01
7	49	<0.01	<1	0.25	<0.1	<0.001	9.0	0.001	<0.02	<0.02	0.01	<1	<5	1.00	0.13	<0.01	7	<0.01	<1	0.15	<0.05	0.03	<1	<0.01	0.13
8	56	<0.01	<1	0.25	<0.1	<0.001	9.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.13	<0.01	5	<0.01	<1	<0.05	<0.05	0.03	<1	<0.01	0.02
9	63	<0.01	<1	0.20	<0.1	<0.001	10.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.16	<0.01	4	<0.01	<1	<0.05	<0.05	0.03	<1	<0.01	<0.01
10	70	<0.01	<1	0.10	<0.1	<0.001	8.5	<0.001	<0.02	<0.02	<0.01	<1	<5	1.10	0.13	<0.01	3	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	<0.01
11	77	<0.01	<1	0.20	<0.1	<0.001	11.5	<0.001	<0.02	<0.02	<0.01	<1	<5	1.05	0.16	<0.01	3	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.03
12	84	<0.01	<1	0.15	<0.1	<0.001	10.5	<0.001	<0.02	<0.02	<0.01	<1	<5	1.05	0.14	<0.01	2	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	<0.01
13	91	<0.01	<1	0.15	<0.1	<0.001	10.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.15	<0.01	2	<0.01	<1	0.05	<0.05	0.01	<1	<0.01	0.15
14	98	<0.01	1	0.15	<0.1	<0.001	10.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.15	<0.01	3	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.07
15	105	<0.01	<1	0.15	<0.1	<0.001	10.5	<0.001	<0.02	<0.02	<0.01	<1	<5	1.10	0.14	<0.01	2	<0.01	<1	<0.05	<0.05	0.03	<1	<0.01	0.39
16	112	<0.01	1	0.10	<0.1	<0.001	10.0	0.002	<0.02	<0.02	<0.01	<1	<5	1.00	0.15	<0.01	2	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.05
17	119	<0.01	<1	0.15	<0.1	<0.001	9.5	0.004	<0.02	<0.02	<0.01	<1	<5	1.15	0.14	<0.01	1	<0.01	<1	<0.05	<0.05	0.02	<1	<0.01	0.02
18	126	<0.01	<1	0.05	<0.1	<0.001	9.5	0.001	<0.02	<0.02	<0.01	<1	<5	1.10	0.14	<0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.11
19	133	<0.01	<1	0.20	<0.1	<0.001	9.5	<0.001	<0.02	<0.02	<0.01	<1	<5	1.10	0.12	<0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.02
20	140	<0.01	<1	0.15	<0.1	<0.001	10.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.16	0.01	1	0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.43
22	154	<0.01	<1	0.10	<0.1	<0.001	13.0	0.004	<0.02	<0.02	<0.01	<1	<5	1.15	0.16	<0.01	2	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	<0.01
24	168	<0.01	<1	0.10	<0.1	<0.001	8.0	0.004	<0.02	<0.02	<0.01	<1	<5	1.00	0.13	<0.01	<1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.03
26	182	<0.01	<1	0.05	<0.1	<0.001	12.0	0.001	<0.02	<0.02	<0.01	<1	<5	1.10	0.16	<0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.01
28	196	<0.01	<1	0.05	<0.1	<0.001	18.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.23	<0.01	<1	<0.01	<1	0.10	<0.05	0.01	<1	<0.01	0.03
30	210	<0.01	<1	0.05	<0.1	<0.001	16.0	0.001	<0.02	<0.02	<0.01	<1	5	1.00	0.20	0.01	<1	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.02
Final Rinse	287	<0.01	<1	<0.05	<0.1	<0.001	47.0	<0.001	<0.02	<0.02	<0.01	<1	5	2.00	0.49	<0.01	2	<0.01	<1	<0.05	<0.05	0.03	<1	<0.01	0.03

International Metallurgical and Environmental Inc.
Humidity Cell Test Data

Project Name: Lupin
Test Sample: B1 @ room temp.
Sample Weight: 2001.3g
Start Date: Feb 18, 1997

Cycle	Days	Weight Added (g)	Weight Rec. (g)	pH	Acidity (mg $CaCO_3$/l)	Alkalinity (mg $CaCO_3$/l)	SO_4 (mg/l)	Conductivity (μmhos)	Redox Potential (mV)
0	0	500	322	7.47	0.96	24	26	5100	207
1	7	500	512	7.44	4.6	33	24	2700	117
2	14	500	492	7.67	2.4	32	29	950	71
3	21	500	503	7.56	1.8	31	28	355	76
4	28	500	504	7.44	2.5	28	28	200	55
5	35	500	501	7.62	1.8	24	20	130	186
6	42	500	494	7.28	1.9	20	19	105	135
7	49	500	505	7.53	1.8	18	21	110	112
8	56	500	496	7.48	1.3	19	18	75	116
9	63	500	500	7.59	1.7	19	15	77	159
10	70	500	505	7.46	1.4	16	22	91	103
11	77	500	505	7.48	2.1	16	21	85	120
12	84	500	492	7.48	1.1	15	23	80	96
13	91	500	494	7.48	0.94	16	18	75	99
14	98	500	498	7.51	1.0	19	15	70	107
15	105	500	496	7.60	1.4	18	14	67	106
16	112	500	503	7.59	1.3	16	14	63	116
17	119	500	504	7.34	1.5	15	14	65	N/A
18	126	500	501	7.34	1.5	18	15	75	200
19	133	500	500	7.24	1.6	15	13	59	125
20	140	500	494	7.29	1.8	18	16	66	164
22	154	1000	1002	7.44	1.6	15	10	59	185
24	168	1000	996	7.36	1.9	15	12	62	200
26	182	1000	999	7.43	1.8	14	21	90	231
28	196	1000	1013	7.33	1.8	13	38	125	220
30	210	1000	997	7.40	1.9	15	36	117	247
41	287	500	464	7.15	2.1	11	145	380	156

International Metallurgical and Environmental Inc.
Humidity Cell Test Data

Project Name: Lupin
Test Sample: B2 @ 4 C
Sample Weight: 2001.5g
Start Date: Feb 25, 1997

Cycle	Days	Weight Added (g)	Weight Rec. (g)	pH	Acidity (mg $CaCO_3$/l)	Alkalinity (mg $CaCO_3$/l)	SO_4 (mg/l)	Conductivity (µmhos)	Redox Potential (mV)
0	0	500	252	7.04	0.63	17	8.6	54	120
1	7	500	510	7.63	2.6	19	18	190	118
2	14	500	502	7.60	2.4	29	16	145	119
3	21	500	509	7.54	3.1	16	17	110	103
4	28	500	506	7.70	1.9	26	13	100	160
5	35	500	488	7.47	1.7	23	11	79	140
6	42	500	514	7.49	2.8	25	10	70	137
7	49	500	505	7.65	1.6	23	9.4	59	133
8	56	500	504	7.67	1.7	21	7.7	59	163
9	63	500	488	7.65	1.9	23	7.8	63	119
10	70	500	501	7.74	1.9	23	6.5	60	130
11	77	500	488	7.57	1.6	21	4.9	54	114
12	84	500	517	7.58	1.4	21	6.1	58	112
13	91	500	477	7.61	1.5	22	7.1	53	111
14	98	500	485	7.76	1.6	24	5.5	60	123
15	105	500	489	7..65	1.5	23	4.6	50	129
16	112	500	495	7.46	1.6	22	3.7	52	N/A
17	119	500	496	7.53	1.5	25	3.9	55	161
18	126	500	494	7.50	1.8	20	3.1	45	126
19	133	500	498	7.60	1.5	24	2.8	50	162
20	140	500	499	7.63	1.2	22	3.2	46	181
22	154	1000	998	7.62	2.1	21	3.6	46	105
24	168	1000	997	7.52	2.1	22	3.0	50	206
26	182	1000	1006	7.70	2.2	21	3.4	45	218
28	196	1000	1009	7.49	1.9	20	3.7	47	127
30	210	1000	996	7.43	3.4	20	2.8	47	193
40	280	500	449	7.40	3.1	17	11.0	55	167

International Metallurgical and Environmental Inc.
Humidity Cell Test Data

Project Name: Lupin
Test Sample: B2 @ 4 C
Sample Weight: 2001.5g
Start Date: Feb 25, 1997

Cycle	Days	Ag mg/l	Al mg/l	As mg/l	Ba mg/l	Be mg/l	Ca mg/l	Cd mg/l	Co mg/l	Cr mg/l	Cu mg/l	Fe mg/l	K mg/l	Mg mg/l	Mn mg/l	Mo mg/l	Na mg/l	Ni mg/l	P mg/l	Pb mg/l	Sb mg/l	Sr mg/l	Ti mg/l	V mg/l	Zn mg/l
0	0	<0.01	<1	0.05	<0.1	<0.001	5.0	0.003	<0.02	<0.02	<0.01	<1	<5	1.10	0.01	<0.01	7	<0.01	<1	<.0.05	<0.05	<0.01	<1	<0.01	0.03
1	7	<0.01	<1	<0.05	<0.1	<0.001	14.0	0.001	<0.02	<0.02	<0.01	<1	5	3.1	0.30	<0.01	12	0.01	<1	<.0.05	<0.05	0.03	<1	<0.01	<0.01
2	14	<0.01	<1	<0.05	<0.1	<0.001	10.0	<0.001	<0.02	<0.02	<0.01	<1	<5	3.0	0.32	<0.01	9	<0.01	<1	<.0.05	<0.05	0.03	<1	<0.01	<0.01
3	21	<0.01	<1	<0.05	<0.1	<0.001	9.5	<0.001	<0.02	<0.02	<0.01	<1	<5	2.2	0.33	<0.01	5	<0.01	<1	<.0.05	<0.05	0.04	<1	<0.01	0.01
4	28	<0.01	<1	<0.05	<0.1	<0.001	10.0	0.001	<0.02	<0.02	<0.01	<1	<5	2.1	0.36	<0.01	4	<0.01	<1	<.0.05	<0.05	0.06	<1	<0.01	<0.01
5	35	<0.01	<1	<0.05	<0.1	<0.001	7.5	<0.001	<0.02	<0.02	<0.01	<1	<5	2.3	0.29	<0.01	2	<0.01	<1	<.0.05	<0.05	0.01	<1	<0.01	<0.01
6	42	<0.01	<1	<0.05	<0.1	<0.001	8.0	<0.001	<0.02	<0.02	0.01	<1	<5	2.0	0.30	<0.01	2	<0.01	<1	<.0.05	<0.05	0.03	<1	<0.01	0.02
7	49	<0.01	<1	<0.05	<0.1	<0.001	8.0	<0.001	<0.02	<0.02	<0.01	<1	<5	2.0	0.28	<0.01	2	<0.01	<1	<.0.05	<0.05	0.02	<1	<0.01	<0.01
8	56	<0.01	<1	<0.05	<0.1	<0.001	8.0	<0.001	<0.02	<0.02	<0.01	<1	<5	2.1	0.27	<0.01	2	<0.01	<1	<.0.05	<0.05	0.04	<1	<0.01	<0.01
9	63	<0.01	<1	<0.05	<0.1	<0.001	7.5	<0.001	<0.02	<0.02	<0.01	<1	<5	2.2	0.28	<0.01	1	<0.01	<1	<.0.05	<0.05	0.01	<1	<0.01	<0.01
10	70	<0.01	<1	<0.05	<0.1	<0.001	8.5	<0.001	<0.02	<0.02	<0.01	<1	<5	2.1	0.30	<0.01	1	<0.01	<1	<.0.05	<0.05	<0.01	<1	<0.01	0.01
11	77	<0.01	<1	<0.05	<0.1	<0.001	7.5	<0.001	<0.02	<0.02	<0.01	<1	<5	1.05	0.27	<0.01	1	<0.01	<1	<.0.05	<0.05	<0.01	<1	<0.01	0.01
12	84	<0.01	<1	<0.05	<0.1	<0.001	8.0	<0.001	<0.02	<0.02	<0.01	<1	<5	2.0	0.30	0.02	1	<0.01	<1	0.05	<0.05	0.03	<1	<0.01	<0.01
13	91	<0.01	<1	0.05	<0.1	<0.001	7.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.27	<0.01	2	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.03
14	98	<0.01	<1	0.05	<0.1	<0.001	7.5	<0.001	<0.02	<0.02	<0.01	<1	<5	1.10	0.28	<0.01	1	0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.06
15	105	<0.01	<1	<0.05	<0.1	<0.001	7.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.32	<0.01	1	<0.01	<1	0.05	<0.05	0.01	<1	<0.01	0.05
16	112	<0.01	<1	<0.05	<0.1	<0.001	7.5	<0.001	<0.02	<0.02	<0.01	<1	<5	1.15	0.31	<0.01	1	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.05
17	119	<0.01	<1	<0.05	<0.1	<0.001	8.5	<0.001	<0.02	<0.02	<0.01	<1	<5	1.10	0.35	<0.01	1	0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	23
18	126	<0.01	<1	<0.05	<0.1	<0.001	7.5	0.002	<0.02	<0.02	<0.01	<1	<5	1.10	0.31	0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	<0.01
19	133	<0.01	<1	0.05	<0.1	<0.001	7.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.32	<0.01	1	0.01	<1	<0.05	<0.05	0.02	<1	<0.01	0.08
20	140	<0.01	<1	<0.05	<0.1	<0.001	9.0	0.009	<0.02	<0.02	<0.01	<1	<5	1.15	0.33	<0.01	1	0.01	<1	0.15	<0.05	0.01	<1	<0.01	0.10
22	154	<0.01	<1	<0.05	<0.1	<0.001	7.5	0.004	<0.02	<0.02	<0.01	<1	<5	1.15	0.34	<0.01	1	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.13
24	168	<0.01	1	<0.05	<0.1	<0.001	8.5	<0.001	<0.02	<0.02	<0.01	<1	<5	1.10	0.35	0.01	<1	0.01	<1	<0.05	0.05	0.01	<1	<0.01	0.01
26	182	<0.01	<1	<0.05	<0.1	<0.001	7.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.32	<0.01	1	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.01
28	196	<0.01	<1	0.05	<0.1	<0.001	7.0	<0.001	<0.02	<0.02	0.65	<1	<5	1.00	0.28	<0.01	<1	0.10	<1	0.05	<0.05	<0.01	<1	<0.01	0.02
30	210	<0.01	<1	<0.05	<0.1	<0.001	7.0	<0.001	<0.02	<0.02	0.11	<1	<5	1.00	0.30	<0.01	<1	0.04	<1	<0.05	<0.05	<0.01	<1	<0.01	0.01
Final Rinse	280	<0.01	<1	<0.05	<0.1	<0.001	7.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.29	<0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	<0.01

International Metallurgical and Environmental Inc.
Humidity Cell Test Data

Project Name: Lupin
Test Sample: B2 @ room temp.
Sample Weight: 2001.5g
Start Date: Feb 18, 1997

Cycle	Days	Weight Added (g)	Weight Rec. (g)	pH	Acidity (mg $CaCO_3$/l)	Alkalinity (mg $CaCO_3$/l)	SO_4 (mg/l)	Conductivity (μmhos)	Redox Potential (mV)
0	0	500	278	7.13	0.24	20	32	212	120
1	7	500	477	7.29	3.6	23	54	225	127
2	14	500	484	7.40	2.1	21	45	180	96
3	21	500	484	7.39	2.2	19	37	150	81
4	28	500	487	7.31	2.3	18	34	125	90
5	35	500	488	7.46	1.6	16	26	124	191
6	42	500	483	7.27	1.4	18	23	100	142
7	49	500	486	7.46	1.9	16	23	100	129
8	56	500	481	7.40	1.3	16	21	75	130
9	63	500	498	7.60	2.1	17	20	80	157
10	70	500	504	7.44	1.6	16	21	85	105
11	77	500	490	7.45	1.3	16	24	90	125
12	84	500	469	7.44	1.3	13	21	79	110
13	91	500	486	7.49	1.4	16	20	75	100
14	98	500	491	7.53	1.0	18	19	79	111
15	105	500	486	7.57	1.4	17	16	69	124
16	112	500	484	7.49	1.6	15	16	65	122
17	119	500	496	7.41	1.0	17	21	76	N/A
18	126	500	493	7.28	1.1	17	18	70	200
19	133	500	497	7.31	1.3	16	16	65	121
20	140	500	502	7.36	1.1	17	17	69	176
22	154	1000	988	7.42	1.8	15	15	64	186
24	168	1000	995	7.38	1.9	16	16	70	181
26	182	1000	996	7.40	1.4	16	19	85	225
28	196	1000	1002	7.34	1.9	15	15	67	217
30	210	1000	1004	7.45	2.2	15	13	64	229
41	287	500	440	7.10	2.8	10	69	220	158

International Metallurgical and Environmental Inc.
Humidity Cell Test Data

Project Name: Lupin
Test Sample: B2 @ room temp.
Sample Weight: 2001.5g
Start Date: Feb 18, 1997

Cycle	Days	Ag	Al	As	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	Sb	Sr	Ti	V	Zn
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
0	0	<0.01	<1	<0.05	<0.1	<0.001	18.5	<0.001	<0.02	<0.02	<0.01	<1	5	2.8	0.04	<0.01	10	<0.01	<1	<0.05	<0.05	0.05	<1	<0.01	<0.01
1	7	<0.01	<1	0.05	<0.1	<0.001	17.5	0.002	<0.02	<0.02	<0.01	<1	5	4.5	0.46	<0.01	14	<0.01	<1	<0.05	<0.05	0.03	<1	<0.01	<0.01
2	14	<0.01	<1	<0.05	<0.1	<0.001	14.0	0.002	<0.02	<0.02	<0.01	<1	5	4.2	0.42	<0.01	8	<0.01	<1	<0.05	<0.05	0.05	<1	<0.01	0.05
3	21	<0.01	<1	<0.05	<0.1	<0.001	12.0	0.001	<0.02	<0.02	<0.01	<1	5	4.0	0.40	<0.01	6	0.01	<1	<0.05	<0.05	0.05	<1	<0.01	0.67
4	28	<0.01	<1	<0.05	<0.1	<0.001	10.5	0.003	<0.02	<0.02	<0.01	<1	<5	3.2	0.33	<0.01	4	<0.01	<1	<0.05	<0.05	0.04	<1	<0.01	0.01
5	35	<0.01	<1	<0.05	<0.1	<0.001	11.0	<0.001	<0.02	<0.02	<0.01	<1	<5	3.2	0.33	<0.01	4	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	<0.01
6	42	<0.01	<1	<0.05	<0.1	<0.001	9.0	0.002	<0.02	<0.02	<0.01	<1	<5	2.3	0.25	<0.01	2	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.01
7	49	<0.01	<1	<0.05	<0.1	<0.001	9.0	<0.001	<0.02	<0.02	<0.01	<1	<5	2.0	0.23	<0.01	2	<0.01	<1	<0.05	<0.05	0.02	<1	<0.01	0.09
8	56	<0.01	<1	<0.05	<0.1	<0.001	9.0	<0.001	<0.02	<0.02	<0.01	<1	<5	2.0	0.22	<0.01	2	<0.01	<1	<0.05	<0.05	0.04	<1	<0.01	<0.01
9	63	<0.01	<1	<0.05	<0.1	<0.001	11.0	<0.001	<0.02	<0.02	<0.01	<1	<5	2.1	0.26	<0.01	2	<0.01	<1	<0.05	<0.05	0.04	<1	<0.01	0.01
10	70	<0.01	<1	<0.05	<0.1	<0.001	8.5	<0.001	<0.02	<0.02	<0.01	<1	<5	2.2	0.21	<0.01	2	<0.01	<1	<0.05	0.10	0.01	<1	<0.01	<0.01
11	77	<0.01	<1	<0.05	<0.1	<0.001	11.5	0.001	<0.02	<0.02	<0.01	<1	<5	2.1	0.23	<0.01	2	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.03
12	84	<0.01	<1	<0.05	<0.1	<0.001	8.5	0.001	<0.02	<0.02	<0.01	<1	<5	1.05	0.16	<0.01	1	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.01
13	91	<0.01	<1	<0.05	<0.1	<0.001	10.0	0.003	<0.02	<0.02	<0.01	<1	<5	2.0	0.21	<0.01	2	<0.01	<1	<0.05	<0.05	0.03	<1	<0.01	<0.01
14	98	<0.01	<1	<0.05	<0.1	<0.001	9.0	<0.001	<0.02	<0.02	<0.01	<1	<5	2.0	0.19	<0.01	2	<0.01	<1	<0.05	0.05	0.01	<1	<0.01	0.01
15	105	<0.01	<1	<0.05	<0.1	<0.001	9.5	0.002	<0.02	<0.02	<0.01	<1	<5	1.10	0.17	<0.01	1	0.01	<1	<0.05	<0.05	0.03	<1	<0.01	0..34
16	112	<0.01	1	<0.05	<0.1	<0.001	10.0	0.002	<0.02	<0.02	<0.01	<1	<5	1.00	0.18	<0.01	1	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.09
17	119	<0.01	<1	<0.05	<0.1	<0.001	12.0	<0.001	<0.02	<0.02	<0.01	<1	<5	2.3	0.20	<0.01	1	<0.01	<1	<0.05	<0.05	0.02	<1	<0.01	0.03
18	126	<0.01	<1	<0.05	<0.1	<0.001	9.5	0.003	<0.02	<0.02	<0.01	<1	<5	1.10	0.17	<0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	<0.01
19	133	<0.01	<1	<0.05	<0.1	<0.001	10.5	<0.001	<0.02	<0.02	<0.01	<1	<5	1.10	0.18	<0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.13
20	140	<0.01	<1	<0.05	<0.1	<0.001	9.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.15	<0.01	1	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.04
22	154	<0.01	<1	<0.05	<0.1	<0.001	11.0	0.004	<0.02	<0.02	<0.01	<1	<5	1.15	0.16	<0.01	1	<0.01	<1	0.05	<0.05	0.01	<1	<0.01	<0.01
24	168	<0.01	<1	<0.05	<0.1	<0.001	9.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.15	<0.01	<1	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.03
26	182	<0.01	<1	<0.05	<0.1	<0.001	11.0	0.001	<0.02	<0.02	<0.01	<1	<5	1.10	0.15	0.01	1	<0.01	<1	<0.05	<0.05	0.02	<1	<0.01	0.02
28	196	<0.01	<1	<0.05	<0.1	<0.001	10.0	<0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.12	<0.01	<1	<0.01	<1	0.05	<0.05	0.01	<1	<0.01	0.03
30	210	<0.01	<1	<0.05	<0.1	<0.001	9.0	0.001	<0.02	<0.02	<0.01	<1	<5	1.00	0.10	<0.01	<1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.03
Final Rinse	287	<0.01	<1	<0.05	<0.1	<0.001	24.0	<0.001	<0.02	<0.02	<0.01	<1	<5	2.00	0.23	<0.01	1	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	0.02

International Metallurgical and Environmental Inc.
Humidity Cell Test Data

Project Name: Lupin
Test Sample: B3
Sample Weight: 2001.3g
Start Date: Feb 18, 1997

Cycle	Days	Weight Added (g)	Weight Rec. (g)	pH	Acidity (mg $CaCO_3$/l)	Alkalinity (mg $CaCO_3$/l)	SO_4 (mg/l)	Conductivity (µmhos)	Redox Potential (mV)
0	0	500	39	7.4	ins	ins	ins	>10000	75
1	7	500	498	7.93	8.1	159	161	>10000	75
2	14	500	487	8.44	<.1	182	78	875	81
3	21	500	485	8.22	3.8	103	46	655	89
4	28	500	488	8.02	5.1	90	49	350	75
5	35	500	485	8.12	3.3	76	31	280	160
6	42	500	484	7.93	3.1	63	31	245	136
7	49	500	481	7.97	2.8	67	32	245	116
8	56	500	484	8.01	1.9	58	38	230	126
9	63	500	483	8.10	2.1	54	36	220	148
10	70	500	489	8.06	2.8	59	39	225	107
11	77	500	481	8.08	2.8	60	40	225	126
12	84	500	476	7.96	2.1	60	43	235	86
13	91	500	485	8.01	1.4	53	37	210	114
14	98	500	490	8.01	1.4	55	32	200	116
15	105	500	479	8.10	1.9	54	33	200	117
16	112	500	491	8.06	1.8	54	30	200	125
17	119	500	498	7.90	1.4	54	30	190	N/A
18	126	500	494	7.90	1.7	51	28	190	142
19	133	500	498	7.76	1.3	48	36	180	117
20	140	500	498	7.90	1.8	49	40	215	146
22	154	1000	1002	7.96	2.6	46	53	230	171
24	168	1000	991	7.85	2.8	47	61	251	172
26	182	1000	998	7.89	1.6	51	70	275	220
28	196	1000	1004	7.85	2.2	48	50	225	190
30	210	1000	999	7.97	2.3	47	53	228	224
41	287	500	471	7.72	5.0	41	857	1700	160

International Metallurgical and Environmental Inc.
Humidity Cell Test Data

Project Name: Lupin
Test Sample: B3
Sample Weight: 2001.3g
Start Date: Feb 18, 1997

Cycle	Days	Ag mg/l	Al mg/l	As mg/l	Ba mg/l	Be mg/l	Ca mg/l	Cd mg/l	Co mg/l	Cr mg/l	Cu mg/l	Fe mg/l	K mg/l	Mg mg/l	Mn mg/l	Mo mg/l	Na mg/l	Ni mg/l	P mg/l	Pb mg/l	Sb mg/l	Sr mg/l	Ti mg/l	V mg/l	Zn mg/l
0	0	<0.01	<1	1.65	1.3	0.001	1030	0.019	<0.02	<0.02	0.03	<1	470	150	22	0.07	>5000	0.12	1	<.0.05	0.35	3.2	<1	<0.01	0.45
1	7	<0.01	<1	2.1	0.9	0.002	300	<0.001	<0.02	<0.02	0.47	1	165	51	6.9	0.11	>5000	0.08	1	0.75	0.05	0.91	<1	0.01	0.84
2	14	<0.01	<1	2.5	<0.1	<0.001	7.5	0.003	<0.02	<0.02	<0.01	<1	15	1.05	0.24	0.07	150	0.01	<1	<.0.05	<0.05	0.02	<1	<0.01	0.01
3	21	<0.01	<1	2.1	<0.1	<0.001	10.0	<0.001	<0.02	<0.02	<0.01	<1	20	2.0	0.38	0.01	105	0.01	<1	<.0.05	<0.05	0.03	<1	<0.01	0.03
4	28	<0.01	<1	2.0	<0.1	<0.001	11.5	0.001	<0.02	<0.02	<0.01	<1	10	2.2	0.41	0.01	37	<0.01	<1	<.0.05	<0.05	0.01	<1	<0.01	0.01
5	35	<0.01	<1	2.2	<0.1	<0.001	17.5	0.001	<0.02	<0.02	<0.01	<1	15	3.2	0.53	<0.01	22	<0.01	<1	<.0.05	0.05	<0.01	<1	<0.01	<0.01
6	42	<0.01	<1	1.85	<0.1	<0.001	17.5	0.001	<0.02	<0.02	0.01	<1	10	3.4	0.48	0.01	10	<0.01	<1	<.0.05	<0.05	0.01	<1	<0.01	0.01
7	49	<0.01	<1	1.55	<0.1	<0.001	23	<0.001	<0.02	<0.02	<0.01	<1	10	3.0	0.58	<0.01	8	0.01	<1	<.0.05	<0.05	0.05	<1	<0.01	0.20
8	56	<0.01	<1	1.90	<0.1	<0.001	22	<0.001	<0.02	<0.02	<0.01	<1	10	3.0	0.51	0.01	7	<0.01	<1	<.0.05	<0.05	0.02	<1	<0.01	0.02
9	63	<0.01	<1	2.0	<0.1	<0.001	28	<0.001	<0.02	<0.02	<0.01	<1	10	3.1	0.56	<0.01	6	<0.01	<1	<.0.05	<0.05	0.08	<1	<0.01	0.01
10	70	<0.01	<1	1.80	<0.1	<0.001	26	<0.001	<0.02	<0.02	<0.01	<1	10	3.3	0.62	<0.01	5	0.01	<1	<.0.05	<0.05	0.02	<1	<0.01	0.10
11	77	<0.01	<1	1.95	<0.1	<0.001	30	<0.001	<0.02	<0.02	<0.01	<1	10	4.3	0.67	<0.01	4	<0.01	<1	<.0.05	<0.05	0.03	<1	<0.01	0.01
12	84	<0.01	<1	1.75	<0.1	<0.001	28	<0.001	<0.02	<0.02	<0.01	<1	10	3.2	0.61	<0.01	4	<0.01	<1	<.0.05	<0.05	0.01	<1	<0.01	0.01
13	91	<0.01	<1	1.95	<0.1	<0.001	27	<0.001	<0.02	<0.02	<0.01	<1	10	3.0	0.52	0.01	4	<0.01	<1	0.05	<0.05	0.03	<1	<0.01	0.02
14	98	<0.01	<1	1.70	<0.1	<0.001	25	<0.001	<0.02	<0.02	<0.01	<1	10	3.0	0.44	<0.01	4	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.03
15	105	<0.01	<1	1.80	<0.1	<0.001	25	<0.001	<0.02	<0.02	<0.01	<1	5	2.2	0.46	<0.01	3	0.01	<1	<0.05	<0.05	0.02	<1	<0.01	0.24
16	112	<0.01	<1	1.70	<0.1	<0.001	28	<0.001	<0.02	<0.02	<0.01	<1	10	2.0	0.50	<0.01	3	0.01	<1	0.05	<0.05	0.02	<1	<0.01	0.07
17	119	<0.01	<1	1.85	<0.1	<0.001	25	<0.001	<0.02	<0.02	<0.01	<1	10	2.3	0.41	<0.01	2	<0.01	<1	<0.05	<0.05	0.02	<1	<0.01	0.09
18	126	<0.01	<1	2.1	<0.1	<0.001	27	0.001	<0.02	<0.02	<0.01	<1	10	2.2	0.42	<0.01	3	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.40
19	133	<0.01	<1	1.70	<0.1	<0.001	23	0.004	<0.02	<0.02	<0.01	<1	5	2.2	0.34	<0.01	3	<0.01	<1	<0.05	<0.05	<0.01	<1	<0.01	<0.01
20	140	<0.01	<1	1.50	<0.1	<0.001	26	0.007	<0.02	<0.02	<0.01	<1	10	2.0	0.39	0.01	2	<0.01	<1	0.35	<0.05	0.02	<1	<0.01	0.06
22	154	<0.01	<1	1.45	<0.1	<0.001	34	0.008	<0.02	<0.02	<0.01	<1	10	2.4	0.44	<0.01	2	<0.01	<1	<0.05	<0.05	0.03	<1	<0.01	0.31
24	168	<0.01	<1	1.20	<0.1	<0.001	33	<0.001	<0.02	<0.02	<0.01	<1	15	2.0	0.46	<0.01	1	<0.01	<1	<0.05	<0.05	0.03	<1	<0.01	0.07
26	182	<0.01	<1	1.40	<0.1	<0.001	42	0.003	<0.02	<0.02	<0.01	<1	15	2.3	0.48	0.01	2	<0.01	<1	<0.05	<0.05	0.03	<1	<0.01	0.02
28	196	<0.01	<1	1.10	<0.1	<0.001	32	<0.001	<0.02	<0.02	<0.01	<1	10	1.00	0.29	<0.01	1	<0.01	<1	<0.05	<0.05	0.01	<1	<0.01	0.03
30	210	<0.01	<1	1.20	<0.1	<0.001	33	<0.001	<0.02	<0.02	<0.01	<1	15	1.00	0.26	<0.01	<1	<0.01	<1	<0.05	<0.05	0.03	<1	<0.01	0.02
Final Rinse	287	<0.01	<1	0.35	<0.1	<0.001	280	<0.001	<0.02	<0.02	<0.01	<1	45	12	2.4	0.01	6	<0.01	<1	<0.05	<0.05	0.19	<1	<0.01	0.03

Water samples from field columns

Coulmn #	Ulu #1			Ulu #2			Occ 8
Set up date	97/01/15			97/01/15			97/01/15
Sample weight (kg)	15			15			12
Composition	Ore samples from V5/V6 Zone, 25-m Level 0.25 oz/t Au; only >1.5 mm particles used			Duplicate of Ulu #1			1/2 KC-2 and 1/2 KC-4 >1.5 mm material used
Date of collection	97/06/18	97/08/27	97/09/12	97/06/18	97/08/27	97/09/12	97/09/12
Sample #	Ulu-1A	Ulu-1B	Ulu-1C	Ulu-2A	Ulu-2B	Ulu-2C	Occ8
Volume of leachate (ml)	1400	450 (est)	400 (est)	1650	450 (est)	400 (est)	400 (est)
Temperature (deg. C)	11.4	11.3	nd	11.3	11.3	nd	nd
Leachate pH	7.67	7.26	nd	7.72	7.62	nd	nd
Conductivity (uS/cm)	9.14	3250	nd	10.1	2220	nd	nd

International Metallurgical and Environmental Inc.

Project Name: Klohn Crippen -Lupin
Date: December 5, 1997

Sample	pH	Acidity (mg $CaCO_3$/l)	Alkalinity (mg $CaCO_3$/l)	SO_4 (mg/l)	Conductivity (µmhos)
ULU-1A	7.67	16	49	84	8500
ULU-2A	7.59	19	39	88	9000
ULU-1B	7.74	7.1	40	192	3200
ULU-2B	7.46	9.0	23	151	2100
ULU-1C	7.70	7.5	45	240	4750
ULU-2C	7.81	21	54	209	3700
OCC 8	7.03	4.8	7.7	229	540

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International Metallurgical and Environmental Inc.

ICP Analysis Summary

Project: Klohn-Crippen
Mine: Lupin
Date: December 18,1997

Sample	Ag mg/l	Al mg/l	As mg/l	Ba mg/l	Be mg/l	Ca mg/l	Cd mg/l	Co mg/l	Cr mg/l	Cu mg/l	Fe mg/l	K mg/l	Mg mg/l	Mn mg/l	Mo mg/l	Na mg/l	Ni mg/l	P mg/l	Pb mg/l	Sb mg/l	Sr mg/l	Ti mg/l	V mg/l	Zn mg/l
ULU-1A	<0.01	<1	0.25	<0.01	<0.001	130	0.003	<0.02	<0.02	<0.01	<1	40	19.0	4.1	0.01	1510	<0.01	<1	<0.05	0.05	0.41	<1	<0.01	0.16
ULU-2A	<0.01	<1	0.20	<0.01	<0.001	135	0.002	<0.02	<0.02	<0.01	<1	45	20	4.9	<0.01	1630	<0.01	<1	<0.05	0.05	0.42	<1	<0.01	0.04
ULU-1B	<0.01	<1	0.40	<0.01	<0.001	96	<0.001	<0.02	<0.02	<0.01	<1	20	11.0	1.80	<0.01	560	<0.01	<1	<0.05	0.05	0.19	<1	<0.01	0.05
ULU-2B	<0.01	<1	0.45	<0.01	<0.001	71	<0.001	<0.02	<0.02	<0.01	<1	15	8.0	1.55	<0.01	360	<0.01	<1	<0.05	0.10	0.11	<1	<0.01	0.01
ULU-1C	<0.01	<1	0.30	<0.01	<0.001	165	<0.001	<0.02	<0.02	<0.01	<1	30	20	3.0	0.01	850	<0.01	<1	<0.05	0.05	0.34	<1	<0.01	0.07
ULU-2C	<0.01	<1	0.25	<0.01	<0.001	120	<0.001	<0.02	<0.02	<0.01	<1	20	15.0	3.3	<0.01	660	<0.01	<1	<0.05	0.10	0.21	<1	<0.01	0.03
OCC-8	<0.01	<1	<0.05	<0.01	<0.001	44	<0.001	<0.02	<0.02	<0.01	<1	30	24	0.19	<0.01	11	0.01	<1	<0.05	0.05	0.11	<1	<0.01	<0.01