



Date: 2026-06-29

**Written Submission from
Orano Canada Inc.**

**Mémoire d'
Orano Canada Inc.**

In the matter of

À l'égard d'

Orano Canada Inc.

Application to renew the McClean Lake
Operating Licence for 2-year term

Orano Canada Inc.

Demande pour le renouvellement du
permis d'exploitation de McClean Lake
pour une période de deux ans

**Hearing in writing based on written
submissions**

**Audience par écrit fondée sur des
mémoires**

September 2026

Septembre 2026

Appendix C

Section A: Historical Data on Uranium Tailings

1. SUMMARY

COGEMA Resources Inc. (COGEMA), operator of the McClean Lake Project, has applied to the Atomic Energy Control Board (AECB) for approval to construct a tailings management facility (TMF) at the mined-out JEB open pit. AECB's assessment of approval applications has identified outstanding issues which need to be addressed prior to requesting a decision on construction approval. Three of these outstanding issues which relate to tailings pore water contaminant concentrations, in particular the arsenic source term, are:

- geochemical and mineralogical analysis of tailings samples,
- results of geochemical modelling of the long-term tailings pore water chemistry for various arsenic reduction alternatives, and
- analysis of the arsenic treatment process that may be incorporated into the mill process circuits.

In order to assist with COGEMA's response to the AECB, Melis Engineering Ltd. (Melis) was commissioned to review the project and file information to collect data on uranium tailings chemistry, particularly as related to uranium, arsenic, nickel and radium. File information on testwork carried out by Minatco Limited on various McClean Lake ores was also reviewed. Permission for use of data proprietary to other clients was obtained as necessary.

The following summarizes observations made from a review of the data obtained on Saskatchewan uranium deposits:

- tailings aging testwork on Midwest pilot plant tailings, which simulated a 10-year aging period, essentially under oxidizing conditions, yielded arsenic levels of 2.1 mg As/L to 15.2 mg As/L in tailings seepage water and 9.6 mg As/L to 31.6 mg As/L in surface runoff water,
- from 10 different sources of tailings test data based on the ammonium sulphate solvent extraction process, made up of 21 individual arsenic analyses, arsenic levels in filtrate from prepared tailings ranged from 0.40 mg As/L to 11.9 mg As/L, with an average of 4.0 mg As/L. There was one anomalously high value (32 mg As/L) in one test program on Midwest ore which, if included in the data, would increase the average tailings filtrate pore water arsenic content to 5.2 mg As/L,
- arsenic levels in filtrate from bulk neutralized tailings prepared on the basis of the strong acid strip solvent extraction process, from eight different sources of test data, made up of 12 arsenic analyses, ranged from 0.43 mg As/L to 48.4 mg As/L for an average of 10.8 mg As/L,

- on average, tailings water prepared on the basis of the strong acid strip process contains higher levels of arsenic than tailings water prepared on the basis of the ammonium sulphate stripping process,
- the arsenic level in tailings pore water prepared from tailings neutralization at pH 8 (average of 16 mg As/L) is approximately one third the arsenic content in pore water prepared from tailings neutralized to pH 11 (average of 44 mg As/L),
- measurements taken on Key Lake tailings in 1985 yielded arsenic analysis of 0.76 mg As/L to 4.6 mg As/L for tailings discharge filtrate, 0.37 mg As/L to 13.0 mg As/L for tailings porewater, and 0.06 mg As/L to 0.07 mg As/L for tailings seepage,
- a 28-day aging test on Midwest tailings, prepared on the basis of the strong acid strip process, showed that arsenic levels stabilized after 7 days at 28 mg As/L, although there was a slight excursion from 28 mg As/L to 32 mg As/L from 14 days to 28 days,
- redissolution tests carried out on pressure filtered Midwest tailings immersed in water (75 g in 500 mL of tailings water) showed that concentrations in the supernatant levelled off after four weeks, to 30 mg As/L to 40 mg As/L,
- a one-year aging test on Midwest/Sue A and B tailings yielded a tailings filtrate analysis of 63 mg As/L,
- a 370-day aging test showed a gradual increase in arsenic content, from 2.8 mg As/L to 18 mg As/L with no barium chloride addition and from 4.5 mg As/L to 15 mg As/L with barium chloride addition,
- the arsenic content in tailings decant water, prepared on the basis of the strong acid strip process, decreased gradually with increasing pH, from 17.0 mg As/L at pH 7.2 to 4.1 mg As/L at pH 11.0,
- the arsenic content in neutralized leach residue filtrate decreased with increasing pH, from 0.64 mg As/L at pH 9 to 0.22 mg As/L at pH 11.5,
- increasing Fe/(As + Mo) ratio in tails water neutralization and treatment greatly reduces arsenic levels in treated water. Ferrous iron and ferric iron appear to be equally effective,
- higher Fe/As ratios in raffinate appear to lead to lower arsenic levels in tailings water in the long term, and
- mineralogical examination of uranium tailings has shown them to be largely a mixture of gypsum and amorphous solids of hydrous oxides and hydroxides, as well as remnant host rock minerals such as quartz and clays.

2. MIDWEST

2.1 Pilot Plant (1981/1982) And Accelerated Tailings Aging Data (1982/1984)

In 1981 and 1982 a major pilot plant program, using ammonium sulphate stripping in the solvent extraction circuit, was undertaken by Canada Wide Mines Limited at Ontario Research Foundation, now called Ortech International (Ortech), in Mississauga, Ontario to develop design criteria for the Midwest uranium project. This program included the deposition of Midwest tailings, approximately nine tonnes in total at a slurry density of 29% to 33% solids(w/w), into a contained tailings containment area, to test the layered tailings concept. Following the deposition of tailings, the tailings facility was monitored by Canada Centre for Mineral and Energy Technology (CANMET) for a period of almost two years, during which time a five-fold accelerated weathering was simulated, including freeze/thaw cycles. It is important to note that this tailings simulation was typically under oxidizing conditions (wetting/drying) and hence the leachate results obtained can likely be considered as a worst case.

The pilot plant feed used in the preparation of these tailings typically assayed 1.87% U to 2.12% U, 3.2% As, 1% Ni and a radium (^{226}Ra) content of 275 Bq/g. Ammonium sulphate stripping was used in the solvent extraction circuit. The following analyses were typical of the tailings during the pilot plant operation and during the accelerated weathering tests:

Ammonium Sulphate Stripping Process - Midwest Pilot Plant Tailings Analyses				
Item	Tailings		Seepage (mg/L or Bq/L)	Runoff (mg/L or Bq/L)
	Solids (% or Bq/g)	Liquid (mg/L or Bq/L)		
Uranium (as U)				
During Pilot Plant Operation	0.25 *	<0.5	-	-
Accelerated Weathering - First 15 months	-	-	0.45 to 1.74	0.75 to 2.34
- Last 7½ months	-	-	1.0 to 1.8	0.48 to 1.2
* high value because of test conditions used in pilot plant evaluation of leaching.				
Arsenic				
During Pilot Plant Operation	2.0 to 2.1	0.4 to 6	1.24 to 3.6	1.35 to 10.9
Accelerated Weathering - First 15 months	-	-	2.1 to 15.2	9.6 to 31.6
- Last 7½ months	2.22	-	8.5 to 12	7.1 to 13
Nickel				
During Pilot Plant Operation	1.2 to 1.5	0.2 to 1	0.1 to 0.5	0.6 to 0.8
Accelerated Weathering - First 15 months	-	-	0.02 to 0.15	0.03 to 0.40
- Last 7½ months	1.26	-	0.10 to 0.33	0.01 to 0.64
Radium -226				
During Pilot Plant Operation	130 to 170	0.37	0.39	0.27
Accelerated Weathering - First 15 months	-	-	0.37 to 1.55	0.16 to 0.59
- Last 7½ months	-	-	2.26	1.48
pH				
During Pilot Plant Operation	-	11	11.6	7.0
Accelerated Weathering - First 15 months	-	-	11.4 to 6.9	6.8 to 7.7
- Last 7½ months	-	-	7.0	7.4

The main conclusions drawn from this test program, which are not in any particular order of importance, were as follows:

- there was some increase in seepage and runoff uranium content but typical levels were in the range of 0.5 mg U/L to 1.8 mg U/L,
- the arsenic in seepage was variable with some spikes but all values were in the range of 1.24 mg As/L to 15.2 mg As/L, except for a flood test which increased the concentration to 45.9 mg As/L,
- the arsenic content in runoff decreased in the first 15 months from about 30 mg As/L to about 10 mg As/L, and leveled off to an average of 11 mg As/L in the last 7½ months,
- the nickel content, which was in the range of 0.02 mg Ni/L to 0.64 mg Ni/L, was generally higher in runoff than in seepage,
- radium content in seepage and runoff rose irregularly during the first 15 months and did not demonstrate a trend in the last 7½ months,
- the radium activity was observed to increase with an increase in fines content,
- the average ratio of arsenic and nickel in tailings was 5 to 3.
- ferric arsenate precipitate was identified as one of the dominant species of the tailings fines, and
- the seepage solution pH declined from pH 11 to pH 7.

2.2 Aging of a Madawaska/Midwest Tailings Mixture (1982)

In order to assess the possibility of disposing Midwest pilot plant tailings into the (formerly operating) Madawaska Mine tailings containment area in Bancroft, Ontario, brief aging tests were completed on a 300/1 blend of Madawaska tailings (<0.06% U, 0.01% As and 0.01% Ni) and Midwest pilot plant tailings (<0.13% U, 3.14% As and 1.52% Ni). The tailings mixture was agitated over a period of 17 days with the pH maintained at pH 8.3 to 8.7. The main intent of this test was to quantify the arsenic concentration in seepage when mixing a small amount of Midwest tailings with the arsenic-free Madawaska tailings.

The arsenic content in the tailings liquid seemed to “plateau” at 0.20 mg As/L to 0.25 mg As/L from an initial value of 0.04 mg As/L, although there was one high value (0.34 mg As/L) after 17 days. The nickel concentration increased to 0.20 mg Ni/L after five days, but decreased to 0.12 mg Ni/L after eight days.

2.3 Bench Scale Testing at Colorado School of Mines Research Institute (CSMRI) (1981)

An extensive bench scale test program was carried out at CSMRI to determine process requirements for the Midwest Project. Part of the testing included bench scale simulation of the layered tailings concept using tailings prepared from a Midwest sample assaying 2% U, 4% As to 5% As and 2% Ni to 2.5% Ni. Ammonium sulphate stripping was used for solvent extraction. Neutralized tailings were prepared by combining neutralized leach residue and precipitates from two stage neutralization/barium chloride treatment of raffinate (with an average content of 2.34 g As/L and 1.23 g Fe/L for an Fe/As ratio of 0.53/1) and seepage and runoff solution. Seven successive layers were placed at two different final tailings pH levels (pH 8 and pH 11) and samples of seepage and runoff were taken for analysis. The following results were obtained:

Ammonium Sulphate Stripping Process - Midwest Bench Scale Layered Tailings Testing - Seepage and Runoff Analysis												
Layer	Seepage						Runoff					
	As (mg/L)		Ni (mg/L)		Ra (Bq/L)		As (mg/L)		Ni (mg/L)		Ra (Bq/L)	
	pH 8	pH 11	pH 8	pH 11	pH 8	pH 11	pH 8	pH 11	pH 8	pH 11	pH 8	pH 11
1	(1)	9	3.0	<0.2	266	139	2.2	6	-	<0.2	115	170
2	5.7	9	9.9	-	108	127	10	13	10	-	167	167
3	5.6	18.7	13.9	<0.02	-	108	10	20	-	<0.02	59	141
4	24	30	19.1	<0.02	52	112	21.3	12	12.6	<0.02	21	97
5	24	75	19.2	0.75	39	117	33	75	7.9	0.9	44	84
6	16	81.3	19.0	1.7	44	103	41.5	-	12.4	-	59	-
7	22	88	20.1	1.6	47	115	-	29	-	0.4	-	50

Note:

1. Anomalous value of 40.5 mg As/L for Layer 1 at pH 8 considered erroneous and is therefore not included in the data.

2.4 Bench Scale Testing for PNC Exploration (Canada) Co. Ltd. (1990)

Testwork was completed for PNC at Lakefield Research Limited in Lakefield, Ontario to compare the ammonium sulphate strip and strong acid strip processes. A 1982 Midwest pilot plant feed sample, which assayed 1.78% U, 3.6% As, 1.8% Ni and 240 Bq/g ²²⁶Ra, was used in this testwork. Tailings were prepared for each process using two stage (pH 5 and pH 11) liquid effluent treatment and final neutralization of resulting precipitates with leach residue at pH 10.5 to pH 11. The total tails supernatant analysis for each test was as follows:

Midwest Total Tails Preparation Analysis (mg/L or Bq/L)				
Analyte	Liquid Effluent		Tailings Supernatant	
	(NH ₄) ₂ SO ₄	Strong Acid	(NH ₄) ₂ SO ₄	Strong Acid
U	372	39	<1	<1
As	4290	3820	0.51	48.4
Ni	2180	1940	0.57	189
Fe ³⁺	820	788	-	-
²²⁶ Ra	-	-	14	33
pH	-	-	10	10
Fe ³⁺ /As Ratio	0.19	0.21	-	-

The high nickel content for the strong acid strip supernatant appears anomalous in light of the high (pH 10.5 to pH 11) neutralization pH.

2.5 Bench Scale Testing for Denison Mines Limited (1990)

Bench scale testwork was completed for Denison Mines Limited at Lakefield Research Limited in Lakefield, Ontario to update the design criteria for the Midwest Project and to generate environmental data for the Midwest Environmental Impact Statement. Tailings were prepared from a strong acid strip process using a composite made up from 1982 pilot plant feed material which assayed 3.99% U, 5.81% As, 3.47% Ni and 500 Bq/g ²²⁶Ra.

Strong Acid Strip Process - Midwest Tailings Analysis					
Item	Supernatant				
	U (mg/L)	As (mg/L)	Ni (mg/L)	²²⁶ Ra (Bq/L)	pH
First Cycle (Test ET7)	<0.5	5.9	20	-	-
Second Cycle (Test ET8)	<0.5	15.0	16	18	-
Large Scale Test (50 kg)	<1	5.02	0.46	14	10.5
Item	Solids				
	U (%)	As (%)	Ni (%)	²²⁶ Ra (Bq/g)	
Large Scale Test (50 kg)	0.041	2.36	1.74	260	-

* supernatant pH <10 due to precipitate with a lower pH added to the final tailings mixture.

The effect of pH on tailings decant water was assessed by increasing the pH of a total tails mixture, prepared on the basis of the strong acid strip process, and measuring the elemental content of tailings decant water. The following results were obtained:

Effect of pH on Midwest Tailings Decant Water Analysis (mg/L)				
pH	U	As	Ni	Mo
7.2	<1	17	5.7	7.5
8.0	<1	14	1.6	9.1
8.5	<1	11	0.6	9.5
9.0	<1	9.5	0.2	10.0
9.5	<1	7.3	<0.1	9.8
10.0	<1	9.0	<0.1	10.0
10.5	<1	5.9	<0.1	9.9
11.0	<1	4.1	<0.1	9.3

2.6 Re-Dissolution Tests (1991)

Tailings tests were completed at Saskatchewan Research Council (SRC) on Midwest tailings made up by Lakefield Research Limited (Lakefield) by processing a 50 kg pilot plant sample using the strong acid strip process. Waste neutralization and treatment involved a two stage treatment circuit and combined neutralization of waste precipitates and tailings to a target pH of 10.5 to produce final tailings. The following analyses were obtained:

Strong Acid Strip Process - Analyses of Midwest Tailings			
Element	Feed (%)	Tails Solids (% or Bq/g)	Tails Filtrate (mg/L or Bq/L)
U	3.99	0.041	0.09
As	5.81	3.20	7.61
Ni	3.47	1.60	0.06
²²⁶ Ra	-	250	30
pH	-	-	8.0

Analyses of tailings filtrate after standing for 0, 7, 14 and 28 days were as follows:

Midwest Tailings Aging Tests - Tails Filtrate Analysis (mg/L)				
Element	0 Days	7 Days	14 Days	28 Days
U	<0.5	<0.5	<0.5	<0.5
As	15	28	28	32
Ni	16	26	27	32

Re-solubility tests were completed on pressure filtered tailings by immersing 75 g of tailings filter cake in 500 mL of water and analyzing the supernatant water after 1, 7, 14, 28, 56 and 84 days.

The following liquid analyses and solid analyses were obtained:

Midwest Tailings Re-solubility Tests - Solids Basis						
Time	As		Ni		²²⁶ Ra	
	%	% Dissolution	%	% Dissolution	Bq/g	% Dissolution
Day 0	3.20	-	1.60	-	250	-
Day 1	3.20	-	1.80	-	250	-
Day 7	3.10	3.1	1.70	-	250	-
Day 14	3.10	3.1	1.70	-	250	-
Day 28	3.00	6.5	1.60	-	250	-
Day 56	3.10	3.1	1.80	-	-	-
Day 84	3.20	-	1.50	6.3	-	-

Midwest Tailings Re-solubility Tests - Liquid Basis						
Time	As		Ni		²²⁶ Ra	
	mg/L	% Dissolution	mg/L	% Dissolution	Bq/L	% Dissolution
Day 0	7.6	-	0.06	-	30	-
Day 1	5.6	0.09	0.30	0.01	15	0.03
Day 7	22.3	0.50	1.2	0.06	26	0.07
Day 14	24.0	0.45	2.2	0.09	25	0.06
Day 28	33.0	0.59	4.2	0.15	24	0.05
Day 56	32.5	0.57	3.8	0.14	20	0.04
Day 84	37.8	0.68	3.1	0.11	20	0.04

2.7 Tailings Preparation for Uranerz Exploration and Mining Limited (Uranerz) (1994)

Testwork was completed for Uranerz at Lakefield to generate data for tailings prepared on the basis of the ammonium sulphate stripping process using a two stage atmospheric/pressure leach. The composite used for testing assayed 3.10% U, 6.84% As, 4.13% Ni, 0.04% Co and 0.12% Mo. To represent the neutralization circuit in use at Rabbit Lake, the total tailings slurry was prepared using separate neutralization of liquid effluents (raffinate, acid scrub, and spent regenerant) and leach residue with no barium chloride or ferric sulphate addition. The neutralized leach residue and precipitates from liquid effluent neutralization were then combined to prepare a final tailings slurry. The following tailings analyses were obtained:

Ammonium Sulphate Stripping Process - Analysis of Midwest Tailings	
Tailings Solids	
U (%)	0.054
As (%)	3.38
Ni (%)	2.20
²²⁶ Ra (Bq/g)	200
Tailings Filtrate	
U (mg/L)	0.015
As (mg/L)	32
Ni (mg/L)	0.10
²²⁶ Ra (Bq/L)	80
pH	8.1

3. MIDWEST/SUE A AND B

3.1 Bulk Neutralization Aging Test (1992)

A one year tailings aging test was completed for Minatco Limited (Minatco) by Lakefield (Projects No. 4307 and 4424-013) on tailings prepared from a blend of Midwest and Sue A and B samples (2.75 % U, 6.2 % As and 3.86% Ni), processed using the strong acid strip process. Bulk neutralization of raffinate (containing 6.06 g As/L and 0.80 g Fe/L, for an Fe/As ratio of only 0.13/1) and barren strip solution, spent regeneration solution and leach residue to pH 11 was used to generate the tailings slurry. The following analysis was obtained after aging the neutralized tailings sample for one year:

Single Stage Bulk Neutralized Midwest/Sue A and B Tailings Based on Strong Acid Strip Process - One Year Aging Test	
Element	Tailings Filtrate Analysis
U (mg/L)	1.5
As (mg/L)	63
Ni (mg/L)	0.52
²²⁶ Ra (Bq/L)	260

3.2 Simulation of JEB Mill and JEB Water Treatment Plant (1994)

COGEMA Resources Inc. (COGEMA)'s SEPA laboratory in Bessines, France prepared tailings on a Midwest/Sue A and B blend using the JEB mill/water treatment plant process. Neutralized residue and waste precipitates were combined and the pH adjusted to 11 to prepare a sample of total tails. The following analyses were obtained:

Midwest/Sue A and B Tailings Analysis - JEB Mill Process (Ammonium Sulphate Stripping)		
Element	Midwest/Sue A and B Blend Feed (% or Bq/g)	Tailings Pore Water (mg/L or Bq/L)
U	2.72	<0.05
As	6.4	4.97
Ni	3.5	0.06
²²⁶ Ra	377	76
pH	-	11.2

3.3 Total Testwork (1992)

As part of the process development testwork for the McClean Lake mill, Minatco Limited commissioned testwork on a Midwest/Sue A and B ore blend (2.99% U, 6.79% As, 4.75% Ni) by Total Compagnie Minière France, Division Nord Massif Central, Département Traitement des Minerais (Total). This work by Total entailed the preparation of neutralized tailings based on the strong acid strip process. The tailings preparation procedure included bulk neutralization of leach residue, raffinate, regeneration solution, gypsum cake and acidic barren solution with lime to pH 4, and then to pH 11. The following filtrate analyses were obtained:

Midwest/Sue A and B Tailings Filtrate Analysis Based on Strong Acid Strip Process			
Item	Feed	First Stage (Lime Only)	Second Stage (BaCl ₂ + Fe ³⁺)
pH	1.3	10.9	6.8
As (mg/L)	6596	28.8	0.15
Ni (mg/L)	6112	0.7	0.25
²²⁶ Ra (Bq/L)	27.1	31.9	<0.01

The first stage filtrate was also treated using BaCl₂ at pH 7 with varying Fe³⁺/(As+Mo) ratios. The following results were obtained:

Treated Effluent Arsenic Reduction Tests			
Fe ³⁺ /(As+Mo)	5/1	10/1	20/1
Filtrate - As (mg/L)	0.15	0.07	0.007

4. SUE A AND B

4.1 Total Testwork (1992)

A blend of Sue A and B ore, assaying 0.95% U, 3.12% As and 3.19% Ni, was used by Total to prepare tailings for testing. Leach residue and raffinate (containing 3.363 g As/L and 0.575 g Fe/L, for an Fe/As ratio of 0.17/1), mixed on the basis of a liquid/solid ratio of 4.5/1, was first neutralized with lime and with and without BaCl₂. The resulting filtrate from the test with no BaCl₂ was then treated at pH 7 with BaCl₂ and Fe²⁺ or Fe³⁺ addition at a Fe/(As+Mo) ratio of 7/1. The following results were obtained:

Sue A and B Tailings Neutralization and Treatment		
First Stage (pH 11)	No BaCl ₂	BaCl ₂ (25 mg/L)
²²⁶ Ra (Bq/L)	16.7	19.7
As (mg/L)	8.9	5.2
Ni (mg/L)	0.1	0.1
Second Stage (pH 7)	Fe ²⁺ /(As+Mo) = 7/1	Fe ³⁺ /(As+Mo) = 7/1
²²⁶ Ra (Bq/L)	0.12	0.10
As (mg/L)	0.20	0.18
Ni (mg/L)	0.08	0.08
Third Stage (pH 7.5, 25 mg BaCl ₂ /L)		
²²⁶ Ra (Bq/L)	0.03	0.02

5. JEB/SUE C/McCLEAN LAKE

5.1 COGEMA Testwork (1994)

COGEMA's SEPA laboratory in Bessines, France prepared tailings from JEB, Sue C and McClean Lake samples using a simulated JEB mill process. The following analyses were obtained:

JEB/Sue C/McClean Lake Tailings - JEB Mill Process (Ammonium Sulphate Stripping)									
Ore	Feed				Tailings Filtrate				
	U (%)	As (%)	Ni (%)	²²⁶ Ra (Bq/g)	U (mg/L)	As (mg/L)	Ni (mg/L)	²²⁶ Ra (Bq/L)	pH
JEB	2.56	0.57	0.60	327	<0.05	5.17	0.02	9.1	9.69
Sue C	5.25	0.15	0.11	674	<0.05	2.02	<0.01	15	10.48
McClean Lake	3.90	0.81	0.34	481	<0.05	11.90	0.02	13	11.15

5.2 Ortech Testwork (1991)

As part of the metallurgical development testwork for the McClean Lake Project, Ortech generated tailings aging test analyses by bulk neutralizing JEB/Sue C/McClean Lake leach residue, raffinate and acid barren strip to pH 10 to 11 with and without barium chloride. The liquid in the feed before neutralization contained 0.972 g As/L and 1.4 g Fe/L, for an Fe/As ratio of 1.44/1. The following tailings filtrate analyses were obtained over a period of 370 days:

JEB/Sue C/McClean Lake Tailings Filtrate Analysis										
Day	Without BaCl ₂ Addition					With BaCl ₂ Addition				
	U (mg/L)	As (mg/L)	Ni (mg/L)	²²⁶ Ra (Bq/L)	pH	U (mg/L)	As (mg/L)	Ni (mg/L)	²²⁶ Ra (Bq/L)	pH
1	0.33	2.8	0.01	130	9.70	0.14	4.5	0.01	140	9.88
7	0.53	6.0	0.02	130	9.13	0.60	7.0	0.03	110	9.15
30	0.85	8	0.03	99	9.49	0.43	7.0	<0.01	93	9.40
90	4.2	11	0.05	54	8.64	4.8	9.8	0.01	34	8.10
180	7.4	12	0.01	82	9.04	7.2	13	<0.01	86	9.07
370	28	18	0.02	95	8.41	20	15	0.02	76	8.33

5.3 Lakefield Testwork - Sue C (1990)

Lakefield completed a hydrometallurgical test program on a composite of Sue C mineralization assaying 4.19% U, 0.16% As and 0.11% Ni. Processing was based on the strong acid strip process. Bulk neutralized tailings were prepared by neutralizing leach residue, raffinate and acidic barren strip liquor to pH 11.5 with lime only. The following analyses were obtained for neutralized tailings filtrate:

Strong Acid Strip Process Sue C Tailings Filtrate Analysis		
Element	Tailings Filtrate Analysis	
	Test ET1	Test ET2
U ₃ O ₈ (mg/L)	<1	<1
As (mg/L)	0.43	0.45
Ni (mg/L)	<0.05	<0.01
²²⁶ Ra (Bq/L)	-	50
pH	8.8	10.4

5.4 Total Testwork - Sue C (1993)

A sample of Sue C ore (3.26% U, 1.04% As, 1.32% Ni) was used by Total to prepare tailings based on the strong acid strip process. Waste streams were first bulk neutralized with lime to pH 11 and the first stage filtrate was treated first at pH 4 and then at pH 7 using BaCl₂ and Fe³⁺/(As+Mo) ratios of 5/1 and 10/1).

The following results were obtained:

Strong Acid Strip Process - Sue C Tailings Treatment Tests						
	Feed	First Stage	Second Stage		Third Stage	
Fe ³⁺ /(As+Mo)			5/1	10/1	5/1	10/1
pH	1.2	10.7	4.0	4.0	7.1	7.3
As (mg/L)	91.7	5.6	<0.05	0.6	0.009	0.009
Ni (mg/L)	124	0.3	0.4	0.5	0.22	0.19
²²⁶ Ra (Bq/L)	26.4	202	0.2	0.2	<0.01	<0.01

6. CIGAR LAKE

6.1 COGEMA Testwork (1994)

As part of development testwork carried out for the Cigar Lake Project at COGEMA's SEPA laboratory in Bessines, France, residue neutralized to pH 8.2 and total tails prepared by two stage bulk neutralization were used to provide the following analyses:

Ammonium Sulphate Stripping Process - Analyses for Cigar Lake Tailings Preparation					
Stream		U (% or mg/L)	As (% or mg/L)	Ni (% or mg/L)	²²⁶ Ra (Bq/g or Bq/L) pH
Feed		15.21	2.57	1.2	1910 -
Neutralized Residue	Solids	0.09	2.12	1.27	- -
	Supernatant	0.21	1.6	0.13	132 8.0
Total Tails Supernatant		-	2.76	-	358 10.25

6.2 Melis Testwork (1993)

Melis prepared Cigar Lake tailings for geotechnical and chemical testing based on a two stage atmospheric/pressure leach and ammonium sulphate stripping. Tailings were prepared from two different Cigar Lake samples using two stage bulk neutralization treatment of leach residue, raffinate and spent regeneration solution with a final pH of 10.4. The following analyses were obtained:

Ammonium Sulphate Stripping Process - Cigar Lake Tailings Analysis					
Feed Sample	U (% or mg/L)	As (% or mg/L)	Ni (% or mg/L)	²²⁶ Ra (Bq/g or Bq/L)	pH
Phase I (13.38% U, 1.52% As)					
- Tailings Solids	0.055	0.99	0.67	850	-
- Tailings Filtrate	0.42	6.4	0.04	100	10.4
Phase II (6.44% U, 1.30% As)					
- Tailings Solids	0.052	1.10	0.81	1100	-
- Tailings Filtrate	0.09	4.8	0.015	250	10.3

6.3 Melis Testwork (1988/1989)

As part of Cigar Lake testwork, simulated Cigar Lake tailings were aged for 49 days and the pH monitored (elemental analysis was not requested). There was a slight drop in pH for three tests with different initial pH values: pH 5.28 to pH 5.00, pH 11.0 to pH 8.92, and pH 12.5 to pH 11. A tailings supernatant collected from a blended sample of tailings prepared by Cogema's SEPA laboratory assayed 0.155 mg U/L, 0.62 mg As/L, 0.11 mg Ni/L and 190 Bq/L ²²⁶Ra.

A tails liquid sample collected from a simulated tailings neutralization and treatment test at a final pH of 8.0 contained 0.15 mg U/L, 0.094 mg As/L, 0.26 mg Ni/L and 330 Bq/L ²²⁶Ra. The

liquid effluent used in this simulated test contained 2.83 g Fe^{2+}/L , 1.8 g Fe^{3+}/L and 0.424 g As/L , for an overall Fe/As ratio of 10.9/1.

The effect of pH on leach residue neutralization was tested with the following results obtained:

Cigar Lake Leach Residue Neutralization - Effect of pH			
pH	Tailings Filtrate Analysis (mg/L)		
	U	As	Ni
9	0.19	0.64	0.5
10	0.09	0.87	0.02
11	0.08	0.36	0.02
11.5	0.10	0.22	0.03

7. KEY LAKE

7.1 Melis Nickel/Arsenic Study for National Uranium Tailings Program (1986)

Tailings Analysis

From data provided by the Key Lake operation, and from testwork carried out on liquid waste streams from the Key Lake mill, the following were estimated concentrations of arsenic and nickel in the Key Lake mill tailings:

Key Lake Tailings - Estimated Arsenic and Nickel Concentrations			
Element	Mill Feed (%)	Tailings	
		Solids (%)	Liquid (mg/L)
As	1.2	0.92	2.0
Ni	1.46	1.46	0.5

Mineralogical Examinations

A total of 13 precipitates prepared in the testwork were examined visually and by a scanning electron microprobe. The precipitates were found to consist of abundant gypsum, some pisoliths (round nodules) of various sizes and colors, and yellow-brown material composed of aggregates of sub-micron size tabular crystals. X-ray diffraction studies showed that the yellow-brown material and the shells of pisoliths were amorphous.

Chemical analyses, expressed as standard oxides, showed that the amorphous residues are hydrous, and can contain up to 37.7% NiO, 25.2% As₂O₃, and 24.5% Fe₂O₃ and lesser quantities of Al₂O₃, SiO₂ and possibly CaO. Vanadium, zinc, cobalt, copper and yttrium were present in minor concentrations. Further Raman microprobe analysis indicated the presence of ferric arsenate.

Study Conclusions

A detailed nickel/arsenic metallurgical balance for the Key Lake circuit indicated that approximately 55% of the nickel and 60% of the arsenic in the Key Lake tailings were present in the form of chemical precipitates produced in the waste treatment circuit. Mineralogical examinations of these precipitates were not successful in identifying the nature of these precipitates since no crystalline nickel or arsenic precipitates could be determined. The precipitates appeared to be a mixture of amorphous solids of hydrous oxides and hydroxides. From assessment of available chemical data, it was concluded that arsenic was present as aluminum and iron arsenates in equilibrium with their respective metal hydroxides.

Implications from geochemical modeling were that aging was thought not to have a detrimental effect on the dissolution of arsenate precipitates. In the anoxic environment of tailings porewater, iron (II) arsenates could be considered thermodynamically stable whereas the dissolution rates of iron (III) and aluminum arsenates are probably sufficiently low to allow

readsorption of dissolved arsenate on metal hydroxide surfaces. In addition, dissolved iron (III) may be reduced to iron (II), during oxidation of arsenic (III) to arsenic (V), thereby allowing the reprecipitation of iron (III) arsenate as iron (II) arsenate. The combined effect of these mechanisms would be thought to yield arsenate concentrations in the mg/L range.

7.2 Knight and Piesold Ltd. Data for National Uranium Tailings Program (1985)

Sampling of Key Lake tailings in 1985 by Knight and Piesold Ltd. for the National Uranium Tailings Program yielded the following analyses:

Key Lake Tailings Liquid Analysis		
Item	As (mg/L)	Ni (mg/L)
Tailings Discharge	0.76 to 4.6	0.11 to 0.29
Tailings Pore Water	0.37 to 13.0	0.041 to 0.56
Tailings Seepage	0.06 to 0.07	0.041 to 0.094

8. AVAILABLE DATA SPECIFIC TO IRON/ARSENIC RATIO

A review of the above information has provided the following tailings chemistry information with respect to iron/arsenic (Fe/As) ratio and its effect on tailings water arsenic content:

Saskatchewan Uranium Tailings - Fe/As Ratio Data							
Ore	Raffinate				Tailings Filtrate		Strip Process
	Fe (g/L)	As (g/L)	Fe/As Ratio		pH	As (mg/L)	
			Weight	Molar			
JEB/Sue C/McClean	1.4	0.972	1.44/1	1.93	9.8 8.4	2.8 to 4.5 (Day 1) 15 to 18 (Day 370)	Strong Acid Strong Acid
Cigar Lake	46.3	0.424	10.9/1	15.7	8	0.094	(NH ₄) ₂ SO ₄
Midwest	1.23	2.34	0.53/1	0.76	8	5.7 (Layer 1) 24 (Layer 4)	(NH ₄) ₂ SO ₄ (NH ₄) ₂ SO ₄
					11	9 (Layer 1) 88 (Layer 7)	(NH ₄) ₂ SO ₄ (NH ₄) ₂ SO ₄
						10	0.51
					0.820	4.29	0.19/1
	0.788	3.82	0.21/1	0.30	10	48.4	Strong Acid
Midwest/Sue A and B	0.80	6.06	0.13/1	0.19	-	63 (1 Year)	Strong Acid
Sue A and B	0.575	3.36	0.17/1	0.24	11	5.2 to 8.9	N/A (Leach Residue and Raffinate only)

Even though the above data originates from different test programs, which were not aimed at quantifying the impact of Fe/As ratio in raffinate on tailings water chemistry, there is a definite trend of lower arsenic levels in tailings water with increasing Fe/As ratios in raffinate, or in the liquid component of tailings slurry.

For example, at a very high Fe/As weight ratio (10.9/1 for a Cigar Lake test), the tails filtrate water arsenic concentration is very low (0.094 mg As/L), whereas comparable ammonium sulphate strip tailings data for Midwest at pH 8 yielded a tails filtrate analysis of 5.7 mg As/L with an Fe/As weight ratio of 0.53/1.

Comparable data based on the strong acid strip process also shows the beneficial effect of high Fe/As ratios on arsenic levels in tailings water with aging, that is lower arsenic in tails water with higher Fe/As ratios. For the JEB/Sue C/McClean ore, the raffinate Fe/As weight ratio was 1.44/1 and the one year (Day 370) aging test result yielded a tailings pore water concentration of 15 to 18 mg As/L. A lower 0.13/1 Fe/As weight ratio in raffinate from Sue A and B ore yielded a higher tails water arsenic content of 63 mg As/L after the same one year aging period.

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Appendix C

Section B: Procedures and Results of Scoping Tests

APPENDIX C

Procedures and Results of the Scoping Tests

C.1 Introduction

Experiments performed at Saskatchewan Research Council (SRC) laboratories in Saskatoon, were designed to identify and evaluate processes that might reduce arsenic concentrations in pore waters of the proposed JEB Tailings Management Facility (TMF). Results of these scoping experiments provided the basis for the design of more extensive and larger scale experiments that were carried out in the COGEMA laboratories in Bessines, France.

Samples of ore material from the JEB pit and from Cigar Lake Mining Company (CLMC) were shipped to the SRC. Upon receipt, SRC produced tailings from the ores using procedures designed by COGEMA Resources. Table C.1 summarizes the results of the solids analyses for the ore and tailings materials used in the scoping tests. Complete analyses of these materials are available upon request. After the solids were prepared and leached, the resulting lixiviants were extracted with organic solvents. The raffinates that were produced after solvent extraction, provided the starting solutions used in most of the laboratory tests.

In a few tests, distilled water was employed instead of raffinate to provide blank samples for comparison. Other types of blanks, such as raffinate samples without tailings were also used in the tests.

C.2 Tests Involving Neutralization and Iron(III) Addition

In the first experiments lime (CaO) was used to neutralize mixtures of raffinate and tailings. The mixtures contained 50 gms of tailings and 550 ml of raffinate. The proportion of raffinate to tailings (11:1) was based upon the volumes of raffinate produced at SRC for the mass of tailings generated in accordance with the test procedure prepared by COGEMA. Table C.2 gives results of the experiments in which lime was added to JEB raffinate and to the JEB tailings/raffinate mixture. The raffinate had an initial molar Fe/As ratio of 1.8. The experiments showed that neutralization of raffinate alone or the raffinate/tailing mixtures reduced arsenic concentrations to values below 3-4 mg/L between about pH 7.6 and 10. Dissolved arsenic values were slightly greater at the higher pH values.

Results of similar neutralization tests of Cigar Lake raffinate and raffinate/tailings mixtures are given in Table C.3. The Cigar Lake raffinate has an initial molar Fe/As ratio of 34/1, so that lime addition causes precipitation of a much larger amount of sorptive HFO than is formed by neutralizing the JEB raffinate. For this reason arsenic concentrations after neutralization are

generally less than 0.5 mg/L. Lowest arsenic values (<0.2 mg/L) are found between pH 5.9 and 9.8.

As indicated in Table C.3, two of the neutralization experiments were run on Cigar Lake raffinate only. Comparison of the results of these tests and tests which involved both raffinate and tailings shows similar dissolved arsenic values at the end of the tests. This suggests that the precipitation of iron dissolved in the raffinate is responsible for most of the reduction in arsenic concentrations upon neutralization.

Shown in Table C.4 is a chemical analysis of the filter cake formed from neutralization of JEB and Cigar Lake Raffinates. The filter cakes presumably contain gypsum (calcium sulfate), mixed with relatively amorphous precipitates of Fe and Al oxyhydroxides. The oxyhydroxides can be expected to be highly sorptive for arsenic.

In the second set of scoping experiments, ferric sulfate solution was mixed with JEB raffinates and raffinate/tailings mixtures, to give a molar Fe/As ratio of 20/1 in the raffinate. Liming then precipitated additional hydrous ferric oxides (HFO) with the potential for adsorbing more arsenic and trace metals. These tests were only performed on JEB materials. Amounts of materials used in the tests are listed in Table C.5.

The experimental results are summarized in Table C.6, which shows that the increased Fe/As ratio has caused a reduction in the dissolve arsenic to 0.17 mg/L or less. These tests also show the need for additional lime to neutralize the added ferric sulfate solution, which at 0.8 molal, had a pH of about 1.8. To obtain pH values near 7 thus required that the added amount of lime be more than doubled relative to what was needed to neutralize JEB raffinate/tailings without added ferric sulfate.

C.3 Tests Involving Arsenic Reduction

Scoping experiments were conducted to evaluate the role that reducing conditions might have on arsenic concentrations in pore waters within the TMF. The experiments involved mixing tailings, raffinate, and various types of organic matter, including peat moss, cow manure, and a bacterial seed, which consisted of organic matter from a slough (swamp). The mixtures were incubated under oxygen-free conditions for approximately one month. Tests were run using JEB as well as Cigar Lake materials, although only the JEB results are presented here.

The conditions for the reducing experiments are listed in Table C.7. For most of the experiments, tailings, liquid (raffinate or distilled water), lime, peat, manure, and seed material were placed in 1 litre bottles. The seed was added to provide reducing bacteria. Bottles were

then placed in a glove bag filled with oxygen-free nitrogen. The liquids were sparged to remove oxygen, and the bottles sealed under N₂ gas in the glove bag to assure anoxic conditions in the bottles.

A blank was also prepared to assure that the organic matter used in the experiments did not provide a significant source of arsenic to the solutions. An analysis showed that the amount of arsenic provided by the organic matter is minimal and could be ignored.

Review of the analytical results for the JEB material in Table C.8 indicates that reducing conditions have led to an increase in dissolved arsenic concentrations when compared to the control experiment. The arsenic speciation results show a substantial increase As(III) concentrations causes the increase in total dissolved arsenic. The increase in As(III) is probably caused by reduction of adsorbed As(V) to As(III) which is less strongly sorbed by HFO and so is released to the solution.

C.4 Coprecipitation of As(V) in Phosphates

That precipitation of arsenate in substitution for phosphate within the mineral apatite might control dissolved arsenic in TMF pore water, has been discussed in Section 3.2.4. Scoping experiments to evaluate this possibility have just begun at the SRC labs in Saskatoon. Experimental procedures, results and recommendations will be presented once they become available.

C.5 Conclusions and Recommendations

The scoping experiments conducted at SRC indicate that raffinates with the highest Fe/As ratios produce lowest concentrations of dissolved arsenic once they are neutralized with lime. Also, by adding iron as ferric sulfate to raffinate or raffinate/tailings mixtures, further dissolved arsenic reductions are obtained. The primary mechanism for the reduction in dissolved arsenic concentrations is adsorption by hydrous ferric oxides (HFO). Arsenic adsorption is most complete at near-neutral pH values, decreasing as the pH rises.

After a month, reducing conditions established by adding organic matter to JEB raffinate and tailings lead to an increase in dissolved arsenic concentrations. This increase, which is largely as As(III) species, is probably caused by reduction of As(V) species adsorbed onto HFO to more soluble, less strongly adsorbed As(III) species. It seems likely that longer experimental times would lead to sulfate reduction and reduction and precipitation of the arsenic in sulfide and arsenide minerals. The reductant scoping tests were probably too short to allow such conditions to develop.

C.6 Initial Geochemical Modeling

Preliminary geochemical modeling using MINTEQA2 (Allison et al., 1991) was performed on data from the experimental results of the neutralization tests involving the Cigar Lake samples. The adsorption model selected was designed to evaluate the adsorption of arsenic onto the surface of HFO. The extent of the adsorption depends upon the amount and nature of the arsenic species in solution, and on the amount of precipitated HFO. The distribution of the various species of arsenic is controlled by the pH, the redox state, and composition of the solution. The model, which is a surface ionization and complexation model, has been used successfully to describe the behavior of a variety of substances in solutions that are in contact with hydrous ferric oxide and other solid phases (cf. Langmuir, 1997).

The concentrations of arsenic, iron, and sulfate in the raffinate provide the initial (dissolved) concentrations for the model calculations. The dissolved iron precipitates as HFO that has weak and strong sorption sites. Concentrations of these sites (the site density) have been determined in numerous experimental studies. A compilation of site density data (Dzombak and Morel, 1990) indicates that the concentration of strong sites (type 1 sites) equals 0.005 times the molar concentration of precipitated iron. The weaker (type 2 sites) sites are more abundant and their concentration equals 0.2 moles/L of precipitated iron. The concentration of iron in the raffinate was 716 mg/L. Therefore, the concentration of type 2 sites was calculated to be 2.56×10^{-3} moles/L and that of the type 1 sites was 6.419×10^{-5} moles/L.

Surface complexation constants for sulfate, calcium, and arsenic (III) and (V) are also provided in the compilation of Dzombak and Morel (1990). All of the arsenic (28 mg/L) was assumed to be in the As(V) state for the model calculations. Sulfate at 2490 mg/L and calcium at 1040 mg/L were also included in the input file to define the major anion and cation in the solution. Figure C.1 compares the model calculated results (the line) with the data points for the Cigar Lake neutralization experiments. The model is conservative and clearly agrees with the results, particularly below pH 10.5.

TABLE C.1**Chemical Analyses of JEB and Cigar Lake Ore and Solid Tailings**

Sample Designation	As ($\mu\text{g/g}$)	Fe ($\mu\text{g/g}$)	Ni ($\mu\text{g/g}$)	SO₄ (%)	S (%)	Al ($\mu\text{g/g}$)
JEB Ore	2,800	23,300	3,300	0.10	0.31	19,700
Cigar Lake Ore	2,300	37,500	640	0.46	0.65	14,000
JEB Tailings	1,400	20,400	1,100	0.78	0.54	16,800
Cigar Lake Tailings	910	46,500	98	2.12	1.51	26,700

TABLE C.2

**Results of JEB Raffinate/Tailings Neutralization Experiments
(Initial Molar Fe/As Ratio in Raffinate was 1.8:1)**

Sample Designation	pH	As (mg/L)	As(III) (mg/L)	As(V) (mg/L)	Fe (mg/L)	Ni (mg/L)	SO ₄ (mg/L)	Al (mg/L)
Raffinate	1.82	382	NM	NM	515	272	7,850	522
Neutralized raffinate	7.6	0.87	NM	NM	0.11	11	2,810	0.21
Neutralized raffinate JEB1-A	7.72	1.1	0.542	0.48	0.053	33	2,480	0.07
Neutralized raffinate JEB1-B	9.26	2.7	0.054	2.44	0.064	0.21	1,980	0.29
Neutralized raffinate plus tailings	9.31	4.2	0.087	3.37	0.15	0.23	2,420	1.4
Neutralized raffinate plus tailings	9.54	2.6	0.131	1.77	0.79	2.6	2,570	1.4
Neutralized raffinate plus tailings	9.74	3.6	0.119	2.34	0.045	0.98	2,350	0.60
Neutralized raffinate JEB1-H*	10.4	3.1	NM	NM	0.013	0.007	1,830	11
Neutralized raffinate plus tailings	10.66	5.6	0.053	3.82	0.01	0.046	2,160	1.3
Neutralized raffinate plus tailings	11.65	3.5	0.042	2.32	0.020	0.008	2,090	1.5
Neutralized raffinate plus tailings	11.95	2.7	0.048	1.58	0.067	0.015	2,320	0.34

Note:

NM = Not measured.

TABLE C.3

Results of Experiments in which Cigar Lake Tailings
and Raffinate were Neutralized by Lime Addition
(Initial Molar Fe/As Ratio in Raffinate was 34:1)

Sample Designation	pH	As (mg/L)	As(III) (mg/L)	As(V) (mg/L)	Fe (mg/L)	Ni (mg/L)	SO ₄ (mg/L)	Al (mg/L)
Raffinate	2.1	28	NM	NM	716	73	12,900	1,130
Neutralized raffinate	5.89	0.16	0.0004	0.075	0.25	32	2,640	0.12
Neutralized raffinate	6.4	0.12	NM	NM	0.29	15	2,490	0.12
Neutralized raffinate	7.81	0.09	0.0032	0.036	0.007	0.41	2,010	0.10
Neutralized raffinate	8.88	0.11	0.0009	0.010	0.042	0.54	1,920	0.63
Neutralized raffinate	9.78	0.16	ND	0.019	0.016	0.011	1,580	1.7
Neutralized raffinate	10.5	0.23	NM	NM	0.020	<0.005	1,860	54
Neutralized raffinate	11.31	0.31	0.0013	0.10	0.006	0.009	1,660	0.21
Neutralized raffinate	11.64	0.44	0.0015	0.094	0.042	<0.005	1,630	0.33

Notes:

NM = Not measured.

ND = Not detected.

TABLE C.4

Analyses of Filter Cake Solids Obtained from Experiments
in which JEB and Cigar Lake Raffinates were Neutralized

Sample Designation	pH ⁽¹⁾	As ($\mu\text{g/g}$)	Fe ($\mu\text{g/g}$)	Ni ($\mu\text{g/g}$)	SO ₄ ($\mu\text{g/g}$)	Al ($\mu\text{g/g}$)	Ca ($\mu\text{g/g}$)
Cigar Lake neutralized raffinate	6.4	3,800	31,300	2,500	413,000	52,900	167,000
JEB neutralized raffinate	7.6	37,400	45,800	18,200	378,000	35,500	171,000
JEB neutralized raffinate	10.4	24,700	30,500	14,100	346,000	24,000	203,000
Cigar Lake neutralized raffinate	10.5	4,700	23,700	1,900	271,000	30,000	142,000

Note:

1. pH of aqueous solution.

TABLE C.5

Experimental Conditions for JEB Raffinate/Tailings
Neutralization Experiments that Included Ferric Sulfate Addition

Sample Designation	Tailings (gms)	Raffinate (gms)	Fe ₂ (SO ₄) ₃ Solution ⁽¹⁾ (gms)	Lime (gms)	pH
Raffinate, tailings, ferric sulfate	50.04	546.8	77.7	9.59	7.09
Raffinate, tailings, ferric sulfate	50.18	562.2	76.9	10.25	7.07
Raffinate, tailings, ferric sulfate	50.26	547.6	77.8	9.75	7.33
Neutralized raffinate only	0	546.3	0	3.79	9.28

Note:

1. Solution is 0.8 m in iron.

TABLE C.6

**Results of JEB Raffinate/Tailings Neutralization Experiments, that
Included Ferric Sulfate Addition to Attain an Fe/As Ratio of 22:1**

Sample Designation	pH	As (mg/L)	Fe (mg/L)	Ni (mg/L)	SO₄ (mg/L)	Al (mg/L)
Raffinate, tailings, ferric sulfate	7.07	0.12	0.23	0.006	2,060	<0.05
Raffinate, tailings, ferric sulfate	7.09	0.17	0.62	0.42	2,220	0.51
Raffinate, tailings, ferric sulfate	7.33	0.09	<0.005	12	2,410	<0.05
Neutralized raffinate only	9.28	3.9	0.029	0.045	1,910	1.6

TABLE C.7

Experimental Conditions in which Organic Matter and Iron Powder were Added to JEB Raffinate and Tailings as Possible Reductants for Arsenic

Sample Designation	Tailings (gms)	Liquid (gms)	Peat (gms)	Manure (gms)	Seed (gms)	Lime (gms)
Tailings, raffinate, reductant	100.04	100 (DW)	10.14	13.86	10.76	0
Tailings, raffinate, reductant	100.12	376.82 (R)	10.36	20.74	15.2	2.35
Tailings, raffinate, reductant	100.41	373.93 (R)	10.18	15.90	16.8	2.7
Iron Powder	0	547.05 (R)	11.7 (Fe)	0	0	0
Blank	0	100 (DW)	10.71	10.8	11.93	0

Notes:

Fe = Iron added instead of peat and other organic substances.

DW = Distilled water added.

R = Raffinate added.

TABLE C.8

Results of Experiments in which Organic Matter and Iron Powder were Added
to JEB Raffinate and Tailings as Possible Reductants for Arsenic

Sample Designation	pH	As (mg/L)	As(III) (mg/L)	As(V) (mg/L)	Fe (mg/L)	Ni (mg/L)	SO ₄ ⁽¹⁾ (mg/L)	Al (mg/L)
Tailings, distilled water, open	3.88	1.3	NM	NM	13	150	2,300	23
Tailings, raffinate, open	4.92	4.3	4.0	0.583	0.46	160	2,930	4.3
Tailings, raffinate, reductants	5.10	13	NM	NM	0.63	15	2,930	0.62
Iron powder	6.01	0.01	<0.040	<0.040	2,770	0.75	7,780	0.68
Tailings, raffinate, reductants	6.21	24	18.5	20.9	3.4	16	2,560	0.39
Tailings, raffinate, reductants	6.53	18	11.5	4.54	2.1	7.9	2,950	<0.05
Blank	6.73	0.048	NM	NM	1.0	0.21	77	0.26

Notes:

1. Total sulfur as sulfate measured by ICP insufficient sample for separate sulfate or sulfide analyses.

NM = Not measured.

Monomethyl arsonic acid (MMA) and dimethyl arsenic acid were included in list of analytes, concentrations were below detection limits.

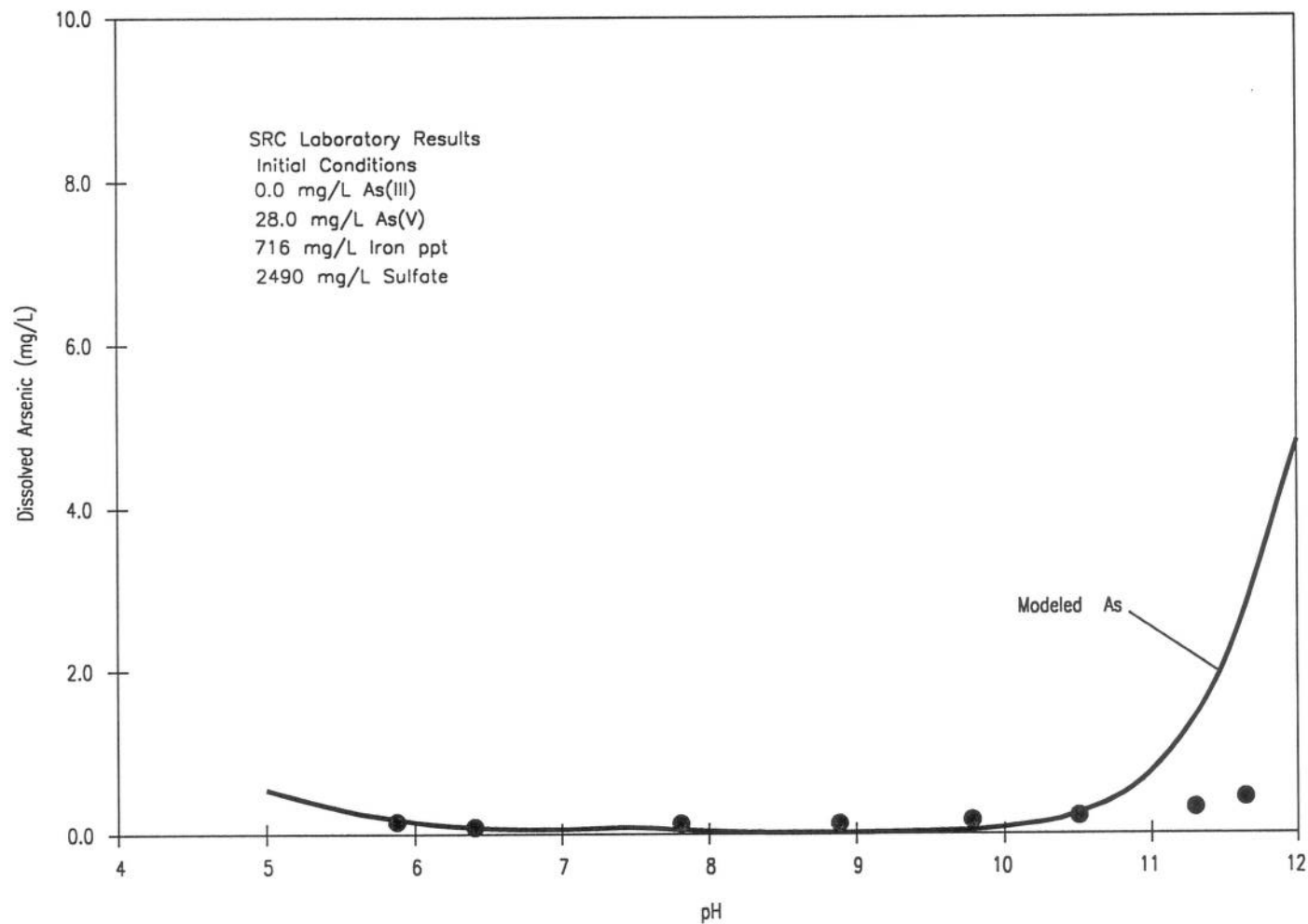


FIGURE C1 - Comparison of model results with experimental data initial conditions based upon Cigar Lake raffinate concentrations.

Appendix C

Section C: Initial Tailings Geochemistry Studies

Part A The Arsenic Source Term

- Subsection A Chemical Composition of Tailings Solids
- Subsection B Chemical and Mineralogical Analysis of Eight Tailings Samples
- Subsection C Chemical Analytical Methods and Results
- Subsection D Calculations Based on Results of the Large-Scale Tests at 4 and 25 C
- Subsection E Arsenic and Nickel Concentrations in Tailings Pore Waters as a Function of Time and their Statistical Significance, Based on Results of the Large-Scale Laboratory Tests
- Subsection F Thermodynamic Data for Selected Aqueous Species and Solids of Arsenic and Nickel

Part B Microprobe Analysis

Part C Letter Dated April 23, 1998

Appendix C

Section C

Part A: The Arsenic Source Term

**GEOCHEMISTRY OF JEB PIT URANIUM MILL TAILINGS:
THE ARSENIC SOURCE TERM**

April 23, 1998

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1.1 Executive Summary

Laboratory tests and geochemical modeling were performed to examine ways to reduce arsenic and nickel source term concentrations in pore waters of the proposed JEB Tailings Management Facility (TMF). Scoping laboratory tests considered removal of the arsenic from tailings raffinates by: (1) addition of ferric sulfate and slaked lime ($\text{Ca}(\text{OH})_2$) causing arsenic precipitation in mineral phases and adsorption; (2) reduction of arsenic by added organic matter; and (3) arsenic coprecipitation with added phosphate solids. Option (1) was chosen as the most promising. Accordingly, this process was studied in detail in large-scale tests of tailings and raffinates from the McClean Lake, Midwest and Cigar Lake ores. Short term (3-hr) tests, performed at 25°C, were designed to duplicate conditions during tailings processing in the JEB mill. Aging tests, which used products of the short term tests as their starting materials, were run for times that ranged from 5 to 50 days, at 4, 25 and 50°C. The aging tests were designed to predict the long-term behavior of arsenic in TMF pore waters at 4°C and arsenic and nickel source term concentrations in the TMF.

Based on the large-scale test results and their interpretation, COGEMA Resources proposes to remove As and Ni from mill effluent waters by adding ferric sulfate and slaked lime to produce a raffinate Fe/As molar ratio of at least 3 to 5 and a long-term pH of 7-8. This pH range is obtained when slaked lime is added to the tailings during processing to produce a nominal pH of 8. For these conditions, statistical, thermodynamic and kinetic analyses of the aging test data indicate that arsenic and nickel source term concentrations of 1 mg/L or less are probable in pore waters of the TMF for 50 to 10,000 years after tailings disposal. During this period, the arsenic will occur chiefly in ferric and nickel arsenate minerals that have been precipitated from the raffinate, with smaller amounts adsorbed by HFO (hydrous ferric oxides), aluminum oxides and clays present in the tailings. Arsenic concentrations may increase very slowly with time in TMF pore waters because of slow breakdown of the arsenate minerals. However, most of the increase will occur during the first few years after burial, with only minor further increases in arsenic concentrations projected for times after 50 yrs.

1.2 Composition and Mineralogy of the Tailings After Treatment

Understanding the results of the large-scale aging tests, and predicting the arsenic and nickel source terms for tailings buried in the TMF, both require that the detailed composition and mineralogy of phases in the tailings after treatment be known. This is because arsenic and nickel concentrations in TMF pore waters are controlled by reactions with tailings solids. The most reactive solids are those that have precipitated from the acid raffinate solutions as a consequence of ferric sulfate and calcium hydroxide addition. Several approaches were taken to determine the composition of these secondary phases. First, final compositions of solutions

after aging times of 120 hrs or later were subtracted from original raffinate compositions to determine amounts of each species incorporated in the secondary solids. The amounts in the solids were expressed as weight and mole percents. The results of these calculations are given in Appendix A. As is evident from the appendix, the mole percent of Ca roughly equals that of SO_4 in all of the processed tailings, consistent with their occurrence in gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), which constitutes most of the weight of precipitated solids in all of the tailings.

As a preliminary method of identifying the other secondary phases precipitated from the raffinates, liming simulations of the raffinates were performed using computer models MINTEQA2 (Allison et al., 1991) and PHREEQC (Parkhurst, 1995) to determine which solid phases might precipitate with increasing pH as evident from computed saturation indices (SI values). SI values of zero within their uncertainties, indicate phases at equilibrium with the solution. Negative and positive SI values identify phases that are undersaturated (cannot precipitate) and saturated (can and may precipitate), respectively. As expected, $\text{SI} \approx 0$ for gypsum in all neutralized raffinates. Among the phases that usually had positive SI values and are capable of precipitating within the short times of the Procedure 1 experiments (minutes to a few hours) were hydrobasaluminite ($\text{Al}_4(\text{SO}_4)(\text{OH})_{10} \cdot 15\text{H}_2\text{O}$), scorodite ($\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$), and HFO, or ferrihydrite. (See Appendix D).

The results of a determination of the composition and mineralogy of eight tailings samples performed by Dr. Maynard Slaughter¹ are presented in Appendix B. The tailings studied included JEB (Fe/As = 0, 3, 5 & 5 aged), Sue C (Fe/As = 7.7), McClean Lake (Fe/As = 4.6), Sue A+B (Fe/As = 0.64), and Blend 0 (Fe/As = 0.9)² where the Fe/As ratios are molar. Dr. Slaughter performed total chemical analyses of the tailings for their content of major and minor elements and element oxidation states. His analysis also included X-ray diffraction measurements to identify crystalline phases present. Dr. Slaughter also considered the results of scanning electron microscopy, electron microprobe, X-ray diffraction and petrographic work on the tailings provided by COGEMA Resources and performed under the direction of COGEMA's SEPA facility in Bessines.

Dr. Slaughter concluded that all of the arsenic present in the tailings was As(V), with no As(III) in the solids. Weight percents of minerals in the eight tailings and average weight percents in the seven processed tailings are given in Table 1.2.1. Average weight percents in decreasing amounts shown parenthetically, are illite clay (25%), quartz (24%), gypsum (21%),

¹Crystal Research Laboratories, Golden, CO

²Blend 0 was not studied in the large-scale tests and is not being considered for emplacement in the TMF.

Table 1.2.1 Weight percent of minerals in tailings solids after processing as determined by Dr. Maynard Slaughter.

Sample	#1	#2	#3	#4	#5	RH262F- JEB.1 (wt %) ^{Note 2}	RH262G- JEB.2 (wt %)	RH262C- JEB.3 (wt %)	Processed Tailings ^{Note 2}	
	RH262A- JEB (wt %)	RH262B- McClellan Lake (wt %)	RH262H- Sue C (wt %)	RH262D- Sue A + B (wt %)	RH262E- Blend 0 ^{Note 1} (wt %)				Average	Standard Deviation
Fe/As (molar)	3.0	4.6	7.7	0.6	0.9	NA	5.0	5.0		
Mineral										
Quartz	21.34	36.19	7.85	35.19	28.34	26.40	22.27	18.01	24.2	10.0
Goethite	1.86	3.56	0.00	2.43	0.02	1.90	2.28	0.29	1.5	1.4
Iron oxyhydroxide	0.00	0.27	0.40	0.00	0.00	0.00	0.00	0.03	0.1	0.2
Gypsum	23.27	19.28	22.47	23.01	27.98	0.00	14.07	13.98	20.6	5.1
Rutile	0.67	0.56	0.89	0.37	0.26	0.94	0.83	0.74	0.6	0.2
Chlorite-Mg	8.48	0.23	2.03	1.51	0.69	12.00	10.20	8.76	4.6	4.4
Jarosite	0.00	0.00	0.00	0.50	3.69	0.00	0.00	0.33	0.6	1.4
Hydrous phosphate	0.28	0.15	0.14	0.14	0.13	0.18	0.32	0.31	0.2	0.1
Pyrite	0.03	0.00	0.00	0.00	0.32	0.09	0.11	0.00	0.1	0.1
Illite	27.15	24.87	38.30	14.18	2.98	40.17	32.81	35.26	25.1	12.6
Kaolinite	1.85	3.68	7.71	0.17	0.00	12.99	9.04	11.59	4.9	4.6
Cabrerite	0.88	0.85	0.63	6.56	14.88	0.29	0.51	0.52	3.5	5.5
Scorodite	0.31	0.03	0.00	1.21	6.31	0.00	0.56	0.74	1.3	2.2
Chalcopyrite	0.12	0.13	0.08	0.05	0.06	0.16	0.16	0.00	0.1	0.1
Galena	0.24	0.17	0.87	0.04	0.28	0.30	0.27	0.26	0.3	0.3
Coffinite	0.00	0.00	3.61	0.00	0.81	0.00	0.00	0.00	0.6	1.3
Hydrobasaluminite	13.33	9.80	14.54	14.60	13.19	4.24	6.25	8.97	11.5	3.2
TOTALS	99.81	99.77	99.52	99.96	99.94	99.66	99.68	99.79		

Note 1: Blend 0 = 75% Midwest + 25% Sue A+B

Note 2: Sample RH262F-JEB.1 was acid leached but not processed and was therefore not used in the average and standard deviation calculations.

hydrobasaluminite (12%), kaolinite clay (4.9%), Mg-chlorite clay (4.6%), cabrerite-annabergite (3.5%), goethite (1.5%; amorphous and crystalline forms with the latter probably from the rock), and scorodite (1.3%). Phases averaging less than 1% include coffinite (0.6%), rutile (0.6%), jarosite (0.6%), and the sulfides galena (0.3%), pyrite (0.1%) and chalcopyrite (0.1%).

Among these phases, the secondary phases, which are those precipitated entirely from the raffinate, include gypsum, hydrobasaluminite, iron (II, III) oxyhydroxide, all of the amorphous 'goethite', cabrerite-annabergite, scorodite, jarosite, and hydrated Ca phosphate. Presumably any crystalline goethite found was present in the original rock.

Most of the arsenic in the tailings is present in the cabrerite-annabergite $[(\text{Ni}, \text{Mg}, \text{Fe})_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}]^3$ and scorodite ($\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$), with the rest adsorbed or coprecipitated with relatively amorphous Al and Fe(III) oxyhydroxide phases and adsorbed by the clays (Table 1.2.2). The nickel is present in the cabrerite-annabergite, with smaller amounts also adsorbed or coprecipitated with the oxyhydroxides and adsorbed by the clays.

1.3 Geochemical Controls on Arsenic Concentrations

1.3.1 Introduction

COGEMA Resources proposes reducing source term concentrations of arsenic in tailings emplaced in the TMF by adding ferric sulfate and then slaked lime for pH control of tailings pore-waters. This approach is supported by theoretical arguments and previous work, and by the laboratory testing described in this report. Based on the evidence, arsenic source term concentrations may increase very slowly with time after tailings emplacement chiefly because of the slow dissolution of arsenate mineral phases with time. In order to fully understand COGEMA's proposed approach, it is useful to review the applicable geochemistry of arsenic.

1.3.2 General Geochemistry of Arsenic

Dissolved arsenic occurs in natural waters chiefly as arsenate (As[V]) species, and less often as arsenite (As[III]) or methyl (organic) arsenate species. The relative stabilities of the inorganic forms are plotted in the Eh-pH diagram shown in Fig 1. The diagram indicates that arsenate forms such as HAsO_4^{2-} dominate in oxidized (high Eh) waters, whereas arsenite species (e.g. H_3AsO_3^0) may occur in low Eh waters, which are oxygen-deficient or anaerobic. Among arsenic species, the least toxic to humans are the methyl arsenates (Cullen and

³Annabergite is the pure nickel end-member.

Table 1.2.2 Arsenic occurrence in processed tailings.

MINERAL	ARSENIC OCCURRENCE	AVERAGE WT % OF MINERAL
Scorodite	$\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$ (minor Al^{3+} for Fe^{3+})	1.3
Cabrerite- Annabergite	$\text{Ni}_2(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$ (minor Mg^{2+} & Fe^{2+} for Ni^{2+})	3.5
Fe(III) oxides	Amorphous FeOOH (assumed composition) Adsorbed arsenic	1.5
CLAYS		
Mg-Chlorite	Adsorbed arsenic	4.6
Illite	Adsorbed arsenic	25.1
Kaolinite	Adsorbed arsenic	4.9

Reimer, 1989), which are uncommon in tailings pore waters. Dissolved As(III) species may be 60 times more toxic than dissolved As(V) species (Ferguson and Gavis, 1972). In tailings and raffinates and in TMF pore waters, however, As(III) is likely to be a minor As form relative to As(V). For example, after liming for pH control in the mill, typical tailings pore waters have pH values above 7-8, are slightly oxidizing, and plot in the field of HAsO_4^{2-} (As[V]) in Fig. 1, although they may contain a few percent of As(III) (i.e. 6.1% of total As is As(III) in the JEB raffinate).

Under oxidizing and somewhat reducing conditions, removal of dissolved arsenic from water occurs by its adsorption onto mineral surfaces, and in high arsenic waters by precipitation of arsenate minerals. Under more reducing conditions dissolved arsenic may precipitate as insoluble sulfide and arsenide minerals. Such minerals are the chief mode of As occurrence in association with the uranium ores of the Athabasca Basin (Atkinson et al., 1975).

1.3.3 Precipitation of Arsenate Minerals

In raffinate solutions, which are high in both As(V) and cations, ferric sulfate addition and neutralization lead to the precipitation of poorly crystalline arsenates that include scorodite ($\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$) and cabrerite-annabergite $[(\text{Ni}, \text{Fe}, \text{Mg})_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}]$ as the pH is increased. As shown in Figs. 2 and 3, scorodite can precipitate under acid, oxidizing conditions, and is unstable relative to HFO at pH values that can range from 3 to 7, depending on the iron(III) and arsenic concentrations⁴. However, its solubility in tailings pore fluids is less than about 10 mg/L below pH 8. Cabrerite-annabergite is also precipitated from tailings raffinates with increasing pH. Thermodynamic data is only available for annabergite, which has a minimum solubility of about 30 mg/L arsenic near pH 7 (Fig. 4). The effect of structural Mg^{2+} substituting for Ni^{2+} on the solubility of cabrerite-annabergite is unknown, but probably lowers the mineral's solubility⁵. The reduction in Ni^{2+} concentrations above pH 9 shown in Fig. 4 results from the precipitation of $\text{Ni}(\text{OH})_2$ solid. Although the arsenates are unstable thermodynamically above pH 7-8 relative to the ferric oxides and nickel hydroxide, their solubilities are sufficiently low under these conditions that their rates of dissolution and alteration to form more stable phases will be extremely slow.

⁴See Appendix F for thermodynamic data used in solubility and speciation calculations.

⁵According to Dr. Maynard Slaughter, this can be predicted from Mg^{2+} and Ni^{2+} bond energy differences in the mineral structure..

1.3.4 Adsorption

Adsorption reactions are an important control on maximum arsenic concentrations in natural waters, and are also important in tailings pore waters. Arsenic is most strongly adsorbed by oxides and hydroxides of iron(III) and aluminum, and to a lesser extent by clay minerals. In general, As(V) species are more strongly adsorbed than arsenite (As[III]) species. The strongest sorbent for arsenic is freshly precipitated iron(III) oxide, which is also termed ferrihydrite, or hydrous ferric oxide (HFO). Fuller et al. (1993) have found that freshly precipitated HFO can adsorb or coprecipitate up to 0.7 moles of As(V) per mole of iron. This corresponds to a minimum Fe(III)/As weight ratio of about 1.1/1. A considerable literature exists on the measurement and modeling of As(V) and/or As(III) adsorption by HFO (cf. Pierce and Moore, 1982; Goldberg, 1986; Robins et al., 1988; Fuller et al., 1993; Bowell, 1994; Langmuir and Mahoney, 1997). As(V) and/or As(III) adsorption by clays has been less measured or modeled (cf. Frost and Griffin, 1977; Goldberg and Glaubig, 1988; Manning and Goldberg, 1997). Authors have often described arsenic removal by HFO as an adsorption process. However, there is strong evidence that when Fe(III) and As(V) are present in acid solutions, and the pH is gradually raised, ferric arsenate solids are precipitated before HFO can attain saturation and precipitate (cf. Harris and Krause, 1993; Demopoulos et al., 1995). In an often cited study, Robins et al. (1988) increased the amount of iron(III) in an acid solution that initially contained 300 mg/L dissolved As(V). Figure 5 shows that arsenic concentrations dropped as the pH and Fe/As ratios were increased. Most of the arsenic removed in these experiments was probably precipitated in ferric arsenate solids. When molar Fe/As ratios exceeded one (weight ratios exceeded 0.75; data not plotted) the remaining As(V) was adsorbed onto HFO. For Fe/As weight ratios greater than 2/1 (Fe/As molar ratios exceeding 2.7/1), the As(aq) remaining in solution was less than 1 mg/L for a wide range of pH values between about 3 and 8. Adsorption by HFO could be viewed as having 'scrubbed' the remaining arsenic from solution. Figures 2 and 5 indicate that liming tailings to pH values above 8-10 may be counterproductive, causing dissolved As(V) concentrations to increase in tailings pore waters (cf. Jones et al., 1997).

The Athabasca sandstones, which constitute more than 90% of the rocks in the Athabasca basin, are stained yellow by the ferric iron mineral limonite (probably chiefly the mineral goethite, FeOOH). Hematite (Fe_2O_3) is also common in the sandstones. The oxides occur as a cement or stain on quartz grains and as a fracture filling. Such rocks surround the proposed TMF and must contact all ground waters that would transport arsenic from the TMF towards Fox Lake. Although hematite and goethite have lower sorption capacities for As than does HFO, any As(V) in the ground water would tend to be adsorbed by these minerals in the sandstone. Presumably for this reason, ground waters in contact with the sandstones in the McClean Lake area have arsenic concentrations that are generally below 7 ug/L.

1.3.5 Oxidation and Reduction

In the vicinity of the uranium ore, arsenic in oxidation states below As(III) occurs as sulfide minerals (substituting for the sulphur in pyrite, FeS_2 , for example), and as arsenide minerals including niccolite (NiAs), rammelsbergite (NiAs_2) and gersdorffite [$(\text{Ni,Fe,Co})\text{AsS}$]. Chalcopyrite (CuFeS_2) and galena (PbS) are also present. The sulfide and arsenide minerals are extremely insoluble at low Eh values, so that in ground waters from the undisturbed McClean Lake and Cigar Lake ore zones, arsenic concentrations are generally below 60 $\mu\text{g/L}$. Shown in Figs. 6 and 7, respectively, are the Eh-pH stability fields of pyrite (FeS_2), and of niccolite (NiAs) and nickel hydroxide. Thermodynamic data are not available for gersdorffite. Also plotted are the fields of measured Eh values in tailings raffinates, and in McClean Lake and Cigar Lake ground waters. The raffinate is slightly oxidizing because of the ore processing, and so has a stability in the field of As(V) species. Eh and pH values in the ground water are reducing, and plot along the equilibrium boundaries between coexisting Fe(III) oxides, and Fe(II) bearing silicates (e.g. chlorite) or sulfides and arsenides. Under such conditions, dissolved As concentrations are lowered substantially.

Chemical and mineralogical analysis of the tailings indicates that most of the original sulfide and arsenide minerals have been destroyed. Small amounts of reductant Fe(II) and/or sulfide are still present within chlorite (4.6% of the tailings; Fe(II) only), chalcopyrite (0.1%; Fe(II) and sulfide) and galena (0.3%; sulfide). Other minerals with reducing capacity that occur in trace amounts (<1%) in some of the tailings include pyrite, 'iron(II) oxyhydroxide', and coffinite (see Appendix B). Traces of organic matter are also present in the tailings, with about 0.46% C in JEB tailings, for example. However, this organic matter is chiefly graphite and bitumen from the original rock, which are relatively inert. Given the trace concentration level of reduced and reactive elements in the processed tailings, it seems likely that they will remain relatively oxidizing for years after burial in the TMF.

1.3.6 Geochemical Modeling

Changes in arsenic concentrations during processing of the tailings and after their burial in the TMF involve chemical reactions. Some reactions go to completion within minutes after ferric sulfate and lime addition. These include the precipitation of arsenate minerals and gypsum, and As and Ni adsorption and/or coprecipitation by HFO and amorphous Al oxyhydroxides. Other reactions, such as dissolution of the metastable arsenate minerals and the crystallization of more stable Fe(III) oxides such as goethite at pH 7-8 may take decades to thousands of years to go to completion, particularly at 4°C, the temperature expected in the TMF. Geochemical models such as MINTQA2 (Allison et al., 1991) and PHREEQC (Parkhurst,

1995) compute concentrations at equilibrium, and so may be used to determine how closely water-rock or tailings- pore water systems approach equilibrium with metastable or thermodynamically stable phases.

As(V) and As(III) mineral solubilities, and As adsorption assuming the diffuse layer model, were modeled with both MINTEQA2 and PHREEQC. The programs were used to model ground water analyses, as well as results of the laboratory tailings-raffinate experiments. The models were also used to predict the precipitation of arsenate solids and Ni and As adsorption during mill processing. PHREEQC and MINTEQA2 were employed to predict the long-term arsenic and nickel source terms in the TMF. Critically evaluated thermodynamic data for As(V) aquo-complexes and arsenate solids from Whiting (1992), along with critically selected Gibbs free energy data for Ni and As sulfide and arsenide minerals were input into both MINTEQA2 and PHREEQC codes. (See Appendix F).

1.4 Laboratory Tests of Tailings and Raffinates

1.4.1 Scoping Tests

Scoping tests were designed to evaluate the three options for arsenic removal described in Section 1.1, with the goal of selecting the most promising approach for more in-depth study in large-scale tests to be performed at the COGEMA/SEPA laboratory in Bessines, France. Accordingly, scoping test experiments examined; (1) arsenic removal caused by ferric sulfate and lime addition as a function of pH and Fe(III)/As ratio, (2) As(V) coprecipitation with phosphate (apatite), and (3) arsenic precipitation by electrochemical reduction with organic matter. The scoping tests were run in the laboratories of the Saskatchewan Research Council (SRC) in Saskatoon under the supervision of Dr. John Mahoney of Hydrologic Consultants, Inc, with the assistance of Wanda Goulden of Clifton Associates. The tests were run on samples of JEB tailings and Cigar Lake tailings. Details of the tests and test results are described in Appendix A of the COGEMA Resources Inc. -McClean Lake Project - Tailings Source Term Manual, submitted to the AECB on November 27, 1997.

Given the extensive published work on arsenic precipitation with Fe(III) salts and adsorption by Fe(III) oxides (Section 1.3.4), and results of the scoping tests involving JEB raffinate and tailings, COGEMA Resources decided that arsenic removal by ferric sulfate and slaked lime addition was the most promising approach for controlling source-term concentrations of arsenic in the TMF. This decision was also based on the fact that arsenic removal by electrochemical reduction or by phosphate coprecipitation do not have a proven track records in such applications, and on potential costs and engineering difficulties associated with these approaches.

1.4.2 Large-Scale Aging Tests

1.4.2.1 Purpose and Design of the Tests

The large-scale tests were performed under the direction of Drs. Michel Roche and Isabelle Picquet in the COGEMA/SEPA laboratories in Bessines, France. Test procedures were designed and written by Drs. Donald Langmuir and John Mahoney, to evaluate the impact of iron(III) additions on dissolved arsenic concentrations in tailings raffinates of the McClean Lake, Midwest and Cigar Lake ores, and in pore waters within tailings to be emplaced in the TMF. Procedure 1 tests were designed to approximate the reactions that take place in the plant tailings neutralization circuit. Procedure 2 tests (the accelerated aging tests) were designed to facilitate the prediction of the long-term arsenic source term in TMF pore waters. Detailed descriptions of test protocols and results are given in Appendix C. The short-term tests, which involved the addition of slaked lime and ferric sulfate to raffinate solutions and tailings, were intended to define optimum conditions for removal of dissolved arsenic from the raffinates during processing of the tailings. All procedure 1 tests were performed at 25°C in contact with atmospheric oxygen (air), and were run for 3 hrs, the expected residence time of the tailings in the neutralization circuit. The second set of tests, which were continued for times that ranged from 5-6 days to as long as 40-50 days, were designed to help predict dissolved arsenic concentrations in pore waters within the TMF for years after tailings disposal. These tests were performed under oxygen-free (anaerobic) conditions as expected in the TMF. Most procedure 2 tests were carried out at 25 and 50°C. A few were also run at 4°C, the probable temperature after burial in the TMF. To speed up all of the tests, reaction vessels were agitated on a shaker table. The compositions of tailings and raffinates chosen for study are given in Tables 1.4.2.1.1 and 1.4.2.1.2.

1.4.2.2 Short-Term Tests

Results of the short-term (3 hr) tests (procedure 1), in which 1 kilogram of tailings was mixed with 6.0 liters of raffinate, are given in Appendix C. All of the short-term tests were run at 25°C only to simulate the process neutralization temperature. Depending on the initial Fe/As ratio of the raffinates (see Table 1.4.2.1.1) experiments were carried out at increasing Fe/As ratios, with the iron added as ferric sulfate solution. The Fe/As ratios employed in the procedure 1 tests at 25°C and procedure 2 tests carried out at 4, 25 and 50°C are summarized in Table 1.4.2.1.2. Results of the 50°C tests are presented in Appendix C, but are not considered further, except in the discussion of the effect of temperature on the solubility of the arsenate minerals (Section 1.5.1) and the kinetics of arsenic release from the tailings (Section 1.5.3).

Table 1.4.2.1.1. Some important chemical properties of raffinates derived from the different ores and their blends without iron addition

Ore	pH	ΣFe (mg/L)	ΣNi (mg/L)	ΣAs (mg/L)	Fe/As molar ratio	As(V) (mg/L)	As(III) (mg/L)	As(V)/ As(III) ratio
JEB	0.85	517	144	271	2.6	218	53	4.2
Sue C	0.3	811	145	141	7.7	112	29	3.9
McClean	0.75	948	164	275	4.6	223	52	4.2
Sue A+B	0.3	1080	2740	2430	0.60	1937	493	3.9
Cigar Lake	0.40	3260	453	580	7.5	454	126	3.6
Blend 1 (75% Sue C, 25% Cigar L.)	0.34	1521	234	268	7.6	211	57	3.7
Blend 2 (55% Midwest, 15% Sue A+B, 30% Cigar L.)	0.99	5165	2491	6807	0.3	6480	2620	2.5

Table 1.4.2.1.2a. Raffinate Fe/As molar ratios employed in procedure 1 and 2 tests, both run at 25°C, and procedure 2 tests run at 50°C.

Ore	Fe/As Molar Ratio	Ore	Fe/As Molar Ratio
JEB	2.6, 3.0, 5.0	Blend 0 (75% Midwest, 25% Cigar L.)	0.9
Sue C	7.7	Blend 1(75% Sue C, 25% Cigar L.)	7.6
McClean	4.6, 5.0	Blend 2 (55% Midwest, 15% Sue A+B, 30% Cigar L.)	1.0, 1.5, 2.0, 2.5
Sue A+B	0.64, 1.0, 1.5, 2.0, 2.5, 3.0, 5.0	Cigar Lake	7.5

Table 1.4.2.1.2b Raffinate Fe/As molar ratios employed in procedure 2 tests run at 4°C.

Ore	Fe/As Molar Ratio
JEB	3.0, 5.0
Sue C	7.7
Blend 2	3

1.4.2.3 Accelerated Aging Tests

Raffinate/tailings mixtures produced for the short-term tests, and prepared at nominal pH values of 7, 8, and 9, were the starting materials for the aging experiments. To provide enough solution for subsequent chemical analyses, a liquid to solid weight ratio of 2/1 or 2.25/1 was used in these tests. In the latter case this represented about 500 gms of tailings mixed with 1125 ml of raffinate solution. Because these tests were intended to simulate conditions expected in TMF pore waters, they were run in closed vessels in the absence of air, allowing raffinate species and solids in the tailings to control pH and redox conditions. The experimental vessels were agitated on a shaker table. During the experiments the test vessels were sampled as a function of time for 120 to 144 hrs (5 to 6 days), and in a few instances for 1000 to 1200 hrs (40 to 50 days). Detailed experimental procedures, methods of analysis and chemical analytical results obtained during the aging experiments are presented in Appendix C. Appendix D includes the results of charge balance calculations for the solution analyses of the 4 and 25°C runs, and a discussion of solution redox potentials and computed mineral saturation states.

1.5 Aging Test Results

1.5.1 Predicted Concentrations with Time

The emphasis in following discussion of test results is on the long-term data obtained at 4 and 25°C using tailings being considered for TMF disposal. For tailings having other Fe/As ratios and for all tests run at 50°C, the arsenic and nickel versus time data obtained in aging tests are shown in tables and plots in Appendix E. To avoid biasing statistical analyses of the long-term data with the early procedure 1 data which changes rapidly, particularly during the first two hours after neutralization, only the data collected at 2 hrs or later was considered in the analysis.

In tailings processing, COGEMA Resources proposes that slaked lime be added to tailings until the solution pH equals about 8. The pH target (in this case pH 8) is described as the nominal pH value of the tailings/raffinate mixture. Following slaked lime addition to nominal pH 8, the pH generally dropped to values between pH 7 and 8, the proposed pH range for TMF pore-waters. A t-test⁶ of regression lines drawn through measured pH values plotted against log time for individual experiments (the plots are not shown) indicated that for tailings being considered for TMF disposal, two of the regression lines had a significant positive slope (the pH increased with time), one had a negative slope, and the remaining eight plots were random and

⁶cf. Miller and Miller (1988)

Table 1.5.1.1 Predicted nickel concentrations in tailings pore-waters at test temperatures and their statistical significance for tailings proposed for burial in the TMF: Based on the results of the large scale laboratory tests.

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation (R ²) ^{Note 1}	Ni (mg/L) predicted at 50 yrs ^{Note 2}	Ni (mg/L) predicted at 10,000 yrs ^{Note 2}	t-test statistic	Value of t for a confidence interval of 95% (1 degree of freedom)
JEB	5.0	4	8	7.3-7.9	no trend	0.81 ± 0.11	0.81 ± 0.11	1.70	4.30
JEB	5.0	25	8	7.2-7.3	no trend	0.57 ± 0.04	0.57 ± 0.04	0.81	4.30
Sue C	7.7	4	8	6.3-8.0	y=0.0289x-0.0046 (0.722)	0.2 ± 0.02	0.2 ± 0.02	2.79	2.78
Sue C	7.7	25	8	6.9-7.5	no trend	1.1 ± 0.74	1.1 ± 0.74	1.29	4.30
McClellan Lake	5.0	25	8	7.3-7.5	no trend	0.18 ± 0.02	0.18 ± 0.02	0.46	4.30
Sue A+B	3.0	25	8	7.3-7.5	no trend	1.1 ± 0.6	1.1 ± 0.6	0.37	4.30
Cigar Lake	7.5	25	8	7.2-7.3	y=0.051x+0.259 (0.961)	0.5 ± 0.01	0.7 ± 0.01	4.98	4.30
Blend 1	7.6	25	8	6.6-7.1	no trend	0.23 ± 0.02	0.23 ± 0.02	0.11	4.30
Blend 2	3.0	4	8	6.7-7.4	no trend	1.4 ± 1.3	1.4 ± 1.3	1.27	2.57
Blend 2	3.0	25	8	7.0-7.3	no trend	1.3 ± 0.08	1.3 ± 0.08	0.92	4.30

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation (R ²) ^{Note 1}	Ni (mg/L) predicted at 50 yrs ^{Note 2}	Ni (mg/L) predicted at 10,000 yrs ^{Note 2}	t-test statistic	Value of t for a confidence interval of 95% (1 degree of freedom)
JEB	5.0	25	9	7.98	no trend	0.02 (one point)	0.02 (one point)	na	na
Sue C	7.7	25	9	7.9-8.2	no trend	0.01 ± 0.01	0.01 ± 0.01	1.41	4.30
McClellan Lake	5.0	25	9	8.0-8.6	no trend	0.02 ± 0.01	0.02 ± 0.01	2.18	4.30
Sue A+B	3.0	25	9	7.6-8.7	no trend	0.36 ± 0.6	0.36 ± 0.6	0.14	4.30
Cigar Lake	7.5	25	9	7.2-7.7	no trend	0.04 ± 0.03	0.04 ± 0.03	3.83	4.30
Blend 1	7.6	25	9	6.8-7.7	no trend	0.03 ± 0.01	0.03 ± 0.01	2.29	4.30
Blend 2	3.0	25	9	7.3-8.4	no trend	0.05 ± 0.01	0.05 ± 0.01	0.11	4.30

Note 1: Linear regression equation where x = log time (hours) and y = concentration of arsenic (mg/L)

Note 2: Predicted values are averages of the data when no trend was evident.

Blend 1 = 75% Sue C + 25% Cigar Lake

Blend 2 = 55% Midwest + 15% Sue A+B + 30% Cigar Lake

displayed no significant pH trend with time. In other words, pH values generally varied independent of time.

Concentrations of nickel for runs at 4 and 25°C in tailings considered for TMF disposal, are plotted against the logarithm of time in Figs. 8-17. A t-test of the data for nominal pH 8 runs, indicated that Ni concentrations increased with time in two experiments, and showed no significant trends with time in eight other experiments (Table 1.5.1.1). Predicted Ni concentrations were 1.4 mg/L or less after 10,000 yrs. ($10^{7.94}$ hrs). In seven nominal pH 9 runs, nickel concentrations showed no trend with time, averaged 0.08 mg/L, and were predicted to be less than 0.4 mg/L at 10,000 yrs.

Arsenic concentrations as a function of time in tailings considered for TMF disposal, are plotted in Figs 18-27. For the nominal pH 8 runs, a t-test of the data regression lines indicates that at 4°C none have a slope significantly different from zero. In other words, arsenic concentrations do not change with time in the 4°C tests. The 4°C values range from 0.10 to 0.68 mg/L, and average 0.45 mg/L arsenic (Table 1.5.1.2). Based on the statistical analysis these are the probable arsenic concentrations, also at 10,000 yrs in TMF pore waters.

Most of the nominal pH 8 arsenic data for 25°C also shows no trend with time, although arsenic concentrations are higher than in the 4°C test. Averaging the random data sets and projecting the positively sloping regression lines for the JEB, Sue C and Sue A+B tailings for the 25°C tests suggests that arsenic concentrations may not exceed 1.9 mg/L after 10,000 yrs at a nominal pH of 8, and 25°C (Table 1.5.1.2). Runs at 25°C and nominal pH 9 gave predicted As concentrations ranging from 0.7 to 5.8 mg/L after 50 yrs, and 0.7 to 7.9 mg/L after 10,000 yrs.

1.5.2 Effect of Fe/As Ratio and Temperature

Previous work discussed in Sections 1.3.3 and 1.3.4 and results of the large-scale tests indicated that for a given pH, higher Fe/As ratios in tailings raffinates lead to more complete arsenic removal from solution. Published studies show that arsenic removal is most complete in the pH range from about 3 to 5. During early test work involving tailings, it was observed that liming to pH values between 7 and 8 generally resulted in adequate arsenic removal without causing unacceptable increases in the dissolved nickel. Most long-term experiments were therefore performed at nominal pH 8 or 9 with the result that final pH values were usually between pH 7 and 8.

As shown in Table 1.5.1, at nominal pH 8, arsenic concentrations did not change with time in the 4°C aging tests, and only changed with time in three of seven tests run at 25°C. Examination of the test results for 25 and 50°C at 120 and 144 hrs, indicates that most of the

Table 1.5.1.2 Predicted arsenic concentrations in tailings pore-waters at test temperatures and their statistical significance for tailings proposed for burial in the TMF: Based on the results of the large scale laboratory tests.

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation (R ²) ^{Note 1}	As (mg/L) predicted at 50 yrs ^{Note 2}	As (mg/L) predicted at 10,000 yrs ^{Note 2}	t-test statistic	Value of t for a confidence interval of 95% (1 degree of freedom)
JEB	5.0	4	8	7.3-7.9	no trend	0.68 ± 0.13	0.68 ± 0.13	0.31	2.36
JEB	5.0	25	8	7.0-7.4	y=0.0735x+0.5833 (0.641)	1.0 ± 0.05	1.2 ± 0.05	2.98	2.45
Sue C	7.7	4	8	6.3-8.0	no trend	0.10 ± 0.05	0.10 ± 0.05	2.01	2.36
Sue C	7.7	25	8	6.9-7.5	y=-0.0471x+0.3672 (0.738)	0 ± 0.03	0 ± 0.03	4.44	2.31
McClellan Lake	5.0	25	8	7.3-7.6	no trend	1.19 ± 0.32	1.19 ± 0.32	1.33	2.45
Sue A+B	3.0	25	8	7.3-7.5	y = 0.1494 x + 0.7189 (0.783)	1.6 ± 0.06	1.9 ± 0.06	4.24	2.45
Cigar Lake	7.5	25	8	7.2-7.3	no trend	0.49 ± 0.11	0.49 ± 0.11	0.73	2.57
Blend 1	7.6	25	8	6.6-7.2	no trend	0.38 ± 0.08	0.38 ± 0.08	0.77	2.57
Blend 2	3.0	4	8	6.7-7.4	no trend	0.54 ± 0.3	0.54 ± 0.3	0.57	2.31
Blend 2	3.0	25	8	7.0-7.5	no trend	1.40 ± 0.13	1.40 ± 0.13	0.44	2.57

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation (R ²) ^{Note 1}	As (mg/L) predicted at 50 yrs ^{Note 2}	As (mg/L) predicted at 10,000 yrs ^{Note 2}	t-test statistic	Value of t for a confidence interval of 95% (1 degree of freedom)
JEB	5.0	25	9	7.7-8	no trend	1.3 ± 0.03	1.3 ± 0.03	0.00	4.30
Sue C	7.7	25	9	7.6-8.4	no trend	0.70 ± 0.06	0.70 ± 0.06	1.77	2.45
McClellan Lake	5.0	25	9	7.5-8.6	y=0.7748x+1.691 (0.675)	6.1 ± 0.37	7.8 ± 0.37	5.65	2.45
Sue A+B	3.0	25	9	7.5-8.7	y=0.9071x+0.6517 (0.816)	5.8 ± 0.24	7.9 ± 0.24	4.71	2.45
Cigar Lake	7.5	25	9	7.2-7.7	no trend	1.34 ± 0.18	1.34 ± 0.18	0.22	2.57
Blend 1	7.6	25	9	6.8-7.9	no trend	0.76 ± 0.09	0.76 ± 0.09	0.05	2.57
Blend 2	3.0	25	9	7.3-8.4	y=0.2838x+1.8957 (0.642)	3.5 ± 0.16	4.1 ± 0.16	2.68	2.57

Note 1: Linear regression equation where x = log time (hours) and y = concentration of arsenic (mg/L)

Note 2: Predicted values are averages of the data when no trend was evident.

Blend 1 = 75% Sue C + 25% Cigar Lake

Blend 2 = 55% Midwest + 15% Sue A+B + 30% Cigar Lake

increase in arsenic concentrations occurs prior to 72 hrs. It was decided therefore to assume that the data collected at 72 hrs and thereafter had most nearly approached steady state conditions, and could be treated as a single population for each run. Accordingly, the arsenic concentrations reported after 72 hrs for runs at 4, 25 and 50°C between pH 7 and 8 were averaged for each run. These averages are plotted versus the molar Fe/As ratio of each raffinate in Fig. 28. The data have been fit with curved regression lines, which have squared regression coefficients that range from about 0.8 to 0.9. The plot shows that arsenic removal increases with increasing Fe/As ratio. Arsenic removal from solution also increases with decreasing temperature and is greatest at 4°C. The Fe/As ratios of tailings that would be emplaced in the TMF range from 3.0 to 7.7. The regression curve for arsenic adsorption at 4°C, the expected temperature of TMF pore waters, shows average As values are less than about 1 mg/L when Fe/As ratios equal or exceed 3.0.

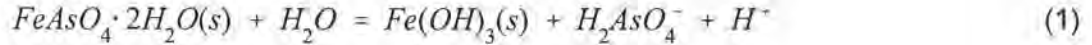
1.6 Chemical Equilibrium and Kinetic Modeling of Aging Test Results

1.6.1 Chemical Equilibrium Modeling of the Dissolved Arsenic Versus Fe/As Relationship

As Fe/As ratios are increased for a given total arsenic concentration, scorodite ($\text{Fe/As} = 1$) apparently precipitates before significant arsenic is available for adsorption. The curves in Fig. 28 reflect scorodite and cabrerite-annabergite precipitation for Fe/As ratios below about 1. At greater Fe/As values, the remaining dissolved arsenic is controlled by adsorption. To confirm this explanation of arsenic behavior, some of the 25°C data in Fig. 28 was reproduced with the geochemical model PHREEQC (Parkhurst, 1995). The modeling was performed in two steps with increasing Fe/As ratios. The first step allowed for mineral precipitation. The second step added reactions to model arsenic adsorption by HFO. The concentrations of species in the raffinates at their lowest Fe/As ratios, were used as initial values for the modeling, with ferric sulfate added to each raffinate in steps to duplicate the Fe/As ratios used in the experiments. The model pH was then raised and maintained at pH 7.5 by the addition of Ca(OH)_2 . In the first step, scorodite, annabergite, gypsum and HFO were allowed to precipitate if they became supersaturated. If HFO was precipitated in step 1, its amount was used in a calculation of arsenic adsorption. Adsorption by HFO was computed with the diffuse layer model, assuming a surface area of 600 m^2/g , and a site density of 0.2 moles of sites per mole of FeOOH (the formula for HFO used in the model). These and other adsorption parameter values used in the calculation were published by Dzombak and Morel (1990). (See also Langmuir, 1997). It was necessary to vary the solubility product of scorodite by ± 0.3 log units ($\approx 1\%$) among the different tailings in order to optimize the model fit to the data. The results, which indicate good agreement between predicted values and the regression curve for the measured data, are shown in Fig. 29.

1.6.2 Effect of Temperature on Arsenic Concentrations

Below about pH 6.5 (See Section 1.6.3 and Figs. 30-36) scorodite ($\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$) and HFO (written as $\text{Fe}(\text{OH})_3$) can coexist at thermodynamic equilibrium in tailings pore waters. The reaction may be written:



The equilibrium constant for this reaction is:

$$K_{eq} = [\text{H}_2\text{AsO}_4^-][\text{H}^+] \quad (2)$$

Based on thermodynamic data in Appendix F, and assuming $-\log K_{sp} = 37.1$ for $\text{Fe}(\text{OH})_3(s)$, $K_{eq} = 10^{-12.3}$ for reaction (1) at 25°C Papangelakis and Demopoulos (1990) give an enthalpy of formation of $\Delta H_f^\circ = -355.0$ kcal/mol for scorodite. Combining this with $\Delta H_f^\circ = -196.7$ kcal/mol for $\text{Fe}(\text{OH})_3(s)$ for HFO (Langmuir, unpublished) and other data from Wagman et al. (1982) we compute $\Delta H_r^\circ = +9.97$ kcal/mol for reaction (1). This indicates that reaction (1) is endothermic: an increase in temperature favors the reaction products. At a given pH, arsenic concentrations should therefore increase with increasing temperature. Figure 28 shows arsenic concentrations as a function of Fe/As ratio and temperature for pH 7-8 runs. The plot shows that in fact arsenic concentrations do increase with temperature, consistent with the enthalpy of reaction (1). Although the concentration data in Fig. 28 is for pH conditions above the stability field of scorodite relative to HFO, arsenic concentrations at 4, 25 and 50°C should be roughly proportional to their values under equilibrium conditions, given the slow breakdown rate of scorodite. For Fe/As = 5, for example, the regression equations in Fig. 28 may be solved to give arsenic concentrations of 0.38, 1.1 and 3.7 mg/L at 4, 25 and 50°C. At constant pH, K_{eq} in Eq. (2) is proportional to the arsenic concentration. The van't Hoff equation, which describes the effect of a change in temperature (T) on the equilibrium constant is written:

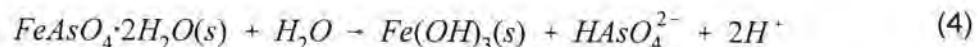
$$-\log \left(\frac{K_2}{K_1} \right) = \frac{\Delta H_r^\circ}{4.576} \left(\frac{1}{T_2} - \frac{1}{T_1} \right) \quad (3)$$

(cf. Langmuir, 1997, *ibid*) where K_2 and K_1 are the equilibrium constants at T_2 and T_1 (K). Substituting the above temperature and concentration data into the van't Hoff equation we can

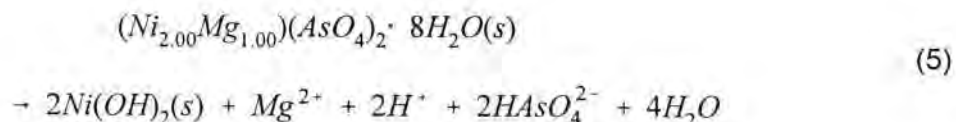
solve for the heat of the reaction and obtain 8.1 and 9.6 kcal/mol between 4 and 25°C, and between 25 and 50°C, respectively. The average enthalpy is thus $\Delta H_r^\circ = 8.9 \pm 1.0$ kcal/mol, in excellent agreement with $\Delta H_r^\circ = +9.97$ kcal/mol computed from the thermodynamic data for reaction (1). In other words, the observed increase in arsenic concentrations with temperature may be controlled by the heat of the reaction between scorodite and HFO.

1.6.3 Reactions Controlling the Arsenic Release Rate

To the extent that arsenic releases with time are controlled by desorption, they should be relatively fast, equilibrating in times that range from seconds to perhaps a few hours (cf. Langmuir, 1997, *ibid*). The rate of dissolution of the arsenate minerals scorodite and cabrerite-annabergite will be much slower and probably controls the changes in arsenic concentrations with time shown in Figs. 18-27. Above pH 7, the breakdown reaction of scorodite to form HFO may be written:



The breakdown of a cabrerite-annabergite that contains 33% of Mg substituting for Ni, may be written:



where it is assumed that the nickel precipitates as nickel hydroxide, which is most likely as pH values approach 8. At lower pH values Ni^{2+} concentrations will be controlled instead by adsorption reactions.

Solids in the above reactions are probably fine grained and poorly crystalline and therefore fairly reactive. Given the chemical complexity of the tailings and our present state of knowledge, it is not possible to identify the elementary rate equations that control arsenic concentrations. However, the overall equations describing the breakdown of scorodite and cabrerite-annabergite provide useful insights into reaction controls. Based on the breakdown reaction for scorodite, the rate of increase in arsenic concentrations as a function of time can be described

by⁷

$$\frac{d(As(V))}{dt} = k_+ \frac{A_w}{M} (\text{scorodite}) - k_- \frac{A_w}{M} (\text{HFO}) [HAsO_4^{2-}]^n [H^+]^m \quad (6)$$

In this expression k_+ and k_- are the forward and reverse rate constants. A_w and M are the wetted surface area of solid scorodite or HFO exposed to solution, and the mass of water, respectively. The exact dependence of the rate on dissolved arsenic and hydrogen ion concentrations is not known. This uncertainty is expressed by the fact that exponents n and m for these species have not been defined. A similar expression may be written for the breakdown of cabrerite-annabergite.

The scorodite breakdown equation provides insights that are consistent with observation. These include that the rate of breakdown of scorodite is slower in tailings with higher Fe/As ratios, consistent with increasing amounts of HFO causing back reaction towards scorodite. Secondly, breakdown rates increase with increasing pH, also consistent with the rate equation.

Breakdown rates of the arsenates should also be proportional to their degree of undersaturation in the tailings, with arsenic concentrations increasing most rapidly in the most undersaturated pore waters. Shown in Figs. 30-38 are the saturation indices of scorodite and annabergite (as a proxy for cabrerite-annabergite) in pore waters of tailings being considered for TMF disposal, based on the aging tests results. Most of the scorodite SI values plotted in Figs. 30-38 are upper bound values, because they were computed assuming the detection limit of 0.02 mg/L, when the iron was below detection. (See Appendix D). The saturation index of scorodite computed for all runs at 25°C which had measureable iron, is plotted against the pH in Fig. 39. Figures 30-39 show that crystalline scorodite is at or above saturation in the raffinates and probably also in pore waters up to about pH 6-7, but becomes increasingly undersaturated relative to HFO as the pH further increases. Corrected scorodite SI values in Fig. 39 range from about -0.1 to +0.9. The MINTEQA2 saturation calculation has assumed $-\log K_{sp} = 25.87$ for scorodite at 25°C. It seems likely that $SI(\text{scorodite}) = +0.9$ represents equilibrium with a relatively amorphous scorodite. If so, its $-\log K_{sp}$ is about 24.1.

The computed saturation state of annabergite in Figs. 30-38 shows similar pH-dependence in most cases, although the mineral is undersaturated in the raffinates. Cabrerite, which contains Mg and Fe(II) substituting for the nickel in annabergite may be more nearly at saturation in tailings pore waters. Although the neutralized raffinates were not sampled at pH values below about 6-7, computer modeling suggests that annabergite approaches or attains saturation in

⁷See also Demopoulos et al. (1994)

most of the tailings at some pH between 5 and 6.

An important question is how long into the future the proposed reaction mechanism of arsenic release is likely to dominate release rates. Certainly if most or all of the scorodite and cabrerite-annabergite have been destroyed, arsenic release rates will not be controlled by the same reactions. To answer this question, the regression equations for arsenic releases from JEB and Sue A+B tailings derived from the 25°C aging test data for nominal pH 8 (Table 1.5.1.2), were used to estimate arsenic pore water concentrations after 10,000 yrs and a million years. Predicted arsenic concentrations were 1.2 and 1.9 mg/L at 10,000 yrs, and 1.3 and 2.2 mg/L at 10⁶ yrs, respectively. JEB tailings contains 0.74% scorodite, and Sue A+B tailings 1.21% scorodite (Table 1.2.1). To attain these predicted concentrations in pore waters at 10,000 or 10⁶ yrs, assuming the sole arsenic source is scorodite dissolution, it is necessary to dissolve about 0.01% of the scorodite in JEB and Sue A+B tailings. This indicates that the wetted surface areas of scorodite and HFO, for example (the A_w terms in Eq. 6) will be nearly constant with time and that a change in the reaction mechanism is unlikely.

Taking the first derivative with respect to time of the equations that describe the regression lines in Figs 18-27 indicates that the rate of breakdown of the arsenate minerals in the tailings is inversely proportional to time, and may be described by equations of the form

$$\frac{d(As(V))}{dt} = \frac{k}{t} \quad (7)$$

where k is constant for a specific tailings and Fe/As ratio, temperature, and nominal pH. In other words, the arsenate mineral breakdown rate decreases rapidly with time, and arsenic concentrations plotted against linear (rather than log) time, will rapidly and asymptotically approach maximum values. Thus, the equation for Sue A+B tailings in Table 1.5.1.2 (Fe/As = 3, 25°C, nominal pH 8) predicts an arsenic concentration of 1.9 mg/L at 10,000 yr, which only increases to 2.2 mg/L at 10⁶ yrs. A survey of published mineral dissolution rate studies (cf. Langmuir, 1997) indicates that such general behavior is typical as solution compositions approach steady state or equilibrium conditions with respect to dissolving minerals.

1.6.4 The Activation Energy of Arsenate Mineral Dissolution Reactions

Examination of the arsenic concentration versus log time plots in Figs. 18-27, and in Appendix E shows that when there are significant positive trends to the data, the slopes of the regression lines are steeper at 50 than at 25°C, and steeper at 25 than at 4°C. The slopes of the trend lines are proportional to the rate of the reaction. In this case the reaction is in fact at least two reactions that include the very slow breakdown of both scorodite and cabrerite-annabergite.

We cannot quantify the separate rates of these reactions, but through the regression slopes can compare their combined overall rates at 4, 25 and 50°C. This can be accomplished through the Arrhenius equation which is written:

$$\log \frac{k_1}{k_2} = \frac{E_a}{2.303 R} \left[\frac{1}{T_2} - \frac{1}{T_1} \right] \quad (8)$$

(cf. Langmuir, 1997). In this expression the log quotient is the difference between the log of the reaction rate constants at temperatures T_1 and T_2 (°K), respectively. E_a and R are the activation energy of the reaction and the gas constant. Because slopes of the regression lines are proportional to the rate constants, we can substitute values of the slopes for the rate constants in the Arrhenius expression and solve for the activation energy. The resultant activation energy is constant, independent of time, even though the instantaneous reaction rates decrease with time.

The data for JEB tailings (Fe/As = 5) at 50 and 25°C leads to $E_a = 17.1$ kcal/mol. This value is similar to measured activation energies for specific mineral dissolution and chemical desorption reactions (Langmuir, 1997). Shown in Fig. 40 are regression lines for JEB (Fe/As = 5) data at 50, 25 and 4°C. An activation energy of 17.1 kcal/mol has been used to predict the As release rate at 4°C. The predicted rate is seen to be almost identical to the measured rate. Aging tests were not run on Sue A+B (Fe/As = 3.0) at 4°C. The regression lines for 50 and 25°C (Fig. 41) have similarly been used to estimate the arsenic release rate at 4°C. To do this based on the 25°C regression, for example, first an arsenic concentration at 25°C and 1 hr is estimated by projecting the arsenic vs log time regression line back to 1 hr. The 4°C value at 1 hr is then estimated from the projected value at 25°C assuming their concentration ratio is the same as given by the 4 and 25°C arsenic concentration curves in Fig. 28. This leads to a predicted arsenic pore-water concentration of less than 0.5 mg/L at 50 yrs for Sue A+B tailings.

Regression lines with significant positive slopes at 50 and 25°C are available for 10 tailings runs with specific Fe/As ratios. Comparison of the slopes leads to an average E_a value of 13.4 ± 4.2 kcal/mol (Table 1.6.4.1). An activation energy of 12.6 kcal/mol indicates a reaction with a rate that doubles with about every 10°C increase. The average E_a value for the aging experiments indicates a slightly greater dependence of the rate on temperature than this. The average activation energy of 13.4 ± 4.2 kcal/mol derived from the 25 and 50°C data, may be used to predict long-term arsenic concentrations in the TMF at 4°C for tailings that were not studied in the aging tests at this temperature, using the same approach as just described for the JEB and Sue A+B tailings. Again, the slope of the estimated 4°C concentration trend line is based on the slope at 25 or 50°C and the activation energy. Projecting the regression line for the 25 or 50°C data back to 1 hr gives an arsenic concentration for that temperature at 1 hr, which is

Table 1.6.4.1 Apparent activation energies (E_a) of arsenate mineral dissolution based upon a comparison of the rates measured at 25 and 50°C.

Tailings	Fe/As (molar)	T (°C)	Measured pH range	E_a (kcal/mol)
JEB (TMF)	5.0	25 50	7.0-7.4 6.3-7.5	17.1
Sue A+B (TMF)	3.0	25 50	7.3-7.5 7.5-7.7	12.6
JEB	3.0	25 50	7.4-7.5 7.7-7.9	19.2
McClellan Lake	4.6	25 50	6.5-7.2 6.6-7.3	17.9
McClellan Lake	5.0	25 50	7.5-8.6 7.4-8.6	8.83
Sue A+B	0.6	25 50	7.8-8.5 7.5-8.5	10.6
Sue A+B	5.0	25 50	7.1-7.5 7.1-7.6	10.7
Sue A+B	5.0	25 50	7.3-8.5 7.3-8.4	7.04
Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake)	0.3	25 50	6.97-7.03 6.2-7.0	13.4
Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake)	3.0	25 50	7.3-8.4 7.3-8.4	17.1
Mean				13.4
Standard Deviation				4.2

Table 1.6.4.2 Equations for concentration vs. log time predicted for 4°C.

Arsenic

Tailings proposed for TMF	Fe/As (molar)	Nominal pH	Regression equation at 25°C or 50°C ^{Note 1, 4}	Slope at 4°C ^{Note 2}	Intercept at 4°C ^{Note 3a}	Equation at 4°C ^{Note 4}	As (mg/L) predicted at 4°C	
							50 yrs	10,000 yrs
JEB	5.0	8	$y=0.0735x+0.5833$	0.0132	0.2114	$y=0.0132x+0.2114$	0.29	0.32
McClellan Lake	5.0	8	$y=1.7431x+0.7894$	0.0546	0.0806	$y=0.0546x+0.0806$	0.39	0.51
Sue A+B	3.0	8	$y=0.1494x+0.7189$	0.0269	0.2920	$y=0.0269x+0.2920$	0.44	0.51
Blend 2	3.0	8	$y=2.2234x+1.4539$	0.0697	0.1918	$y=0.0697x+0.1918$	0.58	0.75

Nickel

Tailings proposed for TMF	Fe/As (molar)	Nominal pH	Regression equation at 25°C or 50°C ^{Note 1, 4}	Slope at 4°C ^{Note 2}	Intercept at 4°C ^{Note 3b}	Equation at 4°C ^{Note 4}	Ni (mg/L) predicted at 4°C	
							50 yrs	10,000 yrs
Cigar Lake	7.5	8	$y=0.051x+0.259$	0.0092	0.0801	$y=0.0092x+0.0801$	0.13	0.15

Note 1: Regression equations taken from Tables 1.5.1.1 and 1.5.1.2 and Appendix E.

Note 2: Calculated with the Arrhenius equation: $\log(\text{slope at } 4^\circ\text{C} / \text{slope at } 25^\circ\text{C or } 50^\circ\text{C}) = E_a / 2.303R \cdot (1/T_2 - 1/T_1)$ for a specific Fe/As ratio where $E_a = 13.4$ kcal/mol (Table 1.6.4.1), $T_1 = 277.15\text{K}$ and $T_2 = 298.15\text{K}$ or 323.15K .

Note 3a: Intercept at 1 hour calculated using average arsenic curves shown in Figure 28.

Note 3b: Calculated using: $y = 233.31x^{-3.9423}$ ($R^2 = 0.912$) from a power function (curvilinear) regression of the nickel concentration data for 4°C where $x = \text{Fe/As (molar)}$ and $y = \text{average nickel (mg/L)}$.

Note 4: Equation where: $x = \log \text{ time (hours)}$ and $y = \text{arsenic (mg/L)}$.

Blend 2 = 55% Midwest + 15% Sue A+B + 30% Cigar Lake

corrected to 4°C using the equations for the same temperatures in Fig. 28.

Equations derived using this approach, that describe arsenic concentrations as a function of time for the different tailings at 4°C, are given in Table 1.6.4.2. Also shown are predicted arsenic concentrations in the TMF after 50 and 10,000 yrs, based on extrapolation of the 4°C regression equations. Uncertainties assigned to the predicted values are based on the uncertainty of ± 4.2 kcal/mol (± 1 SD) in the activation energy. The table suggests that arsenic concentrations in the TMF at 4°C and nominal pH 8 may not exceed 1 mg/L after 50 to 10,000 yrs. A similar approach to nickel concentrations in Cigar Lake tailings at 4°C leads to predictions of 0.13 and 0.15 mg/L Ni^{2+} at 50 and 10,000 yrs, respectively.

It is important to note that reaction rates have been accelerated in the aging tests by placing the reaction vessels on a shaker table which creates mixing and convective flow of solutions. In TMF pore waters, however, dissolved reactants will move by diffusion only. Diffusion rates will be extremely low in the bulk of the tailings because of the near absence of arsenic concentration gradients except at the outer edge of the TMF.

1.6.5 Possible Crystallization of Amorphous Hydrated Ferric Oxide (HFO)

Rapid neutralization of acid Fe(III) and arsenic rich raffinates leads to removal of most of the arsenic in precipitated ferric and nickel arsenate solids. Additional Fe(III) is precipitated in HFO which is a strong sorbent for dissolved arsenic (cf. Fuller et al., 1993). Concerns have been expressed that this HFO will rapidly crystallize to form the mineral goethite ($\alpha\text{-FeOOH}$), which has a lower sorption capacity for arsenic than does HFO, producing increased arsenic source term concentrations in the TMF. Depending on the conditions during its precipitation and aging, in fact HFO may crystallize to form either goethite or hematite ($\alpha\text{-Fe}_2\text{O}_3$) (cf. Atkinson et al., 1968). However, there are several reasons why crystallization of HFO will be very slow and may not occur in the TMF, particularly during the 50 yrs following tailings emplacement.

First, crystallization of HFO is strongly inhibited by specifically adsorbed anions such as sulfate, arsenate, and silicate all of which are abundant in the raffinates (cf. Cornell et al., 1987; Paige et al., 1994). Brady et al. (1986) reported that in the presence of 2000 mg/L sulfate, and in solutions in which the initial $\text{SO}_4/\text{Fe(III)}$ molar ratio exceeded 1.5, only HFO was precipitated. Crystallization of the HFO to goethite did not take place during 30 days of aging at pH 6. In raffinates from the McClean Lake deposits, sulfate values are controlled by the solubility of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) and generally exceed 2000-4000 mg/L. Further, the SO_4/Fe ratio of the various raffinates ranges from 9 to 30.

Baltpurvins et al. (1996) observed that HFO crystallization depended on pH as well as sulfate

concentration. At pH 7 and 8, with $\text{SO}_4/\text{Fe} = 1.5$, no measurable crystallization of HFO had occurred in their experiments after aging for 1 yr. In our study, the lack of significant trends in arsenic concentrations in the long-term scoping tests at 4°C, most of which were run for at least 1000 hrs, probably reflects the absence of important crystallization of HFO during these tests. This suggests that HFO crystallization will be very slow and may be negligible for many years after tailings emplacement in the TMF.

1.7 Summary and Conclusions

The acid raffinates of tailings proposed for burial in the JEB Tailings Management Facility (TMF) have molar Fe/As ratios that range from 0.3 to 7.7. In order to control arsenic concentrations (the arsenic source term) in pore waters of the tailings after their burial in the TMF, COGEMA Resources proposes adding ferric sulfate to the raffinates to increase the Fe/As ratios of Sue A+B and Blend 2 tailings to 3, and the JEB and McClean Lake tailings to 5. Tailings/raffinate pH values will then be adjusted to a nominal pH of 8 by slaked lime addition, to result in a pH of 7-8 in TMF pore waters.

Mineralogical and chemical analysis of the tailings after treatment indicates that the arsenic is chiefly present in the minerals scorodite ($\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$) and cabrerite-annabergite ($(\text{Ni,Mg,Fe})_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$), with minor amounts adsorbed to ferrihydrite (hydrous ferric oxide, HFO), and to aluminum oxyhydroxides and clays. The nickel occurs chiefly in the cabrerite-annabergite, and is also adsorbed onto HFO, the Al solids and clays. Geochemical modeling indicates that the arsenates are metastable relative to HFO and dissolved Ni^{2+} or $\text{Ni}(\text{OH})_2(\text{s})$ between pH 7 and 8, and should slowly break down with time, releasing arsenic to TMF pore waters.

Large-scale laboratory tests of the McClean Lake, Midwest and Cigar Lake ores were performed to study the effects of adding different amounts of ferric sulfate and slaked lime to the tailings/raffinates for arsenic and nickel control. Short term (3 hr) tests run at 25°C were designed to duplicate conditions during tailings processing in the JEB mill. Aging tests, which used products of the short-term tests as their starting materials, were run for times that ranged from 5 to 50 days, and temperatures of 4, 25 and 50°C. The aging tests were designed to predict arsenic and nickel source term concentrations in the TMF with time.

Mineralogical analysis of the processed tailings and geochemical modeling of the test results indicate that most of the arsenic and nickel precipitate in relatively amorphous scorodite and cabrerite-annabergite as the pH is increased by slaked lime addition. In tailings raffinates with sufficiently high Fe/As ratios, HFO is subsequently precipitated and adsorbs most of the remaining arsenic. A kinetic model is presented that describes scorodite breakdown with time to form HFO and release dissolved arsenic. The model explains the observation that arsenic

Table 1.7.1 Predicted arsenic concentrations in tailings pore waters at nominal pH 8 and 4°C for tailings proposed for burial in the TMF. ^{Note 1}

Tailings	Fe/As (molar)	Data Trend ^{Note 3}	Source of Trend Line	As (mg/L) predicted at 50 yrs	As (mg/L) predicted at 10,000 yrs
JEB	5.0	no trend	data regression	0.68 ± 0.13	0.68 ± 0.13
JEB	5.0	$y=0.0132x+0.2114$	Arrhenius equation	0.29 ± 0.03	0.32 ± 0.05
Sue C	7.7	no trend	data regression	0.10 ± 0.05	0.10 ± 0.05
McClean Lake ^{Note 2}	5.0	no trend	data regression	0.43 ± 0.30	0.43 ± 0.30
McClean Lake	5.0	$y=0.0546x+0.0806$	Arrhenius equation	0.39 ± 0.22	0.51 ± 0.30
Sue A+B	3.0	$y=0.0269x+0.2920$	Arrhenius equation	0.44 ± 0.04	0.51 ± 0.07
Cigar Lake ^{Note 2}	7.5	no trend	data regression	0.16 ± 0.11	0.16 ± 0.11
Blend 1 ^{Note 2}	7.6	no trend	data regression	0.13 ± 0.08	0.13 ± 0.08
Blend 2	3.0	no trend	data regression	0.54 ± 0.3	0.54 ± 0.3
Blend 2	3.0	$y=0.0697x+0.1918$	Arrhenius equation	0.58 ± 0.26	0.75 ± 0.37

Note 1: Uncertainty in predicted values based on the Arrhenius equation reflect the standard deviation of the average activation energy. Uncertainty in predicted values which are averages of the data showing no trend, are standard deviations of the averages.

Note 2: Data for 25°C which showed no trend adjusted to 4°C using regression relationships in Figure 28.

Note 3: Equation where: $x = \log$ time (hours) and $y = \text{arsenic (mg/L)}$.

Blend 1: 75% Sue C + 25% Cigar Lake

Blend 2: 55% Midwest + 15% Sue A+B + 30% Cigar Lake

Table 1.7.2 Predicted nickel concentrations in tailings pore waters at nominal pH 8 and 4°C for tailings proposed for burial in the TMF.^{Note 1}

Tailings	Fe/As (molar)	Data Trend ^{Note 3}	Source of Trend Line	Ni (mg/L) predicted at 50 yrs	Ni (mg/L) predicted at 10,000 yrs
JEB	5.0	no trend	data regression	0.81 ± 0.11	0.81 ± 0.11
Sue C	7.7	$y=0.0289x-0.0046$	data regression	0.2 ± 0.02	0.2 ± 0.02
McClean Lake ^{Note 2}	5.0	no trend	data regression	0.18 ± 0.02	0.18 ± 0.02
Sue A+B ^{Note 2}	3.0	no trend	data regression	1.1 ± 0.6	1.1 ± 0.6
Cigar Lake	7.5	$y=0.0092x+0.0801$	Arrhenius equation	0.13 ± 0.02	0.15 ± 0.03
Blend 1 ^{Note 2}	7.6	no trend	data regression	0.23 ± 0.02	0.23 ± 0.02
Blend 2	3.0	no trend	data regression	1.4 ± 1.3	1.4 ± 1.3

Note 1: Uncertainty in predicted values based on the Arrhenius equation reflect the standard deviation of the average activation energy. Uncertainty in predicted values which are averages of the data showing no trend, are standard deviations of the averages.

Note 2: Data for 25°C - no data available for 4°C.

Note 3: Equation where: x = log time (hours) and y = nickel (mg/L).

Blend 1: 75% Sue C + 25% Cigar Lake

Blend 2: 55% Midwest + 15% Sue A+B + 30% Cigar Lake

concentrations and the arsenic release rate are reduced at high Fe/As ratios and in nominal pH 8 pore waters relative to those of nominal pH 9.

Statistical and kinetic analyses of the long-term test data have been used to predict arsenic and nickel concentrations at 4°C in TMF pore waters after 50 and 10,000 yrs. Where neither approach was applicable for a particular tailings, but the test data for 25°C showed no trend, arsenic concentrations at 4°C have been computed from the average concentration at 25°C, using the temperature functions given by regression equations in Fig. 28. The results of these several calculations are given in Tables 1.7.1 and 1.7.2. Predictions based on the three approaches give consistent results, and show that arsenic and nickel concentrations in pore waters at 4°C are unlikely to exceed 1 mg/L and 2 mg/L in any individual tailings, even after 10,000 yrs of burial in the TMF.

Appendix C

Section C - Part A

Subsection A: Chemical Composition of Tailings Solids

APPENDIX A

CHEMICAL COMPOSITION OF TAILINGS SOLIDS

- A1. Composition of Solids Precipitated from Tailings Raffinates, This Study**
- A2. Composition of Tailings Solids Reported by Steffan, Robertson & Kirsten (1994)**

Table A1.1 Computed weight and molar composition of solids precipitated from addition of Ca(OH)_2 and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

JEB tailings: Fe/As = 2.6 and nominal pH = 8 (25°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 120 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	503		0.02	3.02	Al_2O_3	101.94	53.96	5.70	0.0559	1.79
As	271		3.81	1.60	As_2O_5	229.829	149.84	2.46	0.0107	0.34
Ca	441	56.8	478	56.6	CaO	56.079	40.1	79.18	1.4118	45.27
Cl	35.2		35.2	0.00E+00	Cl	35.453	35.45	0.00	0.0000	0.00
Fe	606		0.02							
Fe^{2+}	413		0.02	2.48	FeO	71.846	55.85	3.19	0.0444	1.42
Fe^{3+}	193		0.02	1.16	Fe_2O_3	159.7	111.69	1.66	0.0104	0.33
K	219		88.9	0.78	K_2O	94.2	78.20	0.94	0.0100	0.32
Mg	303		208	0.57	MgO	40.32	24.31	0.95	0.0234	0.75
Na	25.8		541	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	144		0.59	0.86	NiO	74.71	58.71	1.09	0.0147	0.47
NO_3	53.6		8.8	0.27	N_2O_5	108.009	124.01	0.23	0.0022	0.07
P	69		1.38	0.41	P_2O_5	141.95	61.95	0.93	0.0065	0.21
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	2.11
SO_4^{2-}	26900	0.23	3519	140.5	SO_3	80.066	96.1	117.12	1.4628	46.91
TOTALS				212.2				217.4	3.1186	100.0
% contamination of Ca(OH)_2 by Na =			0.95%							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				135.5						
Difference in SO_4 calculations (g) =				4.98						

Notes:

1. Calcium calculated from amount of Ca(OH)_2 added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.2 Computed weight and molar composition of solids precipitated from addition of $\text{Ca}(\text{OH})_2$ and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

Sample for Dr. Slaughter										
JEB tailings: Fe/As = 3.0 and nominal pH = 8 (25°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 120 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	503		0.02	3.02	Al_2O_3	101.94	53.96	5.70	0.0559	1.79
As	271		2.66	1.61	As_2O_5	229.829	149.84	2.47	0.0107	0.34
Ca	441	56.8	463	56.7	CaO	56.079	40.1	79.30	1.4141	45.24
Cl	35.2		34.5	4.20E-03	Cl	35.453	35.45	0.00	0.0001	3.79E-03
Fe	606		0.02							
Fe^{2+}	413		0.02	2.48	FeO	71.846	55.85	3.19	0.0444	1.42
Fe^{3+}	193		0.02	1.16	Fe_2O_3	159.7	111.69	1.66	0.0104	0.33
K	219		89.4	0.78	K_2O	94.2	78.20	0.94	0.0099	0.32
Mg	303		207	0.58	MgO	40.32	24.31	0.96	0.0237	0.76
Na	25.8		553	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	144		0.59	0.86	NiO	74.71	58.71	1.09	0.0147	0.47
NO_3	53.6		8.7	0.27	N_2O_5	108.009	124.01	0.23	0.0022	0.07
P	69		1.6	0.40	P_2O_5	141.95	61.95	0.93	0.0065	0.21
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	2.11
SO_4^{2-}	26900	0.23	3450	140.9	SO_3	80.066	96.1	117.46	1.4671	46.94
TOTALS				212.7				217.9	3.1255	100.0
% contamination of $\text{Ca}(\text{OH})_2$ by Na =			0.97%							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				135.8						
Difference in SO_4 calculations (g) =				5.18						

Notes:

1. Calcium calculated from amount of $\text{Ca}(\text{OH})_2$ added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.3 Computed weight and molar composition of solids precipitated from addition of $\text{Ca}(\text{OH})_2$ and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

Sample for Dr. Slaughter										
JEB tailings: nominal pH = 8 with Fe/As = 5.0 (4°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 1 = initial time (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	434		0.07	2.60	Al_2O_3	101.94	53.96	4.92	0.0482	2.70
As	366		0.88	2.19	As_2O_5	229.829	149.84	3.36	0.0146	0.82
Ca	590	28.1	496	28.7	CaO	56.079	40.1	40.15	0.7160	40.12
Cl	38.7		68.9	0.00	Cl	35.453	35.45	0.00	0.0000	0.00
Fe	1365		0.02							
Fe^{2+}	310		0.02	1.86	FeO	71.846	55.85	2.39	0.0333	1.87
Fe^{3+}	1055		0.02	6.33	Fe_2O_3	159.7	111.69	9.05	0.0567	3.18
K	241		110	0.79	K_2O	94.2	78.20	0.95	0.0101	0.56
Mg	341		185	0.94	MgO	40.32	24.31	1.55	0.0385	2.16
Na	148		545	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	201		0.73	1.20	NiO	74.71	58.71	1.53	0.0205	1.15
NO_3	25.3		27.3	0.00	N_2O_5	108.009	124.01	0.00	0.0000	0.00
P	91		0.14	0.55	P_2O_5	141.95	61.95	1.25	0.0088	0.49
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	3.69
SO_4^{2-}	15300	2.41	3340	74.2	SO_3	80.066	96.1	61.82	0.7721	43.27
TOTALS				123.3				130.9	1.7846	100.0
% contamination of $\text{Ca}(\text{OH})_2$ by Na =			1.94 %							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				68.7						
Difference in SO_4 calculations (g) =				5.43						

Notes:

1. Calcium calculated from amount of $\text{Ca}(\text{OH})_2$ added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.4 Computed weight and molar composition of solids precipitated from addition of $\text{Ca}(\text{OH})_2$ and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

Sample for Dr. Slaughter										
JEB tailings: nominal pH = 8 with Fe/As = 5.0 (4°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 144 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	434		0.02	2.60	Al_2O_3	101.94	53.96	4.92	0.0483	2.69
As	366		0.53	2.19	As_2O_5	229.829	149.84	3.36	0.0146	0.82
Ca	590	28.1	441	29.0	CaO	56.079	40.1	40.62	0.7242	40.36
Cl	38.7		47.2	0.00	Cl	35.453	35.45	0.00	0.0000	0.00
Fe	1365		0.02							
Fe^{2+}	310		0.02	1.86	FeO	71.846	55.85	2.39	0.0333	1.86
Fe^{3+}	1055		0.02	6.33	Fe_2O_3	159.7	111.69	9.05	0.0567	3.16
K	241		89.6	0.91	K_2O	94.2	78.20	1.09	0.0116	0.65
Mg	341		202	0.83	MgO	40.32	24.31	1.38	0.0343	1.91
Na	148		557	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	201		0.72	1.20	NiO	74.71	58.71	1.53	0.0205	1.14
NO_3	25.3		9.5	0.09	N_2O_5	108.009	124.01	0.08	0.0008	0.04
P	91		1.9	0.53	P_2O_5	141.95	61.95	1.23	0.0086	0.48
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	3.67
SO_4^{2-}	15300	2.41	3280	74.5	SO_3	80.066	96.1	62.12	0.7759	43.24
TOTALS				124.1				131.7	1.7946	100.0
% contamination of $\text{Ca}(\text{OH})_2$ by Na =			1.98%							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				69.5						
Difference in SO_4 calculations (g) =				5.00						

Notes:

1. Calcium calculated from amount of $\text{Ca}(\text{OH})_2$ added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.5 Computed weight and molar composition of solids precipitated from addition of $\text{Ca}(\text{OH})_2$ and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

JEB tailings: Fe/As = 5.0 and nominal pH = 8 (25°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 120 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	503		0.02	3.02	Al_2O_3	101.94	53.96	5.70	0.0559	1.72
As	271		0.79	1.62	As_2O_5	229.829	149.84	2.49	0.0108	0.33
Ca	441	61.1	471	61.0	CaO	56.079	40.1	85.29	1.5209	46.66
Cl	35.2		34.2	0.01	Cl	35.453	35.45	0.01	0.0002	0.01
Fe	1010		0.02							
Fe^{2+}	413		0.02	2.48	FeO	71.846	55.85	3.19	0.0444	1.36
Fe^{3+}	597		0.02	3.58	Fe_2O_3	159.7	111.69	5.12	0.0321	0.98
K	219		95.6	0.74	K_2O	94.2	78.20	0.89	0.0095	0.29
Mg	303		221	0.49	MgO	40.32	24.31	0.82	0.0202	0.62
Na	25.8		548	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	144		0.52	0.86	NiO	74.71	58.71	1.10	0.0147	0.45
NO_3	53.6		1.2	0.31	N_2O_5	108.009	124.01	0.27	0.0025	0.08
P	69		0.69	0.41	P_2O_5	141.95	61.95	0.94	0.0066	0.20
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	2.02
SO_4^{2-}	26900	1.27	3487	141.7	SO_3	80.066	96.1	118.15	1.4756	45.28
TOTALS				220.2				227.9	3.2592	100.0
% contamination of $\text{Ca}(\text{OH})_2$ by Na =			0.90%							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				146.0						
Difference in SO_4 calculations (g) =				4.26						

Notes:

1. Calcium calculated from amount of $\text{Ca}(\text{OH})_2$ added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.6 Computed weight and molar composition of solids precipitated from addition of $\text{Ca}(\text{OH})_2$ and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

Sample for Dr. Slaughter										
Sue C tailings: nominal pH = 8 without iron addition (25°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 144 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	708		0.02	4.25	Al_2O_3	101.94	53.96	8.02	0.0787	1.86
As	141		0.3	0.84	As_2O_5	229.829	149.84	1.29	0.0056	0.13
Ca	629	79.0	481	79.9	CaO	56.079	40.1	111.77	1.9930	47.14
Cl	31.1		35.3	0.00	Cl	35.453	35.45	0.00	0.0000	0.00
Fe	811		0.02							
Fe^{2+}	633		0.02	3.80	FeO	71.846	55.85	4.89	0.0680	1.61
Fe^{3+}	178		0.02	1.07	Fe_2O_3	159.7	111.69	1.53	0.0096	0.23
K	209		91.6	0.70	K_2O	94.2	78.20	0.85	0.0090	0.21
Mg	455		328	0.76	MgO	40.32	24.31	1.26	0.0313	0.74
Na	39.8		565	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	145		0.58	0.87	NiO	74.71	58.71	1.10	0.0148	0.35
NO_3	37.1		2.3	0.21	N_2O_5	108.009	124.01	0.18	0.0017	0.04
P	18.2		1.39	0.10	P_2O_5	141.95	61.95	0.23	0.0016	0.04
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	1.56
SO_4^{2-}	35000		3796	187.2	SO_3	80.066	96.1	156.05	1.9490	46.10
TOTALS				283.7				291.1	4.2282	100.0
% contamination of $\text{Ca}(\text{OH})_2$ by Na =			0.72%							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				191.3						
Difference in SO_4 calculations (g) =				4.10						

Notes:

1. Calcium calculated from amount of $\text{Ca}(\text{OH})_2$ added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.7 Computed weight and molar composition of solids precipitated from addition of $\text{Ca}(\text{OH})_2$ and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

Sample for Dr. Slaughter										
McClellan Lake tailings: nominal pH = 8 without iron addition (25°C) .										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 144 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	393		0.02	2.36	Al_2O_3	101.94	53.96	4.45	0.0437	1.33
As	275		2.53	1.63	As_2O_5	229.829	149.84	2.51	0.0109	0.33
Ca	126	66.0	494	63.8	CaO	56.079	40.1	89.27	1.5918	48.54
Cl	30.1		34.9	0.00	Cl	35.453	35.45	0.00	0.0000	0.00
Fe	948		0.02							
Fe^{2+}	419		0.02	2.51	FeO	71.846	55.85	3.23	0.0450	1.37
Fe^{3+}	531		0.02	3.19	Fe_2O_3	159.7	111.69	4.56	0.0285	0.87
K	174		88	0.52	K_2O	94.2	78.20	0.62	0.0066	0.20
Mg	61.7		77.4	0.00	MgO	40.32	24.31	0.00	0.0000	0.00
Na	31.7		607	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	164		0.19	0.98	NiO	74.71	58.71	1.25	0.0167	0.51
NO_3	35.9		2.2	0.20	N_2O_5	108.009	124.01	0.18	0.0016	0.05
P	23		1.11	0.13	P_2O_5	141.95	61.95	0.30	0.0021	0.06
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	2.01
SO_4^{2-}	26100		2625	140.9	SO_3	80.066	96.1	117.40	1.4663	44.72
TOTALS				220.1				227.7	3.2791	100.0
% contamination of $\text{Ca}(\text{OH})_2$ by Na =			0.92%							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				152.8						
Difference in SO_4 calculations (g) =				11.96						

Notes:

1. Calcium calculated from amount of $\text{Ca}(\text{OH})_2$ added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.8 Computed weight and molar composition of solids precipitated from addition of $\text{Ca}(\text{OH})_2$ and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

McClellan Lake tailings: Fe/As = 5.0 and nominal pH = 8 (25°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 144 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	393		0.02	2.36	Al_2O_3	101.94	53.96	4.45	0.0437	1.35
As	275		1.7	1.64	As_2O_5	229.829	149.84	2.52	0.0109	0.34
Ca	126	64.4	482	62.2	CaO	56.079	40.1	87.10	1.5531	48.05
Cl	30.1		34.8	0.00	Cl	35.453	35.45	0.00	0.0000	0.00
Fe	1025		0.02							
Fe^{2+}	419		0.02	2.51	FeO	71.846	55.85	3.23	0.0450	1.39
Fe^{3+}	606		0.02	3.64	Fe_2O_3	159.7	111.69	5.20	0.0326	1.01
K	174		89.5	0.51	K_2O	94.2	78.20	0.61	0.0065	0.20
Mg	81.7		77.9	0.02	MgO	40.32	24.31	0.04	0.0009	0.03
Na	31.7		609	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	164		0.2	0.98	NiO	74.71	58.71	1.25	0.0167	0.52
NO_3	35.9		2.2	0.20	N_2O_5	108.009	124.01	0.18	0.0016	0.05
P	23		1.13	0.13	P_2O_5	141.95	61.95	0.30	0.0021	0.07
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	2.04
SO_4^{2-}	26100	0.20	2862	139.6	SO_3	80.066	96.1	116.38	1.4535	44.97
TOTALS				217.8				225.2	3.2325	100.0
% contamination of $\text{Ca}(\text{OH})_2$ by Na =			0.95%							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				149.1						
Difference in SO_4 calculations (g) =				9.47						

Notes:

1. Calcium calculated from amount of $\text{Ca}(\text{OH})_2$ added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.9 Computed weight and molar composition of solids precipitated from addition of $\text{Ca}(\text{OH})_2$ and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

Sample for Dr. Slaughter										
Sue A+B tailings: nominal pH = 8 and low iron addition - Fe/As = 0.64 (25°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 144 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	1690		0.02	10.14	Al_2O_3	101.94	53.96	19.15	0.1879	4.08
As	2430		20.6	14.46	As_2O_5	229.829	149.84	22.17	0.0965	2.10
Ca	304	68.2	438	67.4	CaO	56.079	40.1	94.26	1.6808	36.52
Cl	35.6		31.6	0.02	Cl	35.453	35.45	0.02	0.0007	0.01
Fe	1160		0.02							
Fe^{2+}	821		0.02	4.93	FeO	71.846	55.85	6.34	0.0882	1.92
Fe^{3+}	339		0.02	2.03	Fe_2O_3	159.7	111.69	2.91	0.0182	0.40
K	357		137	1.32	K_2O	94.2	78.20	1.59	0.0169	0.37
Mg	716		316	2.40	MgO	40.32	24.31	3.98	0.0987	2.14
Na	46.8		643	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	2740		2.65	16.4	NiO	74.71	58.71	20.90	0.2797	6.08
NO_3	39.8		2.9	0.22	N_2O_5	108.009	124.01	0.19	0.0018	0.04
P	27.2		0.59	0.16	P_2O_5	141.95	61.95	0.37	0.0026	0.06
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	1.43
SO_4^{2-}	37100	0.21	4076	198.4	SO_3	80.066	96.1	165.33	2.0649	44.86
TOTALS				321.8				341.2	4.6026	100.0
% contamination of $\text{Ca}(\text{OH})_2$ by Na =			0.94%							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				161.4						
Difference in SO_4 calculations (g) =				36.99						

Notes:

1. Calcium calculated from amount of $\text{Ca}(\text{OH})_2$ added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.10 Computed weight and molar composition of solids precipitated from addition of Ca(OH)_2 and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

Sue A+B tailings: Fe/As = 3.0 and nominal pH = 8 (25°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 144 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	1690		0.03	10.1	Al_2O_3	101.94	53.96	19.15	0.1879	3.35
As	2430		1.11	14.6	As_2O_5	229.829	149.84	22.35	0.0973	1.74
Ca	304	92.0	385	91.5	CaO	56.079	40.1	128.01	2.2827	40.74
Cl	35.6		38.3	0.00	Cl	35.453	35.45	0.00	0.0000	0.00
Fe	5436		0.02							
Fe^{2+}	821		0.02	4.93	FeO	71.846	55.85	6.34	0.0882	1.57
Fe^{3+}	4615		0.02	27.7	Fe_2O_3	159.7	111.69	39.59	0.2479	4.42
K	357		128	1.37	K_2O	94.2	78.20	1.66	0.0176	0.31
Mg	716		249	2.80	MgO	40.32	24.31	4.65	0.1153	2.06
Na	46.8		571	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	2740		0.92	16.4	NiO	74.71	58.71	20.91	0.2799	5.00
NO_3	39.8		5	0.21	N_2O_5	108.009	124.01	0.18	0.0017	0.03
P	27.2		3.42	0.14	P_2O_5	141.95	61.95	0.33	0.0023	0.04
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	1.17
SO_4^{2-}	37100	11.24	3489	212.9	SO_3	80.066	96.1	177.46	2.2164	39.56
TOTALS				386.6				424.6	5.6029	100.0
% contamination of Ca(OH)_2 by Na =			0.62%							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				219.1						
Difference in SO_4 calculations (g) =				6.23						

Notes:

1. Calcium calculated from amount of Ca(OH)_2 added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.11 Computed weight and molar composition of solids precipitated from addition of $\text{Ca}(\text{OH})_2$ and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

Sue A+B tailings: Fe/As = 5.0 and nominal pH = 8 (25°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 144 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	1690		0.02	10.14	Al_2O_3	101.94	53.96	19.15	0.1879	2.99
As	2430		0.61	14.58	As_2O_5	229.829	149.84	22.36	0.0973	1.55
Ca	304	107.7	392	107.1	CaO	56.079	40.1	149.91	2.6731	42.48
Cl	35.6		28.7	0.04	Cl	35.453	35.45	0.04	0.0012	0.02
Fe	9060		0.02							
Fe^{2+}	821		0.02	4.93	FeO	71.846	55.85	6.34	0.0882	1.40
Fe^{3+}	8239		0.02	49.4	Fe_2O_3	159.7	111.69	70.68	0.4426	7.03
K	357		126	1.39	K_2O	94.2	78.20	1.67	0.0177	0.28
Mg	716		233	2.90	MgO	40.32	24.31	4.81	0.1192	1.89
Na	46.8		566	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	2740		0.77	16.4	NiO	74.71	58.71	20.91	0.2799	4.45
NO_3	39.8		5.1	0.21	N_2O_5	108.009	124.01	0.18	0.0017	0.03
P	27.2		2.09	0.15	P_2O_5	141.95	61.95	0.35	0.0024	0.04
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	1.05
SO_4^{2-}	37100	20.6	3464	222.4	SO_3	80.066	96.1	185.37	2.3153	36.80
TOTALS				433.7				485.7	6.2923	100.0
% contamination of $\text{Ca}(\text{OH})_2$ by Na =			0.53 %							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				256.6						
Difference in SO_4 calculations (g) =				34.21						

Notes:

1. Calcium calculated from amount of $\text{Ca}(\text{OH})_2$ added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.12 Computed weight and molar composition of solids precipitated from addition of Ca(OH)_2 and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

Cigar Lake tailings: Fe/As = 7.5 and nominal pH = 8 (25°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 128 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	4280		0.03	25.7	Al_2O_3	101.94	53.96	48.51	0.4759	6.26
As	580		0.36	3.48	As_2O_5	229.829	149.84	5.33	0.0232	0.31
Ca	724	109.3	444	111.0	CaO	56.079	40.1	155.27	2.7687	36.44
Cl	81		34.3	0.28	Cl	35.453	35.45	0.28	0.0079	0.10
Fe	3260		0.05							
Fe^{2+}	2870		0.02	17.2	FeO	71.846	55.85	22.15	0.3083	4.06
Fe^{3+}	590		0.02	3.54	Fe_2O_3	159.7	111.69	5.06	0.0317	0.42
K	388		151	1.42	K_2O	94.2	78.20	1.71	0.0182	0.24
Mg	2330		1470	5.16	MgO	40.32	24.31	8.56	0.2122	2.79
Na	129		478	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	453		0.36	2.72	NiO	74.71	58.71	3.46	0.0463	0.61
NO_3	40.5		3.7	0.22	N_2O_5	108.009	124.01	0.19	0.0018	0.02
P	156		1.13	0.93	P_2O_5	141.95	61.95	2.13	0.0150	0.20
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	0.87
SO_4^{2-}	67200		9204	348.0	SO_3	80.066	96.1	290.04	3.6225	47.68
TOTALS				523.5				546.6	7.5975	100.0
% contamination of Ca(OH)_2 by Na =			0.44 %							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				265.8						
Difference in SO_4 calculations (g) =				82.18						

Notes:

1. Calcium calculated from amount of Ca(OH)_2 added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.13 Computed weight and molar composition of solids precipitated from addition of $\text{Ca}(\text{OH})_2$ and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

Sample for Dr. Slaughter										
Blend 0 (75% Midwest+25% Sue) tailings A+B: nominal pH = 8 and a low iron addition - Fe/As = 0.9 (25°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 144 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	2940		0.02	17.6	Al_2O_3	101.94	53.96	33.32	0.3269	4.58
As	9100		61.4	54.2	As_2O_5	229.829	149.84	83.18	0.3619	5.07
Ca	192	101.7	427	100.3	CaO	56.079	40.1	140.34	2.5026	35.05
Cl	40.7		31.8	0.05	Cl	35.453	35.45	0.05	0.0015	0.02
Fe	6037		0.23							
Fe^{2+}	2680		0.21	16.1	FeO	71.846	55.85	20.68	0.2879	4.03
Fe^{3+}	3357		0.02	20.1	Fe_2O_3	159.7	111.69	28.80	0.1803	2.53
K	208		68.6	0.84	K_2O	94.2	78.20	1.01	0.0107	0.15
Mg	752		279	2.84	MgO	40.32	24.31	4.71	0.1167	1.63
Na	38.8		605	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	6690		59.9	39.8	NiO	74.71	58.71	50.62	0.6776	9.49
NO_3	40.9		8.9	0.19	N_2O_5	108.009	124.01	0.17	0.0015	0.02
P	18.6		0.61	0.11	P_2O_5	141.95	61.95	0.25	0.0017	0.02
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	0.92
SO_4^{2-}	44300	8.17	3944	250.3	SO_3	80.066	96.1	208.63	2.6057	36.49
TOTALS				506.5				575.7	7.1410	100.0
% contamination of $\text{Ca}(\text{OH})_2$ by Na =			0.59%							
Equal number of moles of SO_4 to Ca from liming to gypsu				240.3						
Difference in SO_4 calculations (g) =				10.06						

Notes:

1. Calcium calculated from amount of $\text{Ca}(\text{OH})_2$ added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.14 Computed weight and molar composition of solids precipitated from addition of Ca(OH)_2 and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

Blend 1 (75% Sue C + 25% Cigar Lake) tailings: Fe/As = 7.6 and pH = 8 (25°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 128 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	1601		0.02	9.61	Al_2O_3	101.94	53.96	18.15	0.1780	3.53
As	251		0.27	1.50	As_2O_5	229.829	149.84	2.31	0.0100	0.20
Ca	653	84.9	468	86.1	CaO	56.079	40.1	120.40	2.1470	42.52
Cl	43.6		60.3	0.00	Cl	35.453	35.45	0.00	0.0000	0.00
Fe	1423		0.02							
Fe^{2+}	1142		0.02	6.85	FeO	71.846	55.85	8.82	0.1227	2.43
Fe^{3+}	281		0.02	1.69	Fe_2O_3	159.7	111.69	2.41	0.0151	0.30
K	254		105	0.89	K_2O	94.2	78.20	1.08	0.0114	0.23
Mg	924		576	2.09	MgO	40.32	24.31	3.46	0.0858	1.70
Na	62.1		568	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	222		0.22	1.33	NiO	74.71	58.71	1.69	0.0227	0.45
NO_3	38.0		2.1	0.22	N_2O_5	108.009	124.01	0.19	0.0017	0.03
P	52.7		1.08	0.31	P_2O_5	141.95	61.95	0.71	0.0050	0.10
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	1.30
SO_4^{2-}	43050		4880	229.0	SO_3	80.066	96.1	190.89	2.3841	47.22
TOTALS				343.5				354.0	5.0494	100.0
% contamination of Ca(OH)_2 by Na =			0.67%							
Moles of SO_4 in gypsum (equal to moles of Ca pptd) =				206.1						
Difference in SO_4 calculations (g) =				22.91						

Notes:

1. Calcium calculated from amount of Ca(OH)_2 added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A1.15 Computed weight and molar composition of solids precipitated from addition of $\text{Ca}(\text{OH})_2$ and $\text{Fe}_2(\text{SO}_4)_3$ (when added) to tailings raffinate.

Blend 2 (55% Midwest+15% Sue A+B+30% Cigar Lake) tailings: Fe/As = 1.0 and nominal pH = 8 (25°C).										
	Raffinate (mg/L)	From Liming or Ferric Sulfate addition (g) ^{Note 1}	End of Procedure 2 = 144 hours (mg/L)	Mass pptd per kilo of tailings (g) ^{Note 2}	Oxide Formulae	Oxide GFW	Species GFW * n	Mass/kg as oxides	Moles of Oxides	Oxide Moles to 100%
Al	2620		0.04	15.7	Al_2O_3	101.94	53.96	29.70	0.2913	3.55
As	7090		21.8	42.4	As_2O_5	229.829	149.84	65.05	0.2830	3.45
Ca	429	128.9	522	128.3	CaO	56.079	40.1	179.57	3.2021	39.08
Cl	49.3		33.5	0.09	Cl	35.453	35.45	0.09	0.0027	0.03
Fe	5287		0.02							
Fe^{2+}	1140		0.02	6.84	FeO	71.846	55.85	8.80	0.1225	1.49
Fe^{3+}	4147		0.02	24.9	Fe_2O_3	159.7	111.69	35.58	0.2228	2.72
K	177		78.4	0.59	K_2O	94.2	78.20	0.71	0.0076	0.09
Mg	1410		583	4.96	MgO	40.32	24.31	8.23	0.2041	2.49
Na	48.4		522	0.00	Na_2O	61.982	45.98	0.00	0.0000	0.00
Ni	5710		12.4	34.2	NiO	74.71	58.71	43.50	0.5823	7.11
NO_3	34.5		12.1	0.13	N_2O_5	108.009	124.01	0.12	0.0011	0.01
P	97.6		2.86	0.57	P_2O_5	141.95	61.95	1.30	0.0092	0.11
SiO_2 ^{Note 3}	674		15	3.95	SiO_2	60.09	60.09	3.95	0.0658	0.80
SO_4^{2-}	54700	9.69	5087	307.4	SO_3	80.066	96.1	256.19	3.1998	39.05
TOTALS				570.1				632.8	8.1942	100.0
% contamination of $\text{Ca}(\text{OH})_2$ by Na =			0.40%							
Moles of SO_4 in gypsum (equal to moles of SO_4 pptd) =				307.4						
Difference in SO_4 calculations (g) =				0.03						

Notes:

1. Calcium calculated from amount of $\text{Ca}(\text{OH})_2$ added.
2. Assuming 6.0 L of raffinate and 1 kg tailings solids.
3. Estimated values from SRC Laboratory analyses.

Table A2.1 Analytical Data for Tailings

(Data from McClean Lake TMF Tailings Pore Water Quality Appendices for MINATCO Ltd. by Steffen, Robertson, and Kirsten, 1994)

Species		Oxide		Midwest				Sue C			
	GFW*n		GFW	Species Analyzed (%)	Oxides Computed (%)	Oxide (Moles)	Oxide Moles to 100 Mole %	Species Analyzed (%)	Oxides Computed (%)	Oxide (Moles)	Oxide Moles to 100 Mole %
Ag	215.74	Ag ₂ O	231.73	0.001	0.001	3.94E-06	3.19E-04	0.001	0.001	2.32E-06	2.18E-04
Al	53.964	Al ₂ O ₃	101.94	2.920	5.516	0.054	4.379	9.680	18.286	0.179	16.870
As	149.844	As ₂ O ₅	229.839	3.640	5.583	0.024	1.966	0.078	0.119	0.001	0.049
B	21.622	B ₂ O ₃	69.619	0.023	0.072	0.001	0.084	0.087	0.280	0.004	0.379
Ba	137.34	BaO	153.36	0.034	0.038	2.48E-04	0.020	0.057	0.064	4.16E-04	0.039
Be	9.012	BeO	25.013	0.001	0.002	8.88E-05	0.007	0.001	0.003	1.33E-04	0.013
Bi	417.96	Bi ₂ O ₃	465.957	0.004	0.004	9.57E-06	0.001	0.004	0.004	9.33E-06	0.001
Ca	40.08	CaO	56.079	5.170	7.234	0.129	10.438	3.300	4.617	0.082	7.743
Cd	112.4	CdO	128.399	1.00E-04	1.14E-04	8.90E-07	7.20E-05	1.00E-04	1.14E-04	8.90E-07	8.37E-05
Cl	35.453	Cl	35.453	0.006	0.006	1.72E-04	0.014	0.006	0.006	1.58E-04	0.015
Co	58.933	CoO	74.94	0.045	0.057	0.001	0.062	0.004	0.005	7.13E-05	0.007
Cr	103.992	Cr ₂ O ₃	151.989	0.019	0.027	1.81E-04	0.015	0.029	0.042	2.75E-04	0.026
Cu	63.54	CuO	79.54	0.019	0.024	3.05E-04	0.025	0.013	0.016	2.00E-04	0.019
Fe ²⁺ Note 1	55.847	FeO	71.846	1.563	2.011	0.028	2.265	1.640	2.110	0.029	2.762
Fe ³⁺ Note 1	111.694	Fe ₂ O ₃	159.7	0.487	0.696	0.004	0.353	0.460	0.658	0.004	0.387
Hg	200.59	HgO	216.58	1.00E-04	1.08E-04	4.99E-07	4.03E-05	1.00E-04	1.08E-04	4.99E-07	4.69E-05
K	78.204	K ₂ O	94.2	0.869	1.047	0.011	0.900	2.280	2.746	0.029	2.742
Mg	24.312	MgO	40.32	0.595	0.986	0.024	1.979	0.743	1.232	0.031	2.873
Mn	54.938	MnO	70.94	0.029	0.038	0.001	0.043	0.041	0.053	0.001	0.071
Mo	191.88	Mo ₂ O ₅	271.875	0.051	0.072	2.66E-04	0.022	0.073	0.103	3.80E-04	0.036
Na	45.982	Na ₂ O	61.982	0.150	0.202	0.003	0.264	0.180	0.243	0.004	0.368
NH ₄	14.007	NH ₃	17.031	0.015	0.018	0.001	0.087	0.018	0.021	0.001	0.118
Ni	58.71	NiO	74.71	2.740	3.487	0.047	3.777	0.108	0.137	0.002	0.173
P	61.948	P ₂ O ₅	141.95	0.041	0.094	0.001	0.054	0.024	0.054	3.83E-04	0.036
Pb	207.19	PbO	223.21	0.235	0.253	0.001	0.092	0.421	0.453	0.002	0.191
Se	78.96	SeO ₃	126.957	0.002	0.003	2.28E-05	0.002	0.003	0.005	3.55E-05	0.003
SiO ₂	60.09	SiO ₂	60.09	47.780	47.780	0.795	64.344	35.550	35.550	0.592	55.640
SO ₄ Note 2	96.06	SO ₃	80.066	10.320	8.602	0.107	8.694	9.360	7.802	0.097	9.164
U	238.03	UO ₂	270.028	0.016	0.018	6.51E-05	0.005	0.015	0.017	6.13E-05	0.006
V	101.884	V ₂ O ₅	181.9	0.104	0.185	0.001	0.083	0.280	0.499	0.003	0.258
Zn	65.37	ZnO	81.38	0.023	0.028	3.44E-04	0.028	0.009	0.011	1.41E-04	0.013
TOTALS				76.901	84.087	1.236	100.000	64.462	75.138	1.063	100.000

Note 1 = Speciated iron values were estimated assuming same ratio as in raffinates. Midwest values calculated using average ratio of other raffinates.

Note 2 = McClean Lake sulfate values were estimated to equal the average values in the other raffinates.

Table A2.2 Analy Data for Tailings

(Data from McClean Lake TMF Tailings Pore Water Quality Appendices for MINATCO Ltd. by Steffen, Robertson, and Kirsten, 1994)

Species		Oxide		JEB				McClean			
	GFW*n		GFW	Species Analyzed (%)	Oxides Computed (%)	Oxide (Moles)	Oxide Moles to 100 Mole %	Species Analyzed (%)	Oxides Computed (%)	Oxide (Moles)	Oxide Moles to 100 Mole %
Ag	215.74	Ag ₂ O	231.73	0.001	0.001	2.32E-06	1.86E-04	0.001	0.001	2.32E-06	1.88E-04
Al	53.964	Al ₂ O ₃	101.94	5.250	9.917	0.097	7.808	5.910	11.164	0.110	8.903
As	149.844	As ₂ O ₅	229.839	0.377	0.578	0.003	0.202	0.664	1.019	0.004	0.360
B	21.622	B ₂ O ₃	69.619	0.036	0.114	0.002	0.132	0.052	0.167	0.002	0.196
Ba	137.34	BaO	153.36	0.041	0.046	2.99E-04	0.024	0.056	0.062	4.07E-04	0.033
Be	9.012	BeO	25.013	0.001	0.001	5.55E-05	0.004	0.001	0.002	9.99E-05	0.008
Bi	417.96	Bi ₂ O ₃	465.957	0.006	0.006	1.32E-05	0.001	0.010	0.011	2.39E-05	0.002
Ca	40.08	CaO	56.079	5.200	7.276	0.130	10.413	3.550	4.967	0.089	7.201
Cd	112.4	CdO	128.399	1.60E-04	1.83E-04	1.42E-06	1.14E-04	2.50E-04	2.86E-04	2.22E-06	1.81E-04
Cl	35.453	Cl	35.453	0.004	0.004	1.10E-04	0.009	0.007	0.007	1.83E-04	0.015
Co	58.933	CoO	74.94	0.019	0.024	3.26E-04	0.026	0.017	0.021	2.85E-04	0.023
Cr	103.992	Cr ₂ O ₃	151.989	0.023	0.033	2.16E-04	0.017	0.022	0.031	2.07E-04	0.017
Cu	63.54	CuO	79.54	0.024	0.029	3.70E-04	0.030	0.028	0.035	4.34E-04	0.035
Fe ²⁺ Note 1	55.847	FeO	71.846	3.786	4.871	0.068	5.441	2.841	3.654	0.051	4.135
Fe ³⁺ Note 1	111.694	Fe ₂ O ₃	159.7	0.954	1.364	0.009	0.685	3.599	5.146	0.032	2.620
Hg	200.59	HgO	216.58	2.70E-04	2.92E-04	1.35E-06	1.08E-04	1.00E-04	1.08E-04	4.99E-07	4.05E-05
K	78.204	K ₂ O	94.2	1.430	1.722	0.018	1.468	1.580	1.903	0.020	1.642
Mg	24.312	MgO	40.32	1.430	2.372	0.059	4.721	0.410	0.680	0.017	1.370
Mn	54.938	MnO	70.94	0.045	0.058	0.001	0.066	0.038	0.049	0.001	0.056
Mo	191.88	Mo ₂ O ₅	271.875	0.010	0.015	5.42E-05	0.004	0.047	0.066	2.42E-04	0.020
Na	45.982	Na ₂ O	61.982	0.250	0.337	0.005	0.436	0.200	0.270	0.004	0.354
NH ₄	14.007	NH ₃	17.031	0.012	0.014	0.001	0.066	0.018	0.021	0.001	0.102
Ni	58.71	NiO	74.71	0.439	0.559	0.007	0.600	0.301	0.382	0.005	0.416
P	61.948	P ₂ O ₅	141.95	0.025	0.058	4.05E-04	0.033	0.037	0.086	0.001	0.049
Pb	207.19	PbO	223.21	0.110	0.119	0.001	0.043	0.127	0.136	0.001	0.050
Se	78.96	SeO ₃	126.957	0.002	0.003	2.41E-05	0.002	0.002	0.004	2.91E-05	0.002
SiO ₂	60.09	SiO ₂	60.09	42.840	42.840	0.713	57.219	47.810	47.810	0.796	64.683
SO ₄ Note 2	96.06	SO ₃	80.066	12.520	10.435	0.130	10.461	8.860	7.385	0.092	7.498
U	238.03	UO ₂	270.028	0.013	0.015	5.50E-05	0.004	0.015	0.017	6.43E-05	0.005
V	101.884	V ₂ O ₅	181.9	0.080	0.142	0.001	0.063	0.242	0.433	0.002	0.193
Zn	65.37	ZnO	81.38	0.017	0.022	2.65E-04	0.021	0.008	0.010	1.24E-04	0.010
TOTALS				74.943	82.975	1.246	100.000	76.450	85.541	1.230	100.000

Note 1 = Speciated iron values were estimated assuming same ratio as in raffinates. Midwest values calculated using average ratio of other raffinates.

Note 2 = Cigar Lake sulfate values were estimated to equal the average values in the other tailings.

Table A2.3 Analytical Data for Tailings

(Data from McClean Lake TMF Tailings Pore Water Quality Appendices for MINATCO Ltd. by Steffen, Robertson, and Kirsten, 1994)

Species		Oxide		Cigar Lake I				Cigar Lake II			
	GFW*n		GFW	Species Analyzed (%)	Oxides Computed (%)	Oxide (Moles)	Oxide Moles to 100 Mole %	Species Analyzed (%)	Oxides Computed (%)	Oxide (Moles)	Oxide Moles to 100 Mole %
Ag	215.74	Ag ₂ O	231.73	0.001	0.001	2.32E-06	2.33E-04	0.001	0.001	2.78E-06	2.40E-04
Al	53.964	Al ₂ O ₃	101.94	4.690	8.860	0.087	8.722	3.630	6.857	0.067	5.807
As	149.844	As ₂ O ₅	229.839	1.170	1.795	0.008	0.784	0.995	1.526	0.007	0.573
B	21.622	B ₂ O ₃	69.619	0.026	0.084	0.001	0.121	0.016	0.052	0.001	0.064
Ba	137.34	BaO	153.36	0.018	0.020	1.31E-04	0.013	0.024	0.027	1.75E-04	0.015
Be	9.012	BeO	25.013	0.003	0.007	2.89E-04	0.029	0.001	0.003	1.22E-04	0.011
Bi	417.96	Bi ₂ O ₃	465.957	0.040	0.045	9.57E-05	0.010	0.027	0.030	6.46E-05	0.006
Ca	40.08	CaO	56.079	11.400	15.951	0.284	28.545	7.540	10.550	0.188	16.240
Cd	112.4	CdO	128.399	0.003	0.003	2.22E-05	0.002	0.002	0.002	1.78E-05	0.002
Cl	35.453	Cl	35.453								
Co	58.933	CoO	74.94	0.116	0.148	0.002	0.198	0.231	0.294	0.004	0.338
Cr	103.992	Cr ₂ O ₃	151.989	0.005	0.007	4.52E-05	0.005	0.004	0.006	4.23E-05	0.004
Cu	63.54	CuO	79.54	1.030	1.289	0.016	1.627	0.406	0.508	0.006	0.552
Fe ²⁺ Note 1	55.847	FeO	71.846	1.589	2.044	0.028	2.855	0.860	1.106	0.015	1.329
Fe ³⁺ Note 1	111.694	Fe ₂ O ₃	159.7	0.351	0.502	0.003	0.316	0.190	0.272	0.002	0.147
Hg	200.59	HgO	216.58	1.00E-05	1.08E-05	4.99E-08	5.00E-06	8.00E-06	8.64E-06	3.99E-08	3.44E-06
K	78.204	K ₂ O	94.2	0.911	1.097	0.012	1.169	0.806	0.971	0.010	0.890
Mg	24.312	MgO	40.32	1.770	2.935	0.073	7.306	0.644	1.068	0.026	2.287
Mn	54.938	MnO	70.94	0.028	0.036	0.001	0.051	0.025	0.032	4.55E-04	0.039
Mo	191.88	Mo ₂ O ₅	271.875	0.139	0.197	0.001	0.073	0.048	0.068	2.50E-04	0.022
Na	45.982	Na ₂ O	61.982	0.590	0.795	0.013	1.288	0.204	0.275	0.004	0.383
NH ₄	14.007	NH ₃	17.031								
Ni	58.71	NiO	74.71	0.847	1.078	0.014	1.448	0.417	0.531	0.007	0.613
P	61.948	P ₂ O ₅	141.95	0.004	0.009	6.46E-05	0.006	0.004	0.009	6.46E-05	0.006
Pb	207.19	PbO	223.21	0.736	0.793	0.004	0.357	0.616	0.664	0.003	0.257
Se	78.96	SeO ₃	126.957	0.008	0.012	9.75E-05	0.010	0.002	0.003	2.53E-05	0.002
SiO ₂	60.09	SiO ₂	60.09	22.035	22.035	0.367	36.801	42.786	42.786	0.712	61.467
SO ₄ Note 2	96.06	SO ₃	80.066	7.813	6.512	0.081	8.163	9.785	8.156	0.102	8.793
U	238.03	UO ₂	270.028								
V	101.884	V ₂ O ₅	181.9	0.068	0.121	0.001	0.067	0.036	0.064	3.53E-04	0.031
Zn	65.37	ZnO	81.38	0.024	0.030	3.67E-04	0.037	0.094	0.117	0.001	0.124
TOTALS				55.413	66.405	0.996	100.000	69.394	75.977	1.158	100.000

Note 1=Speciated iron values were estimated assuming same ratio as in raffinates. Midwest values calculated using average ratio of other raffinates.

Note 2= Cigar Lake sulfate values were estimated to equal the average values in the other raffinates.

Appendix C

Section C - Part A

Subsection B: Chemical and Mineralogical Analysis of Eight Tailings Samples

APPENDIX B

CHEMICAL AND MINERALOGICAL ANALYSIS OF EIGHT TAILINGS SAMPLES

**by Dr. Maynard Slaughter
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SYSTEM DESIGN, PROGRAMMING AND SAMPLE ANALYSIS

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April 20, 1998

Report of Mineral Analysis of Eight Tailings Samples

Attached find the results of chemical and mineral analysis of tailings samples submitted by COGEMA. Each sample analysis comprises four pages. Page 1 contains the mineral analysis. Page 2 has the composition of illite determined by optimization analysis. Page 3 has the chemical composition of minerals used for that sample that could not be determined by optimization, and Page 4 lists the chemical analysis. Notes on methods of analysis and mineral determinations follow this section.

Sample Preparation and X-Ray Diffraction

Samples were ground in small sealed containers for ten minutes to minimize oxidation of iron. Aliquots were split with a small splitter for x-ray diffraction, XRF analysis, FeO analysis, carbon and sulfur analysis, and water analysis.

Bulk samples were analyzed by x-ray diffraction (XRD) from 2 to 70 degrees two-theta with Cu K_α radiation. Attempts to settle the fine fraction for XRD failed because of flocculation. To avoid chemical reaction with soluble phases, dispersing agents were not used. Instead, smear mounts were made and tested. However, they showed no more than the bulk mounts.

Chemical Analyses

Major and Minor Elements:

The following elements were determined by quantitative x-ray spectrometry (XRF) using multiple standards and the "Fundamental Parameters Method" of matrix correction: Si, Al, Ti, Fe, Mn, Mg, Ca, Na, K, P, Ni, Cu, As, Ba, Pb, U.

Sulfur:

Total sulfur was determined by a Leco Analyzer on the total sample. Sulfide sulfur was determined by dissolving sulfate with 3N HCl and analyzing the residue. Duplicate analyses were done on two different weight aliquots. The results represent upper limits of sulfide sulfur.

Ferrous Iron Oxide:

FeO was determined by the USGS method: dissolution of the sample in fuming acids and titrating with potassium dichromate. Fe-bearing sulfides and magnetite do not dissolve.

Carbonate Carbon:

Carbonate carbon expressed as CO₂ was determined by acid dissolution and titration with NaOH (Coulometry).

Organic Carbon:

Organic carbon was determined by total carbon analysis by combustion in a Leco Analyzer with subtraction of carbonate carbon. Organics (ORG) were estimated by multiplying organic carbon content by 1.3.

Water:

H₂O- or "adsorbed water" was determined gravimetrically by heating ground samples to 90°C for three hours. H₂O+ or "structural water" was determined gravimetrically by heating at various temperatures and subtracting predetermined amounts. The two forms were adjusted during mineral analysis.

Mineralogy

The following minerals and their characteristics were determined. The method is that of Slaughter (1989).

Major Primary Minerals

Quartz and amorphous silica - Most SiO₂ is abundant and well crystallized quartz. Diffraction patterns show little or no amorphous silica at around 4.05 Å (20 degrees two-theta), where amorphous silica usually appears as a broad band.

Illite - (K,Na) (Al, Mg, Fe)₂ (Si, Al)₄ O₁₀(OH)₂. The illite has a composition of an altered muscovite, and should be called a muscovitic or sericitic illite. The illite could have a little more Na than we allowed. Compositions are near K_{.84}Na_{.02}(Al_{1.8}Mg_{.15}Fe⁺³_{.04}Fe⁺²_{.01})(Si_{3.3}Al_{.7})O₁₀(OH)₂.

Chlorite, magnesian - The original chlorite was a low-iron chlorite near the clinocllore-sheridanite boundary. The chlorite in all samples has been altered, with the brucite layer at least partially destroyed. Diffractions show partial collapse of the brucite layer, with spacings more typical of higher iron chlorites. For example, the (004) d-spacing in most samples occurs at the d-spacing of high-iron chlorites: well separated from and on the high-angle side of the kaolinite (002) d-spacing. Compositions of the degraded chlorites had to be determined manually; therefore, the compositions are approximate. Probably, much of the Mg, Fe⁺², and Fe⁺³ in the raffinates came from partial dissolution of the chlorites, with partial oxidation of the Fe⁺².

Kaolinite and kaolin allophane - Some kaolinite appears to be reasonably well crystallized to the extent that it is not a kaolin allophane, but processing by COGEMA has probably degraded the crystallinity in most samples. The (001) kaolinite diffractions are present, but they overlap the chlorite (002) diffractions. However, the (002) kaolinite diffractions are present at 3.57 Å, as are (hk) bands. Probably some of the reported kaolinite is a near-kaolinite kaolin allophane.

Minor and Trace Primary Minerals

Goethite - Goethite diffractions were found in most samples; however, in some samples goethite appears to be poorly crystallized with a broad strongest diffraction. Goethite when heated converts to hematite. All samples were heated to 570°C for 24 hours, and sample colors noted. Colors qualitatively matched the goethite relative diffraction intensities and determined amounts.

Pyrite, Chalcopyrite, Galena - These minerals are in such small quantities that determining exact compositions was impossible. Their presence was noted as black insoluble residues when during the FeO analyses. Diffractions were problematically found, but identification was unreliable. The amount of sulfide sulfur determines the upper limit of sulfide content.

Rutile - The strongest diffraction of rutile was noted in one sample; therefore, its presence was implied in all samples.

Major and Minor Secondary Minerals

Gypsum - Gypsum was found in all samples except one. It was well crystallized and the dominant sulfate mineral.

Hydrobasaluminite - This mineral was found in all samples as poorly crystallized basaluminite of composition near $\text{Al}_4\text{SO}_4(\text{OH})_{10} \cdot 5\text{H}_2\text{O}$. Hydrobasaluminite is reported to have the composition $15\text{H}_2\text{O}$ and $36\text{H}_2\text{O}$. The $15\text{H}_2\text{O}$ hydration state was used. However, the large water content suggests the 36-hydration state may be more nearly correct. Hydrobasaluminite converts to basaluminite spontaneously at room temperature. The aluminum probably derived mainly from dissolution of chlorite, illite, and kaolinite.

Scorodite - A scorodite-like phase was found in almost all samples. It was most clearly identified in the sample with the largest quantity: the Sue A+B, Midwest blend. The composition in this sample had some aluminum with the iron: approximately $\text{Fe}_9\text{Al}_1\text{AsO}_4 \cdot 2\text{H}_2\text{O}$. Diffractions were broad, indicating small particle size and/or disorder. Most of the scorodite-like phase is amorphous, showing as a broad diffraction band centered around 28 degrees two-theta. Compositions in the other samples were assumed to be that in the blend.

Cabrerite - This is the magnesian form of annabergite: $(\text{Ni},\text{Mg})_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$. However, the minerals in these samples have small amounts of Fe^{+2} and variable compositions.

Jarosite - Jarosite, with pure composition $(\text{K},\text{Na})\text{Fe}_3(\text{SO}_4)_2(\text{OH})_6$, occurs in several samples and is

amorphous. The same composition was used in all samples: $\text{Na}_{.05}\text{K}_{.95}\text{Fe}_3(\text{SO}_4)_2(\text{OH})_6$. The K to Na ratio approximates that of the illite.

Coffinite - Two samples have significant uranium. We assumed a less soluble silicate form without diffraction evidence. The mineral may or may not be coffinite.

Identification of Minerals and Chemical Phases

The identification of the phases in the COGEMA samples, because of their complexity, was done by using x-ray diffraction, chemical analyses, examination of electron microprobe analyses, and examination of thin section data. Each kind of data contributed to the identification of the phases. The chemical analyses were done as previously described. X-Ray diffractions of bulk mounts were collected from 2 to 70 degrees two-theta, and are included in this appendix. Diffractions of smear mounts of samples were collected from 2 to 35 degrees two-theta, but yielded no information not found in the bulk mounts; hence, are not presented here. Less than 2 μm samples were not prepared, because of dispersing agents would affect secondary phases, and the electron microprobe analysis showed the secondary phases were mainly coatings on larger grains, and would have been lost during separation. Electron microprobe and thin section data supplied to us by COGEMA were used to help confirm mineral and chemical phases. The electron microprobe data were from SEPA "Study 8875" by J. Reyx, February, 1998. Thin section data were from "Study 8875, Petrographic and XRD study of 5 samples from the JEB tailings" by P. Bruneton, January, 1998. We also used the results of a study of scorodite and its amorphous equivalent, by Krause and Ettel (1988).

Diffraction patterns of the samples and JCPDS data of determined and related phases are included in this appendix. Except for Sample RH262E SUE A+B, Midwest blend, two diffraction patterns are presented for each sample. Each pattern has been scaled and smoothed with a three-point smoothing. For Sample RH262E SUE A+B, Midwest blend, a third, unsmoothed pattern is included to help identify the Ni-arsenate phase.

Phase Identification and Character of the Phases

The x-ray diffractions and optical data showed clearly there were two mineral modes: more or less well crystallized major and minor original or added minerals (primary phases), and a background of minor, poorly crystallized minerals and/or amorphous mineral analogues (secondary phases). Table 1. Lists the diffractions found. All diffractions listed in Table 1 are not present in all samples.

Major and Minor Primary Phases:

Table 1 lists the diffractions found for the major and minor original and added minerals or primary phases. The list of Table 1 was assembled from the 2 to 40 degrees two-theta diffraction patterns presented here (17 patterns). The mineral identification comprised straight-forward comparison of d-spacings (two-theta angles) with JCPDS diffraction file data (JCPDS, 1993). JCPDS files through Set 43 (1993) were used. The major and minor primary minerals are in almost all samples. The diffractions characterize the primary phases as follows:

Quartz - A major mineral, well crystallized with sharp diffractions. Present in all samples. Quartz occurs as sand and silt grains as indicated by thin section and electron microprobe analyses.

Illite - Also a major mineral, well crystallized with relatively sharp diffractions. This illite has diffractions typical of weathered or chemically altered muscovite, almost a sericite or muscovitic illite. Petrographic analyses of Bruneton and our diffraction analyses agree.

Gypsum - A major mineral in all samples except RH262F JEB.1. Well crystallized with sharp diffractions.

Chlorite - A minor or trace mineral in all samples. The diffractions, particularly the (001), indicate chemical degradation. D-Spacings of the (001) diffractions in all but RH262F JEB.1 are 13+ Å, indicating degradation of the brucite layer and the octahedral layer. Acid or thermal degradation of the brucite layer is usually accompanied by partial degradation of the octahedral layer. Diffractions are broad, not typical of a lower iron chlorite. However, the chlorite diffractions in Sample RH262F JEB.1 are sharp with the (004) at 25.2 degrees two-theta, characteristic of a lower iron phase near the penninite/clinochlore boundary.

Kaolinite - A minor mineral with only (001) lines and the (hk) band evident. The kaolinite appears to be poorly to moderately well crystallized. Chlorite (002) overlaps the major kaolinite line: (001), but in samples with little chlorite the kaolinite (001) diffraction is observed. The (002) of kaolinite in most samples at 24.9-25.0 degrees two-theta is separated from the chlorite (004) at about 25.2 to 25.3 degrees two-theta. The chlorite (004) at 25.2 degrees and the kaolinite (002) at 25.0 degrees shows well in Sample RH262F JEB.1.

Goethite - Goethite occurs in most samples as a minor to trace phase. Goethite has a definitive, moderately sharp diffraction at 21.25 degrees two-theta. The sharpness of this diffraction forces its characterization as a primary mineral. The main goethite peak is overlapped by a weak muscovitic illite line at 21.5 degrees two-theta in Sample RH262F JEB.1, and its presence cannot be confirmed by x-ray diffraction. Optical data assigned a reddish mineral to hematite. We could not confirm hematite by color or by diffraction because of line overlaps. However, when samples were heated to 570° C for 24 hours, hematite was evident in those samples with higher goethite. As stated previously, goethite converts to hematite at high temperature.

Sulfides - The chemical analyses show little sulfide sulfur; therefore, sulfides could only be trace in amount. We accepted the optical identification of chalcopyrite and pyrite as two iron bearing sulfides. We arbitrarily assigned lead to galena in agreement with optical data.

Rutile - A small rutile diffraction occurs at 27.45 degrees two-theta in sample RH262F JEB.1, the least gypsum-diluted sample, with the largest amount of TiO₂ (0.93 %). We therefore assign all Ti to rutile in all samples, rather than ilmenite as reported optically.

Minor Secondary Phases:

The secondary phases in the samples are difficult to determine, because of their small amounts and

poor diffraction patterns. To determine the secondary phases we used the electron microprobe, x-ray diffraction, and chemical analyses to deduce the phases. From chemical analyses, the important possible minor secondary phases are arsenates, arsenides, arsenites, sulfates, sulfites, phosphates, and hydroxides. Possible important secondary phase cations are Mg, Ni, Al, Fe^{+3} , and Fe^{+2} as FeO. (Note: the analysis of FeO does not include Fe^{+2} in sulfides.) The x-ray analysis of the chlorite in the samples forces inclusion of much of the small amount of Fe^{+2} as FeO in chlorite; therefore, FeO can only occur as a minor substituent element in a secondary phase. The assignment of major and minor elements to the primary minerals does not allow arsenides, As^{+3} , or sulfites. The assignment of As as arsenides leaves oxygen short for the major phases and the assignment of As as As^{+3} results in excess oxygen; the same reasoning applies to sulfur. From the experimental data, only arsenates and sulfates can occur as secondary phases.

The large amount of $\text{H}_2\text{O}+$ ("structural" water) and $\text{H}_2\text{O}-$ ("loose" or surface adsorbed water), and the loss of much water at low temperature (less than 120°C), indicates the secondary phases are highly hydrated. (The clay minerals illite, chlorite, and kaolinite lose (OH) water at temperatures above 400°C , and gypsum loses molecular water starting at 128°C .)

As stated, diffractions show that chlorite has been partially degraded (dissolved), with illite and kaolinite less so. The major partial acid dissolution products of chlorite, the most soluble major mineral component in the samples, are Fe^{+2} , Al, and Mg, the iron oxidizing to Fe^{+3} . The major partial acid dissolution products of illite are K and Al. In the case of partial dissolution of muscovitic illite, Na is a minor product.

The chemistry, diffraction characteristics of the minerals, water content, temperature of water loss, and the allocation of elements to minerals require mostly or all hydrated secondary phases of arsenates and sulfates of Fe^{+3} , Ni, Mg, K, Al, and minor Fe^{+2} and Na.

Electron microprobe data show important associations of elements, helping to determine the phases present in the COGEMA samples. Two associations are important and nearly ubiquitous: the association of Fe and As with minor Ni as coating on grains, and the association of Ni and As with minor Fe, also as coatings on grains. These two (Boolean-like) associations and others are as follows:

JEB samples:

1. Fe and As and minor Ni,
2. Ni and As and minor Fe,
3. Ca, P, As and minor Fe and not Al,
4. Ca and P and not Fe and As,
5. Ca, P, As, Fe.

McClean sample:

1. Fe, As, and minor Ni and not Ca or S (coating on grains),
2. As alone on muscovitic illite (special case discussed below).

SUE C: No analyses presented.

SUE A+B:

1. Ni, As, minor Fe, minor Al (grain coating),
2. As, Ni, and minor Fe (coating on grains) and not Ca and S,
3. As, O, Al, minor Fe (Ni not analyzed),
4. Ni, As, Al, minor Fe and not Ca and S,
5. Al, P, minor As.

SUE A+B, Midwest:

1. Fe, As and O, minor Ni and not Al, S and Ca (coating on large grain).

Summary of Microprobe Associations and Conclusions for all Samples:

Most secondary minerals in these samples constitute coatings on larger grains of quartz and phyllosilicates. The phases are mostly intimately mixed together. The predominant association is approximately equi-molar Fe and As in an arsenate. Ni and minor Fe are associated in arsenates. Mg which would have been predicted in a secondary phase was not analyzed by electron microprobe analysis. Rarely, As is in high concentration with low concentration Fe and Ni on a phyllosilicate. The electron microprobe analyst called this arsenic "native"; we do not think it is native arsenic. This arsenic appears to be adsorbed on or in the phyllosilicate as As^{+3} or As^{+5} , but probably as As^{+5} , coordinated with O, OH, and/or waters.

Hydrous Ca-Phosphate - Ca and P are a clear association, P and As do not substitute for each other significantly in solids because of ion size differences; therefore, the association in JEB samples is a mixture of a Ca, P phase and an Fe, As phase. The Ca, P phase is a Ca-phosphate phase, but since there are no diffractions for apatite, it is probably not present. Because the phosphate phase occurs as a secondary phase with the Fe, As association, the Ca, P phase is either colophane or hydrous Ca-phosphate; both are common amorphous phases. The best fit with the total chemistry is hydrous Ca-phosphate.

Scorodite (Kankite) - All samples show Fe, As association with no or minor Ni. This phase is an iron arsenate with some aluminum, and it is probably hydrated, as inferred from the samples' large water content. There are five Fe, As compounds and minerals fitting the electron microprobe data and the low FeO content. One is a heating product of scorodite at high temperatures, leaving four possibilities. By superimposing diffraction patterns of low As tailings on high As tailings, such as JEB on SUE A+B, Midwest blend, we identified three Fe, As phases, all the same composition except for hydration state. The phases are scorodite ($\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$), with its major diffraction at 4.46 Å (19.9 degrees two-theta), kankite ($\text{FeAsO}_4 \cdot 3.5\text{H}_2\text{O}$), with its major diffraction at 12.9 Å (6.9 degrees two-theta), and an amorphous phase indicated by a broad band with its maximum at about 28 degrees two-theta (see Krause and Ettel, 1988), possibly a composition between between kankite-like mineral and a scorodite-like mineral. For the JEB, McClean, and SUE samples, we call the mineral scorodite. Note: only part of the the major scorodite diffraction at 4.46 Å is due to scorodite in RH262E SUE A+B, Midwest blend, the sample with the most scorodite-like compound.

Hydrobasaluminite - The mineral basaluminite ($\text{Al}_4\text{SO}_4(\text{OH})_{10} \cdot 5 \text{H}_2\text{O}$) has a definitive broad diffraction at 9.4 Å (9.4 degrees two-theta). This diffraction is noted in the diffraction patterns as a broad weak peak, extending from 9.2 to 9.8 degrees two-theta. The basaluminite hydration state is variously reported at four to five waters. However, the water content of the samples, and particularly the large amount of H_2O -, suggests that the mineral is the much more highly hydrated mineral hydrobasaluminite, with the same composition as basaluminite, except for water content. Hydrobasaluminite's hydration state is given as 15 and 36 waters per molecule (Gaines, et al., 1997 and JCPDS). Hydrobasaluminite and kankite have their strongest lines at 12.6 Å (7.0 degrees two-theta); one or the other or both have lines at that angle. Hydrobasaluminite converts to basaluminite on drying. As we did with the Fe-arsenate, we used the smaller hydration state of 15 waters for our determination; however, we think the higher hydration state is more probable, based on the total water content of the samples.

Jarosite - Jarosite ($(\text{K}, \text{Na})\text{Fe}_3(\text{SO}_4)_2(\text{OH})_6$) shows two of its three strongest lines as small peaks and bands at about 14.9 and 28.7 degrees two-theta. The strongest line is overlapped by illite and gypsum. Even though only two lines are found, the chemistry is consistent with the presence of jarosite in small quantity. The electron microprobe and x-ray analyses done by others do not address the presence or absence of jarosite.

Cabrerite - Electron microprobe image data show one or more nickel arsenate phases intimately mixed with iron arsenate or scorodite-like phases, as well as separate nickel arsenate phases. All phases coat larger grains. When the phases are not mixed, the electron microprobe images yield intense Ni $\text{K}\alpha$ and As $\text{K}\alpha$ emissions and weak Fe $\text{K}\alpha$ emissions. Since the mass absorption coefficients and the fluorescent yields for a normal operating voltage of the electron beam are close for the three elements, these Ni, As, Fe compounds contain Ni nearly equal to or greater in amount than the As, with small amounts of Fe. The common hydrated mineral form of similar composition is annabergite ($\text{Ni}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$), with a small amount of Mg and Fe^{+2} substituting for Ni, and compounds related compositionally to annabergite. Magnesian annabergite (cabrerite in nature) has significant amounts of Mg substituting for Ni. The included JCPDS data for magnesian annabergite has composition $(\text{Ni}_{2.2}\text{Mg}_{0.7}\text{Fe}_{0.1})(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$. Annabergite and cabrerite have the same form and similar diffraction patterns. The upper limit of substitution of Mg for Ni in cabrerite is not known. Phases similar to annabergite/cabrerite have lower hydration states: $\text{Ni}_3(\text{AsO}_4)_2 \cdot \text{H}_2\text{O}$, and $\text{Ni}_3(\text{AsO}_4)_2$ (xanthiosite), $\text{Ni}_2(\text{As}_2\text{O}_7)$, $\text{NiHAsO}_4 \cdot 2\text{H}_2\text{O}$. Other forms are known with Ni less than or equal to half As, or compounds formed at high temperatures. The phase $\text{Ni}_3(\text{AsO}_4)_2 \cdot \text{H}_2\text{O}$ is made by partially dehydrating annabergite/cabrerite. The d-spacings, angles, and intensities of the strongest diffractions of this partially dehydrated phase are as follows:

d-spacing (Å)	Two-Theta	Relative Intensity
6.36	13.9	70
4.57	19.45	60
3.711	24.0	70
3.672	24.25	70
3.206	27.8	100
3.183	28.0	60
2.754	32.5	70
2.508	35.8	90

The ionic radius of Mg is .65 Å, and the radius of Ni is .72 Å. Thus, the cell dimensions of a $\text{Ni}_3(\text{AsO}_4)_2 \cdot \text{H}_2\text{O}$ phase with significant amounts of Mg substituting for Ni will be slightly smaller, and the diffractions will be shifted to slightly higher two-theta angles, relative to the pure Ni phase. Shifting observed weak diffractions about .2 to .3 to degrees to lower two-theta angles or shifting the JCPDS-reported angles by about .2 to .3 upwards gives a reasonably good fit with diffractions in RH262E SUE A+B, Midwest blend, providing the pattern is not smoothed. Our conclusion is that the actual phase seen in the diffraction patterns is a partially dehydrated cabrerite. In the mineral analyses, we have used the hydrated form: cabrerite. To correct to a partially dehydrated form, multiply each value by an appropriate gravimetric factor; however, we think the more highly hydrated phase is the correct one in a solution. Further, due to the differences in chemical bonding between Mg and Ni, the solubility of the Mg-rich phase will be less than that of the pure Ni phase.

Amorphous phases - Other than the scorodite-like phase, dissolution of the primary minerals kaolinite, chlorite, and illite could produce amorphous phases. There is no evidence of an amorphous silica phase. Amorphous silica yields a band centered about 20 degrees two-theta. There is none in any sample. Kaolinite loses Al at low pH to give a silica-rich allophane with an Al-oxyhydroxide band centered about 25 degrees two-theta. At high pH, kaolinite acts like a Bronsted acid, forming a kaolin allophane, also with a broad band centered around 25 degrees two-theta. There are low bands about 25 degrees two theta in most samples. Kaolin allophane is expressed as kaolinite in the mineral analyses. Note: Sample RH262E SUE A+B, Midwest blend has its amorphous band centered about 30 to 32 degrees two-theta.

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ANALYZED MINERAL CONTENT

SAMPLE NO. - RH262A-JEB #1

MINERAL	WT. PERCENT	VOL. PERCENT
QUARTZ	21.34	19.69
PYRITE	.03	.02
GOETHITE	1.86	1.04
ILLITE	27.15	28.26
RUTILE	.67	.39
CHALCOPYRITE	.12	.07
CHLORITE-Mg	8.48	7.54
HYDROUS PHOSPHATE	.28	.25
GYPSUM	23.27	24.53
CABRERITE	.88	.66
SCORODITE	.31	.17
KAOLINITE	1.85	1.73
GALENA	.24	.08
HYDROBASALUMINITE	13.33	15.37
TOTAL	= 99.80	

COMPOSITION OF REFINED MINERALS, SAMPLE NO. - RH262A-JEB #1

ILLITE

SI	3.30
AL	2.50
MG	.14
FE	.05
Fe	.01
K	.82
NA	.03
O	12.00
H+	2.00

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SAMPLE NO. - RH262A - JEB #1

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MINERAL FORMULAE NOT DETERMINED BY MINERAL ANALYZER

No.	Mineral Name	Density
	Formula	
1.	QUARTZ	2.65
	SI1.00 O2.00	
2.	GYPSUM	2.32
	CA1.00 S1.00 O6.00 H+4.00	
3.	CHLORITE-Mg	2.75
	SI2.75 AL2.35 Fe .17 FE .17 MG3.81 O16.5 H+6.50	
4.	RUTILE	4.22
	TI1.00 O2.00	
5.	GALENA	7.50
	PB1.00 S1.00	
6.	CHALCOPYRITE	4.20
	CU1.20 Fe .80 S2.00	
7.	HYDROUS PHOSPHATE	2.75
	CA1.00 P1.00 O4.00 H+1.00	
8.	PYRITE	5.02
	Fe1.00 S2.00	
9.	GOETHITE	4.37
	FE1.00 O2.00 H+1.00	
10.	JAROSITE	3.16
	NA .05 K .95 FE1.00 S2.00 O14.0 H+6.00	
11.	CABRERITE	3.23
	NI1.25 AS2.00 O16.0 H+16.0 MG1.25 Fe .50	
12.	SCORODITE	4.37
	FE .90 AL .10 O6.00 H+4.00 AS1.00	
13.	HYDROBASALUMINITE	2.12
	AL4.00 S1.00 O29.0 H+40.0	
15.	KAOLINITE	2.62
	SI2.00 AL2.00 H+4.00 O9.00	

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SAMPLE NO. - RH262A - JEB #1

WEIGHT PERCENT COMPOUNDS

		ABSOLUTE	NORMALIZED
SI	O2 -	35.67	35.33
TI	O2 -	.616	.610
AL2	O3 -	14.51	14.38
FE2	O3 -	2.10	2.08
FE	O -	.330	.327
CA	O -	7.12	7.05
K2	O -	2.46	2.44
MG	O -	2.74	2.71
NA2	O -	.068	.067
MN	O -	.069	.068
BA	O -	.065	.064
P2	O5 -	.137	.136
S	O3 -	11.76	11.64
NI	O -	.137	.136
CU	O -	.0685	.0678
AS2	O5 -	.479	.475
PB	O -	.205	.203
U	O2 -	.00	.00
H2	O- -	7.80	7.80
H2	O+ -	13.98	13.98
C	O2 -	.01	.01
ORG	-	.42	.42

TOTAL 100.74

Sulfide sulfur = .145 %

Total sulfur = 4.71 %

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ANALYZED MINERAL CONTENT

SAMPLE NO. - RH262B - McClean #2

MINERAL	WT. PERCENT	VOL. PERCENT
QUARTZ	36.19	34.00
ILLITE	24.87	26.34
GOETHITE	3.56	2.03
IRON OXYHYDROXIDE	.27	.22
KAOLINITE	3.68	3.50
RUTILE	.56	.33
CHLORITE-Mg	.23	.21
HYDROUS PHOSPHATE	.15	.14
GYPSUM	19.28	20.69
CABRERITE	.85	.66
SCORODITE	.03	.02
CHALCOPYRITE	.13	.08
GALENA	.17	.06
HYDROBASALUMINITE	9.80	11.51
TOTAL	= 99.78	

COMPOSITION OF REFINED MINERALS, SAMPLE NO. - RH262B - McClean #2

ILLITE

SI	3.53
AL	1.90
MG	.26
FE	.30
Fe	.01
K	.71
NA	.03
O	12.00
H+	2.00

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SAMPLE NO. - RH262B - McClean #2

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MINERAL FORMULAE NOT DETERMINED BY MINERAL ANALYZER

No.	Mineral Name	Density
	Formula	
1.	QUARTZ	2.65
	SI1.00 O2.00	
2.	GYPSUM	2.32
	CA1.00 S1.00 O6.00 H+4.00	
3.	CHLORITE-Mg	2.75
	SI2.75 AL2.35 Fe .17 FE .16 MG3.82 O16.5 H+6.50	
4.	RUTILE	4.22
	TI1.00 O2.00	
5.	GALENA	7.50
	PB1.00 S1.00	
6.	CHALCOPYRITE	4.20
	CU1.20 Fe .80 S2.00	
7.	HYDROUS PHOSPHATE	2.75
	CA1.00 P1.00 O4.00 H+1.00	
8.	GOETHITE	4.37
	FE1.00 O2.00 H+1.00	
9.	IRON OXYHYDROXIDE	3.00
	Fe1.60 FE .40 O2.40 H+3.60	
10.	CABRERITE	3.23
	NI1.40 AS2.00 O16.0 H+16.0 MG1.25 Fe .35	
11.	SCORODITE	4.37
	FE .90 AL .10 O6.00 H+4.00 AS1.00	
12.	HYDROBASALUMINITE	2.12
	AL4.00 S1.00 O29.0 H+40.0	
13.	KAOLINITE	2.62
	SI2.00 AL2.00 H+4.00 O9.00	

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SAMPLE NO. - RH262B - McClean #2

WEIGHT PERCENT COMPOUNDS

		ABSOLUTE	NORMALIZED
SI	O2 -	47.98	48.13
TI	O2 -	.526	.527
AL2	O3 -	9.99	10.02
FE2	O3 -	4.46	4.47
FE	O -	.310	.311
CA	O -	5.93	5.95
K2	O -	1.95	1.96
MG	O -	.751	.753
NA2	O -	.075	.075
MN	O -	.038	.038
BA	O -	.034	.034
P2	O5 -	.0751	.0753
S	O3 -	9.69	9.72
NI	O -	.150	.151
CU	O -	.0751	.0753
AS2	O5 -	.345	.346
PB	O -	.150	.151
U	O2 -	.00	.00
H2	O- -	5.92	5.92
H2	O+ -	11.11	11.11
C	O2 -	.01	.01
ORG	-	.17	.17
TOTAL		99.74	

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ANALYZED MINERAL CONTENT

SAMPLE NO. - RH262H - SUE C

MINERAL	WT. PERCENT	VOL. PERCENT
QUARTZ	7.85	7.24
CHALCOPYRITE	.08	.05
ILLITE	38.30	39.83
IRON OXYHYDROXIDE	.40	.32
KAOLINITE	7.71	7.19
RUTILE	.89	.51
CHLORITE-Mg	2.03	1.81
HYDROUS PHOSPHATE	.14	.13
GYPSUM	22.47	23.67
CABRERITE	.63	.48
GALENA	.87	.28
COFFINITE	3.61	1.23
HYDROBASALUMINITE	14.54	16.77
TOTAL	= 99.50	

COMPOSITION OF REFINED MINERALS, SAMPLE NO. - RH262H - SUE C

ILLITE

SI	3.52
AL	2.13
MG	.24
FE	.10
Fe	.01
K	.71
NA	.02
O	12.00
H+	2.00

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SAMPLE NO. - RH262H - SUE C

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MINERAL FORMULAE NOT DETERMINED BY MINERAL ANALYZER

No.	Mineral Name	Density
	Formula	
1.	QUARTZ	2.65
	SI1.00 O2.00	
2.	GYPSUM	2.32
	CA1.00 S1.00 O6.00 H+4.00	
3.	CHLORITE-Mg	2.75
	SI2.75 AL2.35 Fe .35 FE .17 MG3.62 O16.5 H+6.50	
4.	RUTILE	4.22
	TI1.00 O2.00	
5.	GALENA	7.50
	PB1.00 S1.00	
6.	CHALCOPYRITE	4.20
	CU1.20 Fe .80 S2.00	
7.	HYDROUS PHOSPHATE	2.75
	CA1.00 P1.00 O4.00 H+1.00	
8.	COFFINITE	7.15
	U1.00 SI1.00 O4.00	
9.	IRON OXYHYDROXIDE	3.00
	Fe1.60 FE .40 O2.40 H+3.60	
10.	CABRERITE	3.23
	NI1.75 AS2.00 O16.0 H+16.0 MG .90 Fe .30	
11.	HYDROBASALUMINITE	2.12
	AL4.00 S1.00 O29.0 H+40.0	
12.	KAOLINITE	2.62
	SI2.00 AL2.00 H+4.00 O9.00	

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SAMPLE NO. - RH262H - SUE C

WEIGHT PERCENT COMPOUNDS

		ABSOLUTE	NORMALIZED
SI	O2 -	30.58	30.62
TI	O2 -	.808	.809
AL2	O3 -	17.11	17.13
FE2	O3 -	.836	.838
FE	O -	.520	.521
CA	O -	6.74	6.74
K2	O -	3.03	3.04
MG	O -	1.41	1.42
NA2	O -	.067	.067
MN	O -	.074	.074
BA	O -	.063	.063
P2	O5 -	.067	.067
S	O3 -	11.52	11.54
NI	O -	.135	.135
CU	O -	.0674	.0674
AS2	O5 -	.236	.236
PB	O -	.741	.742
U	O2 -	2.69	2.70
H2	O- -	7.82	7.82
H2	O+ -	14.77	14.77
C	O2 -	.01	.01
ORG	-	.60	.60

TOTAL 99.89

Sulfide sulfur = .115 %
Total sulfur = 4.66 %

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ANALYZED MINERAL CONTENT

SAMPLE NO. - RH262D - SUE A+B #4

MINERAL	WT. PERCENT	VOL. PERCENT
QUARTZ	35.19	33.26
HYDROBASALUMINITE	14.60	17.25
GOETHITE	2.43	1.39
CHLORITE-Mg	1.51	1.37
RUTILE	.37	.22
CHALCOPYRITE	.05	.03
JAROSITE	.50	.40
HYDROUS PHOSPHATE	.14	.13
GYPSUM	23.01	24.84
KAOLINITE	.17	.16
SCORODITE	1.21	.69
GALENA	.04	.01
CABRERITE	6.56	5.09
ILLITE	14.18	15.12
TOTAL	= 99.96	

COMPOSITION OF REFINED MINERALS, SAMPLE NO. - RH262D-SUE A+B #4

ILLITE

SI	3.57
AL	1.88
MG	.25
FE	.29
Fe	.01
K	.66
NA	.03
O	12.00
H+	2.00

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MINERAL FORMULAE NOT DETERMINED BY MINERAL ANALYZER

No.	Mineral Name	Density
	Formula	
1.	QUARTZ	2.65
	SI1.00 O2.00	
2.	GYPSUM	2.32
	CA1.00 S1.00 O6.00 H+4.00	
3.	CHLORITE-Mg	2.75
	SI2.75 AL2.35 Fe .04 FE .17 MG3.93 O16.5 H+6.50	
4.	RUTILE	4.22
	TI1.00 O2.00	
5.	GALENA	7.50
	PB1.00 S1.00	
6.	CHALCOPYRITE	4.20
	CU1.20 Fe .80 S2.00	
7.	HYDROUS PHOSPHATE	2.75
	CA1.00 P1.00 O4.00 H+1.00	
11.	GOETHITE	4.37
	FE1.00 O2.00 H+1.00	
13.	JAROSITE	3.16
	NA .05 K .95 FE1.00 S2.00 O14.0 H+6.00	
14.	CABRERITE	3.23
	NI1.58 AS2.00 O16.0 H+16.0 MG1.20 Fe .22	
15.	SCORODITE	4.37
	FE .90 AL .10 O6.00 H+4.00 AS1.00	
16.	HYDROBASALUMINITE	2.12
	AL4.00 S1.00 O29.0 H+40.0	
17.	KAOLINITE	2.62
	SI2.00 AL2.00 H+4.00 O9.00	

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SAMPLE NO. - RH262D - SUE A+B #4

WEIGHT PERCENT COMPOUNDS

	ABSOLUTE	NORMALIZED
SI O2 -	40.70	40.80
TI O2 -	.343	.344
AL2 O3 -	7.96	7.98
FE2 O3 -	3.31	3.32
FE O -	.230	.231
CA O -	7.07	7.09
K2 O -	1.10	1.10
MG O -	1.30	1.31
NA2 O -	.069	.069
MN O -	.063	.063
BA O -	.0343	.0344
P2 O5 -	.068	.068
S O3 -	11.96	11.99
NI O -	1.30	1.31
CU O -	.0343	.0344
AS2 O5 -	3.11	3.12
PB O -	.0343	.0344
U O2 -	.00	.00
H2 O- -	5.92	5.92
H2 O+ -	15.05	15.05
C O2 -	.01	.01
ORG -	.13	.13

TOTAL 99.82

Sulfide sulfur = .08 %

Total sulfur = 4.79 %

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ANALYZED MINERAL CONTENT

SAMPLE NO. - RH262E - SUE A+B, Midwest (blend) #5

MINERAL	WT. PERCENT	VOL. PERCENT
QUARTZ	28.34	28.09
HYDROBASALUMINITE	13.19	16.34
PYRITE	.32	.17
GOETHITE	.02	.01
RUTILE	.26	.16
JAROSITE	3.69	3.07
CHLORITE-Mg	.69	.66
HYDROUS PHOSPHATE	.13	.12
CABRERITE	14.88	12.10
ILLITE	2.98	3.33
CHALCOPYRITE	.06	.03
GALENA	.28	.10
COFFINITE	.81	.30
GYPSUM	27.98	31.67
SCORODITE	6.31	3.79
TOTAL	= 99.94	

COMPOSITION OF REFINED MINERALS, SAMPLE NO. - RH262E-SUE A+B,
Midwest (blend) #5

ILLITE

SI	3.57
AL	1.88
MG	.25
FE	.29
Fe	.01
K	.66
NA	.03
O	12.00
H+	2.00

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SSAMPLE NO. - RH262E - SUE A+B, Midwest (blend) #5 Page 3
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MINERAL FORMULAE NOT DETERMINED BY MINERAL ANALYZER

No.	Mineral Name	Density
	Formula	
1.	QUARTZ	2.65
	SI1.00 O2.00	
2.	GYPSUM	2.32
	CA1.00 S1.00 O6.00 H+4.00	
3.	CHLORITE-Mg	2.75
	SI2.75 AL2.35 Fe .04 FE .17 MG3.93 O16.5 H+6.50	
4.	RUTILE	4.22
	TI1.00 O2.00	
5.	GALENA	7.50
	PB1.00 S1.00	
6.	CHALCOPYRITE	4.20
	CU1.40 Fe .60 S2.00	
7.	HYDROUS PHOSPHATE	2.75
	CA1.00 P1.00 O4.00 H+1.00	
8.	COFFINITE	7.15
	U1.00 SI1.00 O4.00	
9.	PYRITE	5.02
	Fe1.00 S2.00	
10.	GOETHITE	4.37
	FE1.00 O2.00 H+1.00	
11.	JAROSITE	3.16
	NA .05 K .95 FE1.00 S2.00 O14.0 H+6.00	
12.	CABRERITE	3.23
	NI1.60 AS2.00 O16.0 H+16.0 MG1.20 Fe .20	
13.	SCORODITE	4.37
	FE .90 AL .10 O6.00 H+4.00 AS1.00	
14.	HYDROBASALUMINITE	2.12
	AL4.00 S1.00 O29.0 H+40.0	

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SAMPLE NO. - RH262E - SUE A+B, Midwest (blend) #5

WEIGHT PERCENT COMPOUNDS

	ABSOLUTE	NORMALIZED
SI O2 -	27.45	27.47
TI O2 -	.239	.239
AL2 O3 -	4.71	4.72
FE2 O3 -	2.68	2.68
FE O -	.540	.540
CA O -	8.29	8.30
K2 O -	.597	.597
MG O -	1.43	1.43
NA2 O -	.060	.060
MN O -	.035	.035
BA O -	.023	.023
P2 O5 -	.0597	.0597
S O3 -	15.19	15.20
NI O -	2.89	2.90
CU O -	.0298	.0299
AS2 O5 -	8.44	8.45
PB O -	.239	.239
U O2 -	.597	.597
H2 O- -	9.23	9.23
H2 O+ -	17.05	17.05
C O2 -	.01	.01
ORG -	.13	.13

TOTAL 99.94

Sulfide sulfur = .135 %

Total sulfur = 6.21 %

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ANALYZED MINERAL CONTENT

SAMPLE NO. - RH262F - JEB.1

MINERAL	WT. PERCENT	VOL. PERCENT
QUARTZ	26.40	25.27
ILLITE	40.17	43.36
GOETHITE	1.90	1.10
PYRITE	.09	.05
RUTILE	.94	.56
CHLORITE-Mg	12.00	11.07
HYDROUS PHOSPHATE	.18	.17
HYDROBASALUMINITE	4.24	5.07
CABRERITE	.29	.23
CHALCOPYRITE	.16	.10
GALENA	.30	.10
KAOLINITE	12.99	12.58
TOTAL	= 99.66	

COMPOSITION OF REFINED MINERALS, SAMPLE NO. - RH262F - JEB.1

ILLITE

SI	3.30
AL	2.50
MG	.14
FE	.05
Fe	.01
K	.80
NA	.05
O	12.00
H+	2.00

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SAMPLE NO. - RH262F - JEB.1

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MINERAL FORMULAE NOT DETERMINED BY MINERAL ANALYZER

No.	Mineral Name	Density
	Formula	
1.	QUARTZ	2.65
	SI1.00 O2.00	
2.	GYPSUM	2.32
	CA1.00 S1.00 O6.00 H+4.00	
3.	CHLORITE-Mg	2.75
	SI2.75 AL2.35 Fe .15 FE .17 MG3.83 O16.5 H+6.50	
4.	RUTILE	4.22
	TI1.00 O2.00	
5.	GALENA	7.50
	PB1.00 S1.00	
6.	CHALCOPYRITE	4.20
	CU1.40 Fe .60 S2.00	
7.	HYDROUS PHOSPHATE	2.75
	CA1.00 P1.00 O4.00 H+1.00	
9.	PYRITE	5.02
	Fe1.00 S2.00	
11.	GOETHITE	4.37
	FE1.00 O2.00 H+1.00	
14.	CABRERITE	3.23
	NI2.55 AS2.00 O16.0 H+16.0 MG .20 Fe .25	
16.	HYDROBASALUMINITE	2.12
	AL4.00 S1.00 O29.0 H+40.0	
17.	KAOLINITE	2.62
	SI2.00 AL2.00 H+4.00 O9.00	

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SAMPLE NO. - RH262F - JEB.1

WEIGHT PERCENT COMPOUNDS

		ABSOLUTE	NORMALIZED
SI	O2 -	55.98	56.09
TI	O2 -	.930	.932
AL2	O3 -	22.04	22.08
FE2	O3 -	2.40	2.41
FE	O -	.430	.431
CA	O -	.0930	.0932
K2	O -	3.81	3.82
MG	O -	4.09	4.10
NA2	O -	.186	.186
MN	O -	.047	.047
BA	O -	.045	.045
P2	O5 -	.0930	.0932
S	O3 -	.880	.881
NI	O -	.0930	.0932
CU	O -	.0930	.0932
AS2	O5 -	.112	.112
PB	O -	.279	.280
U	O2 -	.00	.00
H2	O- -	.120	.120
H2	O+ -	7.59	7.59
C	O2 -	.0100	.0100
ORG	-	.490	.490

TOTAL 99.81

Sulfide sulfur = .225 %

Total sulfur = .35 %

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ANALYZED MINERAL CONTENT

SAMPLE NO. - RH262G - JEB.2

MINERAL	WT. PERCENT	VOL. PERCENT
QUARTZ	22.27	21.07
PYRITE	.11	.05
GOETHITE	2.28	1.31
ILLITE	32.81	35.01
RUTILE	.83	.49
CHALCOPYRITE	.16	.10
CHLORITE-Mg	10.20	9.30
HYDROUS PHOSPHATE	.32	.29
GYPSUM	14.07	15.21
CABRERITE	.51	.40
SCORODITE	.56	.32
KAOLINITE	9.04	8.65
GALENA	.27	.09
HYDROBASALUMINITE	6.25	7.39
TOTAL	= 99.67	

COMPOSITION OF REFINED MINERALS, SAMPLE NO. - RH262G - JEB.2

ILLITE

SI	3.30
AL	2.50
MG	.14
FE	.05
Fe	.01
K	.80
NA	.05
O	12.00
H+	2.00

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SAMPLE NO. - RH262G - JEB.2

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MINERAL FORMULAE NOT DETERMINED BY MINERAL ANALYZER

No.	Mineral Name	Density
	Formula	
1.	QUARTZ	2.65
	SI1.00 O2.00	
2.	GYPSUM	2.32
	CA1.00 S1.00 O6.00 H+4.00	
3.	CHLORITE-Mg	2.75
	SI2.75 AL2.35 Fe .17 FE .17 MG3.81 O16.5 H+6.50	
4.	RUTILE	4.22
	TI1.00 O2.00	
5.	GALENA	7.50
	PB1.00 S1.00	
6.	CHALCOPYRITE	4.20
	CU1.20 Fe .80 S2.00	
7.	HYDROUS PHOSPHATE	2.75
	CA1.00 P1.00 O4.00 H+1.00	
8.	COFFINITE	7.15
	U1.00 SI1.00 O4.00	
9.	PYRITE	5.02
	Fe1.00 S2.00	
10.	GOETHITE	4.37
	FE1.00 O2.00 H+1.00	
11.	CABRERITE	3.23
	NI2.55 AS2.00 O16.0 H+16.0 MG .20 Fe .25	
12.	SCORODITE	4.37
	FE .90 AL .10 O6.00 H+4.00 AS1.00	
13.	HYDROBASALUMINITE	2.12
	AL4.00 S1.00 O29.0 H+40.0	
14.	KAOLINITE	2.62
	SI2.00 AL2.00 H+4.00 O9.00	

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(303) 279-1094

Hydrologic Consultants, Inc.
Lakewood, Colorado

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SAMPLE NO. - RH262G - JEB.2

WEIGHT PERCENT COMPOUNDS

		ABSOLUTE	NORMALIZED
SI	O2 -	43.38	43.41
TI	O2 -	.776	.777
AL2	O3 -	17.38	17.40
FE2	O3 -	2.65	2.65
FE	O -	.410	.410
CA	O -	4.42	4.43
K2	O -	2.95	2.95
MG	O -	3.26	3.26
NA2	O -	.155	.155
MN	O -	.078	.078
BA	O -	.076	.076
P2	O5 -	.155	.155
S	O3 -	7.22	7.22
NI	O -	.155	.155
CU	O -	.0776	.0777
AS2	O5 -	.450	.450
PB	O -	.233	.233
U	O2 -	.00	.00
H2	O- -	5.46	5.46
H2	O+ -	10.15	10.15
C	O2 -	.01	.01
ORG	-	.490	.490

TOTAL 99.93

Sulfide sulfur = .185 %
Total sulfur = 2.89 %

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ANALYZED MINERAL CONTENT

SAMPLE NO. - RH262C - JEB.3 #3

MINERAL	WT. PERCENT	VOL. PERCENT
QUARTZ	18.01	16.75
JAROSITE	.33	.25
GOETHITE	.29	.17
IRON OXYHYDROXIDE	.03	.03
KAOLINITE	11.59	10.90
RUTILE	.74	.43
ILLITE	35.26	36.97
CHLORITE-Mg	8.76	7.85
HYDROUS PHOSPHATE	.31	.28
GYPSUM	13.98	14.85
CABRERITE	.52	.39
SCORODITE	.74	.42
GALENA	.26	.09
HYDROBASALUMINITE	8.97	10.42
TOTAL	= 99.80	

COMPOSITION OF REFINED MINERALS, SAMPLE NO. - RH262C - JEB.3 #3

ILLITE

SI	3.52
AL	1.94
MG	.24
FE	.29
Fe	.01
K	.70
NA	.03
O	12.00
H+	2.00

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SAMPLE NO. - RH262C - JEB.3 #3

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MINERAL FORMULAE NOT DETERMINED BY MINERAL ANALYZER

No.	Mineral Name	Density
	Formula	
1.	QUARTZ	2.65
	SI1.00 O2.00	
2.	GYPSUM	2.32
	CA1.00 S1.00 O6.00 H+4.00	
3.	CHLORITE-Mg	2.75
	SI2.75 AL2.34 Fe .17 FE .18 MG3.83 O16.5 H+6.50	
4.	RUTILE	4.22
	TI1.00 O2.00	
5.	GALENA	7.50
	PB1.00 S1.00	
6.	CHALCOPYRITE	4.20
	CU .95 Fe1.05 S2.00	
7.	HYDROUS PHOSPHATE	2.75
	CA1.00 P1.00 O4.00 H+1.00	
8.	GOETHITE	4.37
	FE1.00 O2.00 H+1.00	
9.	IRON OXYHYDROXIDE	3.00
	Fe1.60 FE .40 O2.40 H+3.60	
10.	JAROSITE	3.16
	NA .15 K .85 FE1.00 S2.00 O14.0 H+6.00	
11.	CABRERITE	3.23
	NI2.50 AS2.00 O16.0 H+16.0 MG .30 Fe .20	
12.	SCORODITE	4.37
	FE .90 AL .10 O6.00 H+4.00 AS1.00	
13.	HYDROBASALUMINITE	2.12
	AL4.00 S1.00 O29.0 H+40.0	
14.	KAOLINITE	2.62
	SI2.00 AL2.00 H+4.00 O9.00	

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SAMPLE NO. - RH262C - JEB.3 #3

WEIGHT PERCENT COMPOUNDS

	ABSOLUTE	NORMALIZED
SI O2 -	42.64	42.83
TI O2 -	.700	.703
AL2 O3 -	17.27	17.35
FE2 O3 -	2.71	2.72
FE O -	.290	.291
CA O -	4.43	4.45
K2 O -	2.80	2.81
MG O -	3.27	3.28
NA2 O -	.156	.156
MN O -	.075	.075
BA O -	.078	.078
P2 O5 -	.156	.156
S O3 -	7.42	7.46
NI O -	.156	.156
CU O -	.0778	.0782
AS2 O5 -	.545	.547
PB O -	.233	.234
U O2 -	.00	.00
H2 O- -	4.29	4.29
H2 O+ -	11.88	11.88
C O2 -	.01	.01
ORG -	.43	.43

TOTAL 99.62

Sulfide sulfur = .11 %

Total sulfur = 3.88 %

Table 1. Diffractions and their mineral assignment for the primary and secondary phases found in the Cogema samples. These lines on the diffraction patterns included in this appendix.

Mineral	2θ degrees	Diffraction* width	Intensity** (relative)
Chlorite (001)	6.2-6.6	B-M-S	Variable
Kankite	6.9	B	100
Hydrobasaluminite	7.0	B	100
Illite (001)	8.8	S-M	100
Basaluminite	9.4	B	100
Gypsum	11.6	S	100
Kaolinite (001)	12.3	M	100
Chlorite (002)	12.4-12.9	M-S	100
Cabrerite	14.2	M	70
Jarosite	14.9	B	45
Basaluminite (?)	14.95	B	35
Jarosite	17.4	B	70
Illite (002)	17.6	S-M	35
Chlorite (003)	~18.5	M	40
Chlorite (020)	~19.2	M	40
Cabrerite	19.45	M	60
Scorodite	~19.6	B	100
Illite (020)	19.8	S-M	90
Kaolinite (02)	20.1	B, Band	60
Gypsum	20.7	S	100
Quartz	20.9	S	22
Goethite	21.25	S	100
Gypsum	23.4	S	17
Cabrerite	24.3	M	70
Cabrerite	24.7	M	70
Kaolinite (002)	24.9	M	100
Illite (shoulder on 26.65)	26.5	M	100
Quartz	26.65	S	100
Rutile	27.45	S	100
Cabrerite (2 lines)	28.0	M	160
Scorodite (crystalline)(?)	28.05	B	100
Jarosite	28.7	B	75
Jarosite (overlapped)	29.0	B, Band	100
Illite (shoulder on 29.1)	29.06	M	50
Gypsum	29.1	S	75
Cabrerite	32.8	M	70
Goethite (shoulder on 33.3)	33.2	M	35
Gypsum	33.3	S	35
Gypsum	36.0	S-M	11
Quartz	36.5	S	8
Quartz	39.5	S	8

* S = sharp, B = broad, M = medium sharp to medium broad.

** Relative intensity is relative to pure mineral with 100 as the most intense line.

FN: 2a.rd

ID: Bulk diff.

SCINTAG/USA

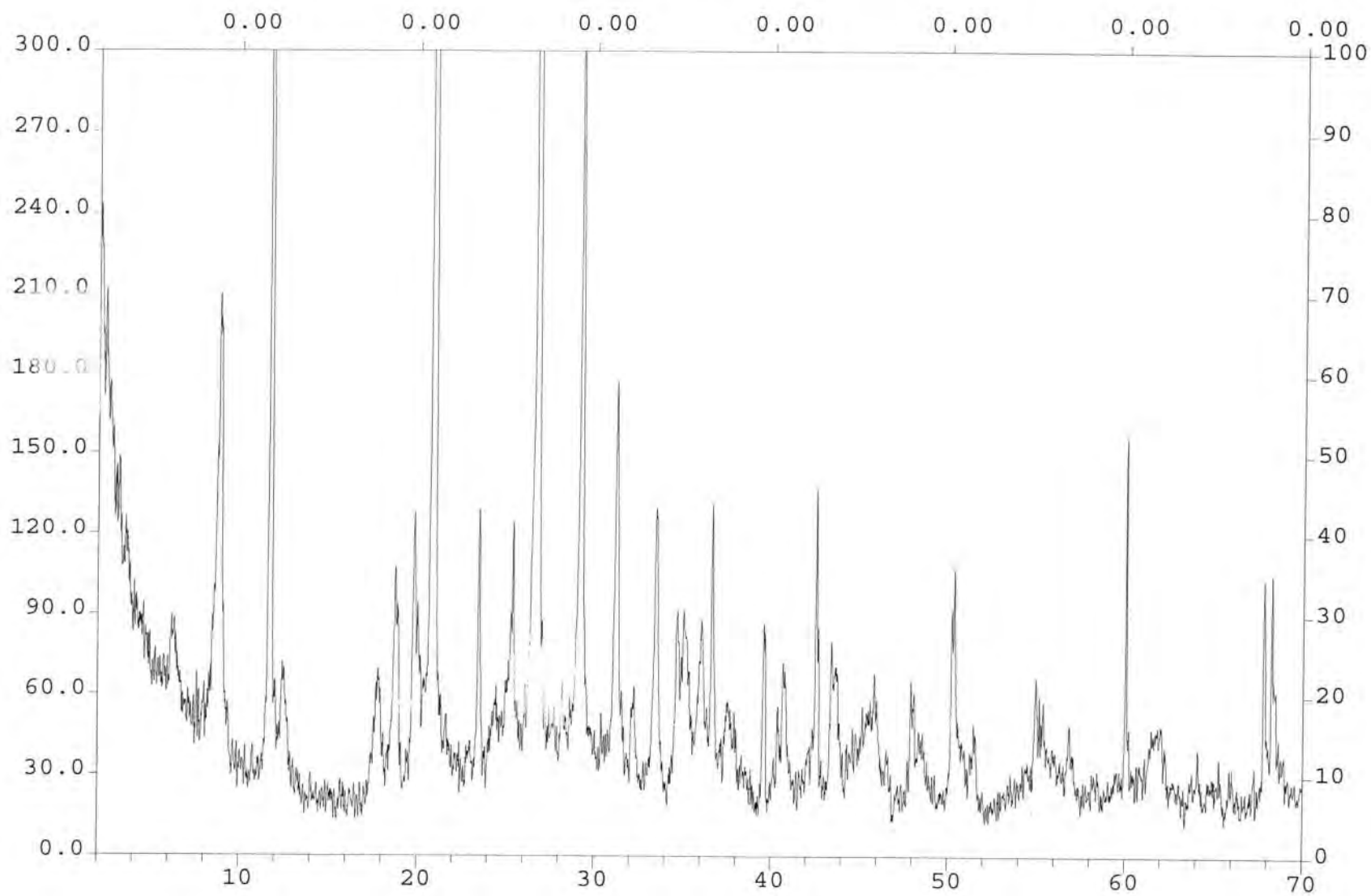
DATE: 3/12/98

TIME: 11:27

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: s262a.rd

ID: Bulk diff.

SCINTAG/USA

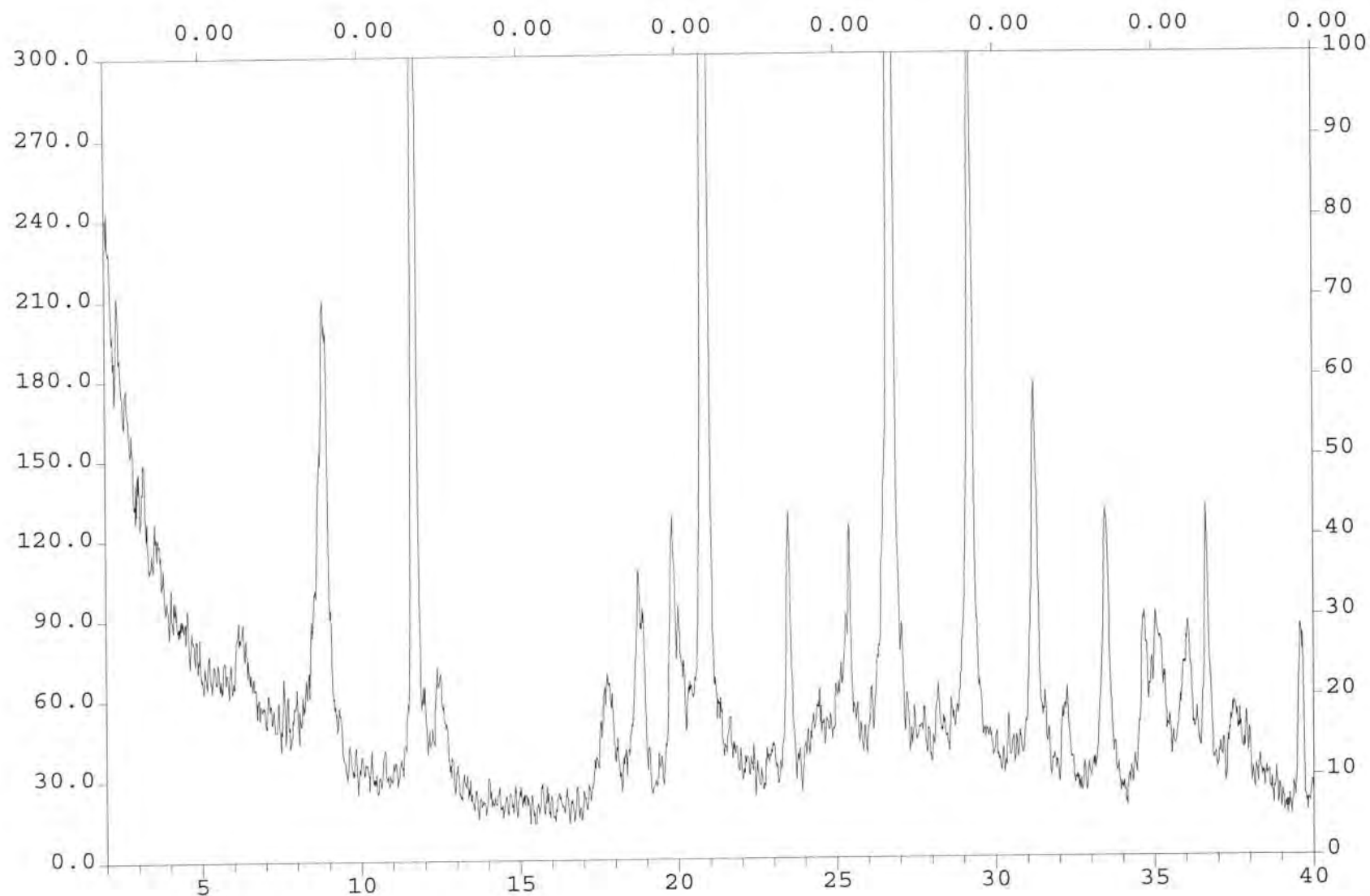
DATE: 3/12/98

TIME: 11:27

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: 52b.rd

ID: Bulk diff.

SCINTAG/USA

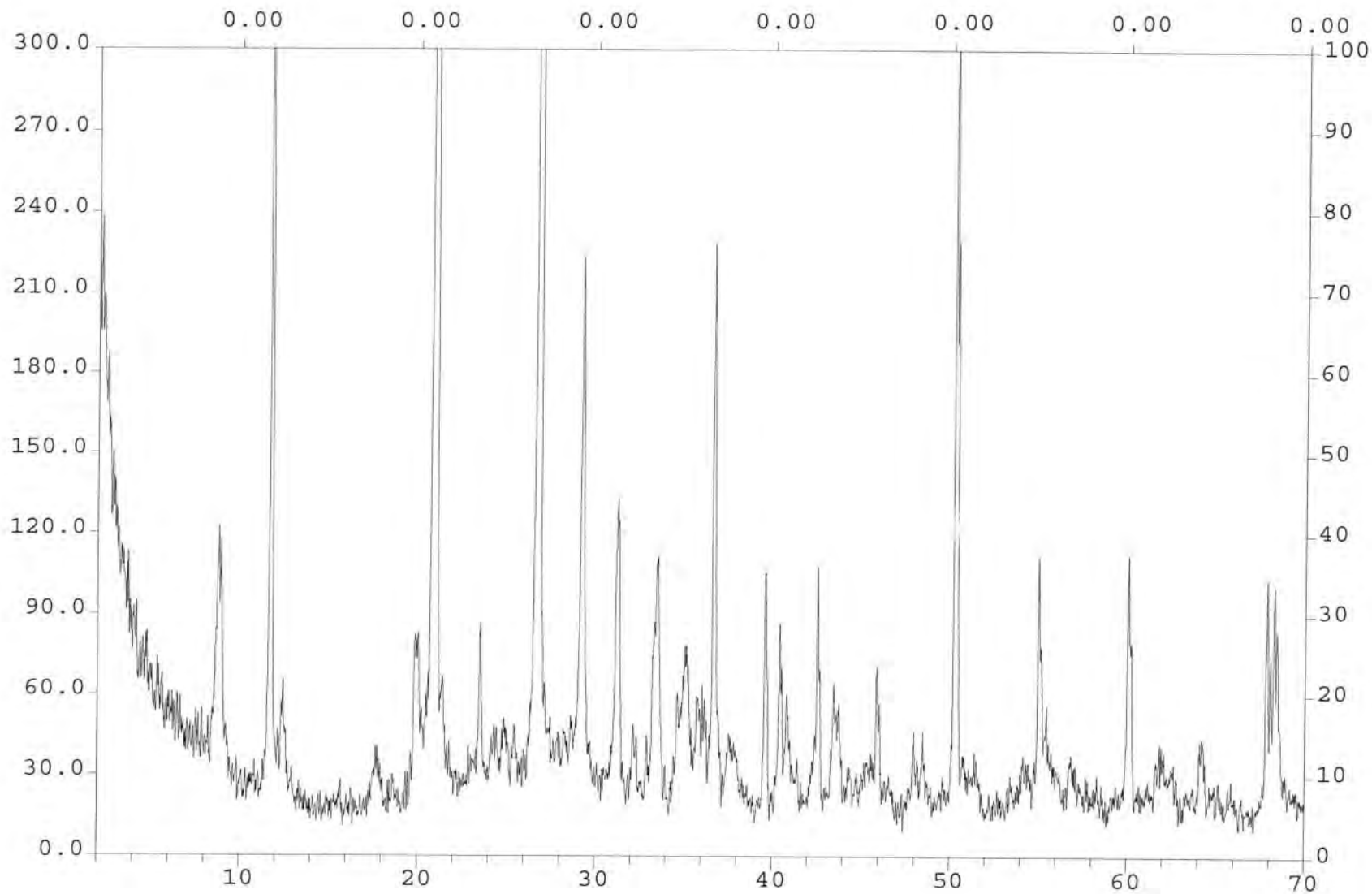
DATE: 3/12/98

TIME: 12:46

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: s262b.rd

ID: Bulk diff.

SCINTAG/USA

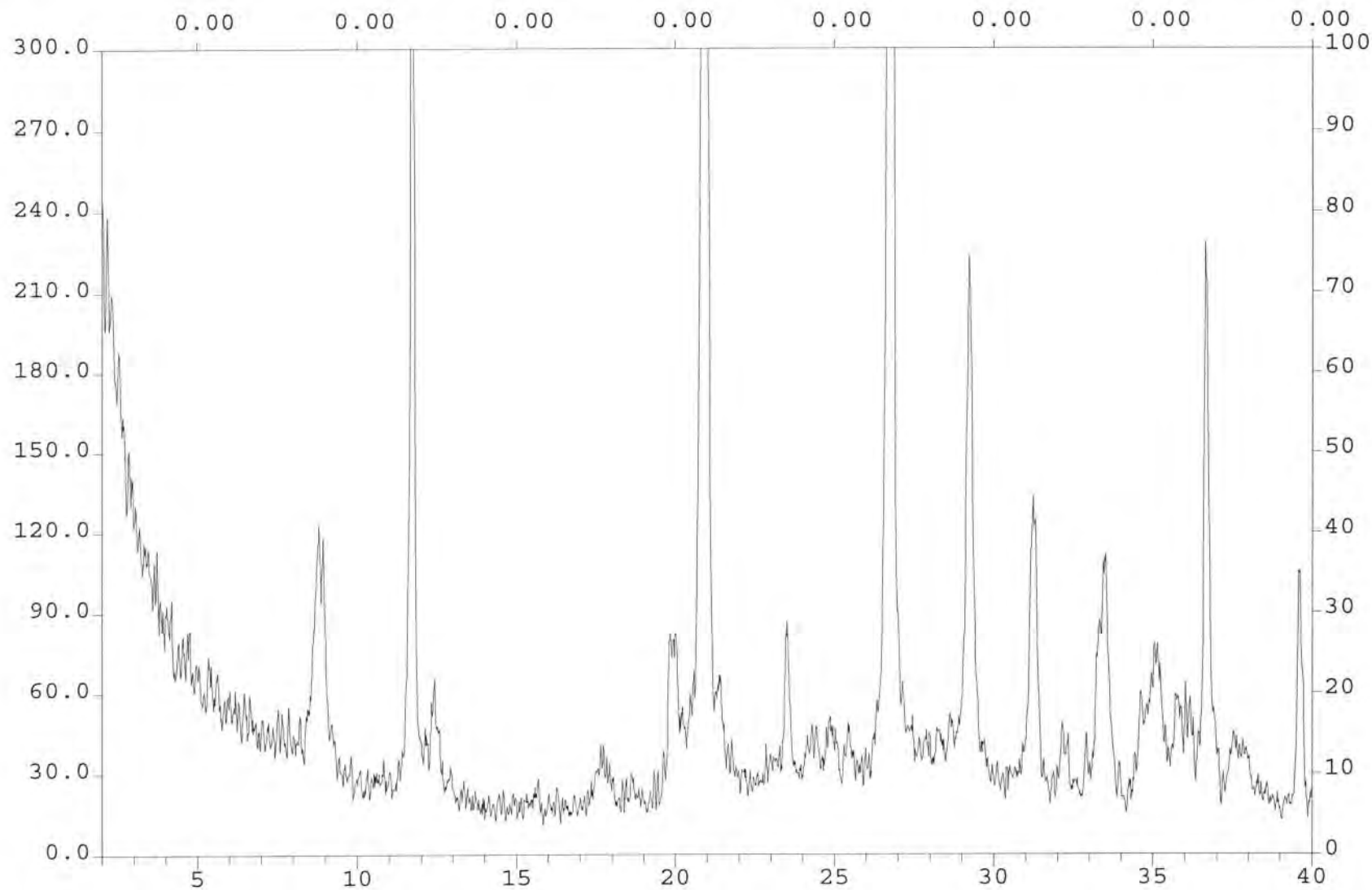
DATE: 3/12/98

TIME: 12:46

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: 12c.rd

ID: Bulk diff.

SCINTAG/USA

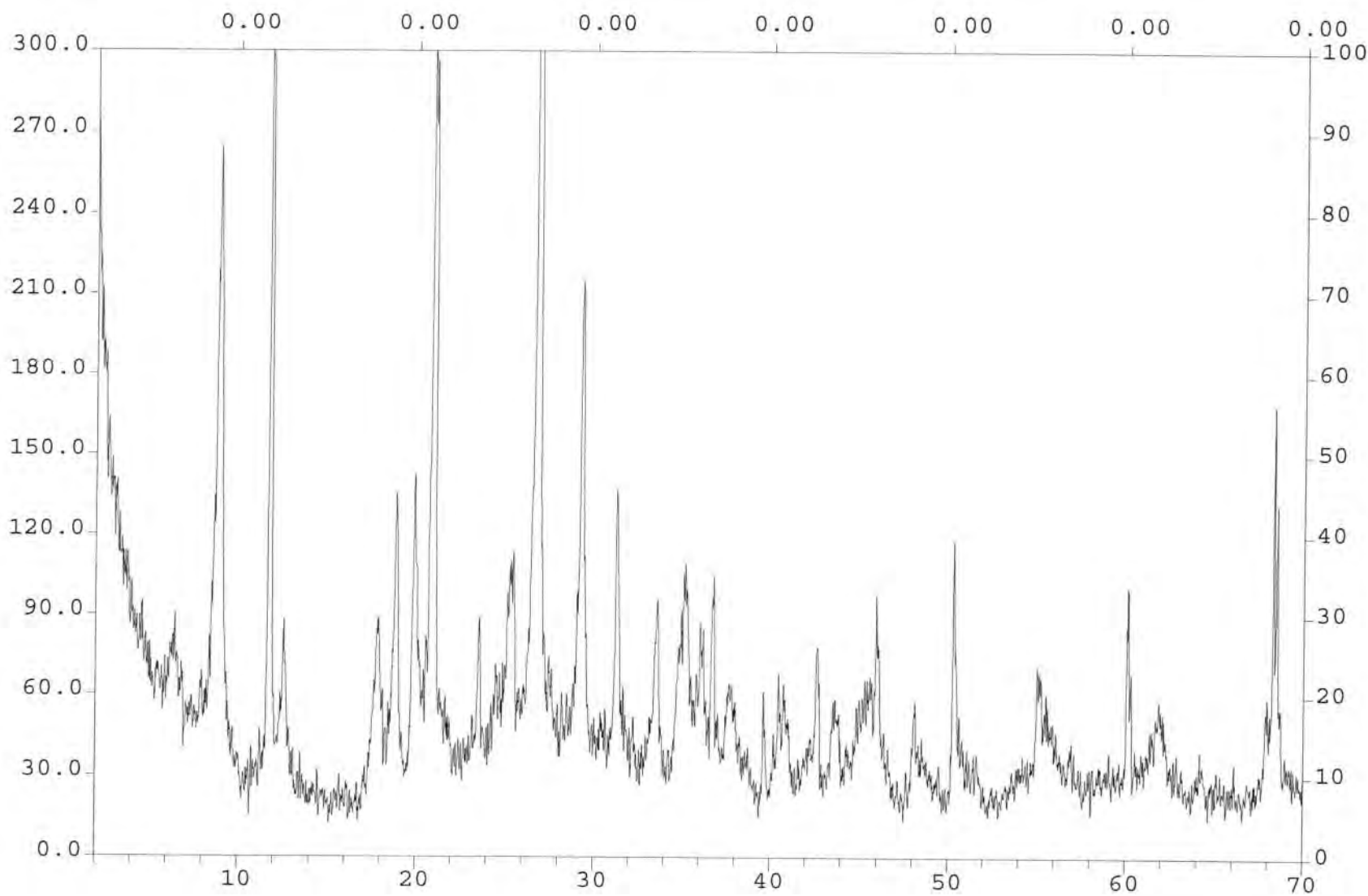
DATE: 3/12/98

TIME: 13:20

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: s262c.rd

ID: Bulk diff.

SCINTAG/USA

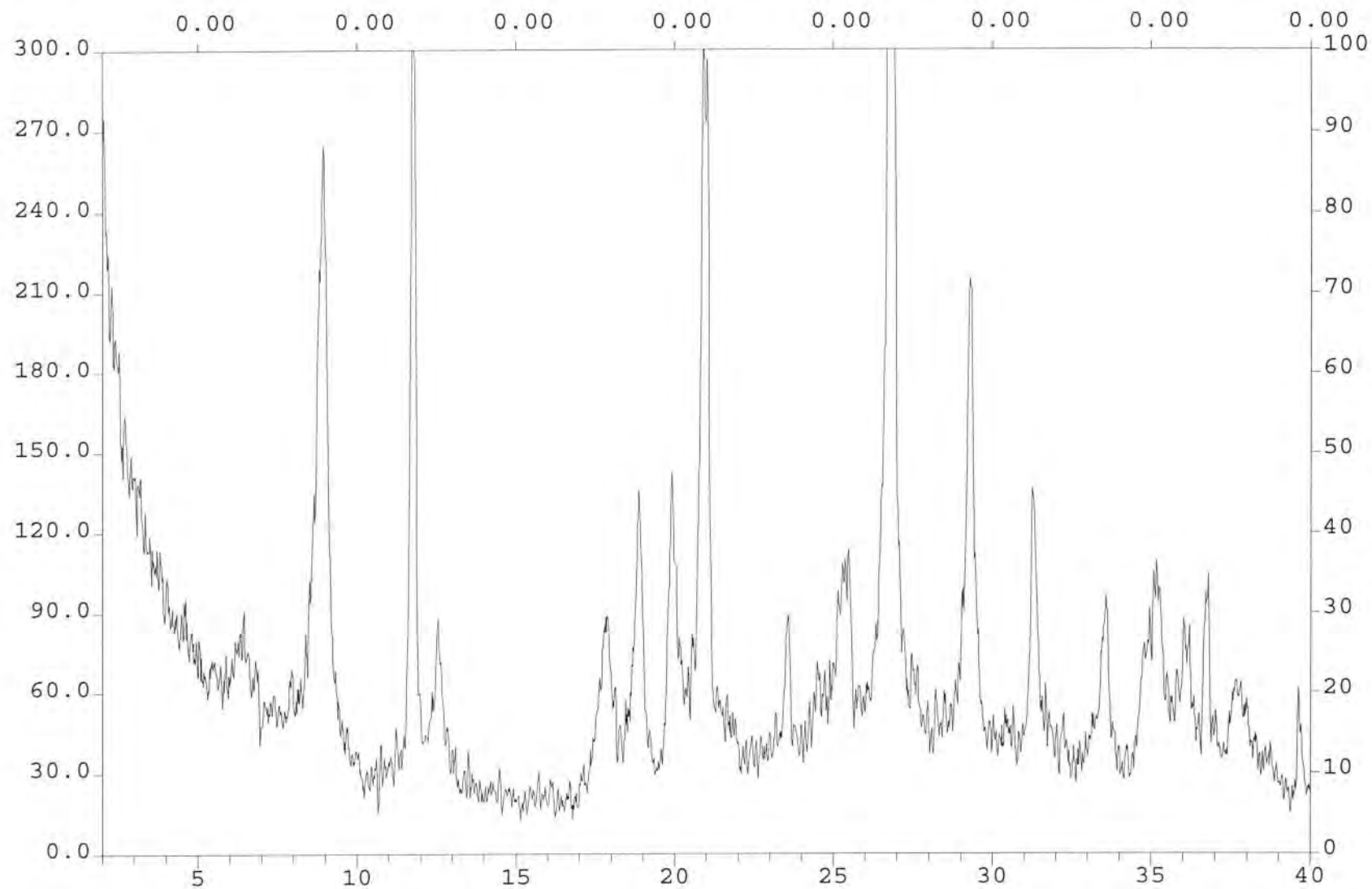
DATE: 3/12/98

TIME: 13:20

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: 62d.rd

ID: Bulk diff.

SCINTAG/USA

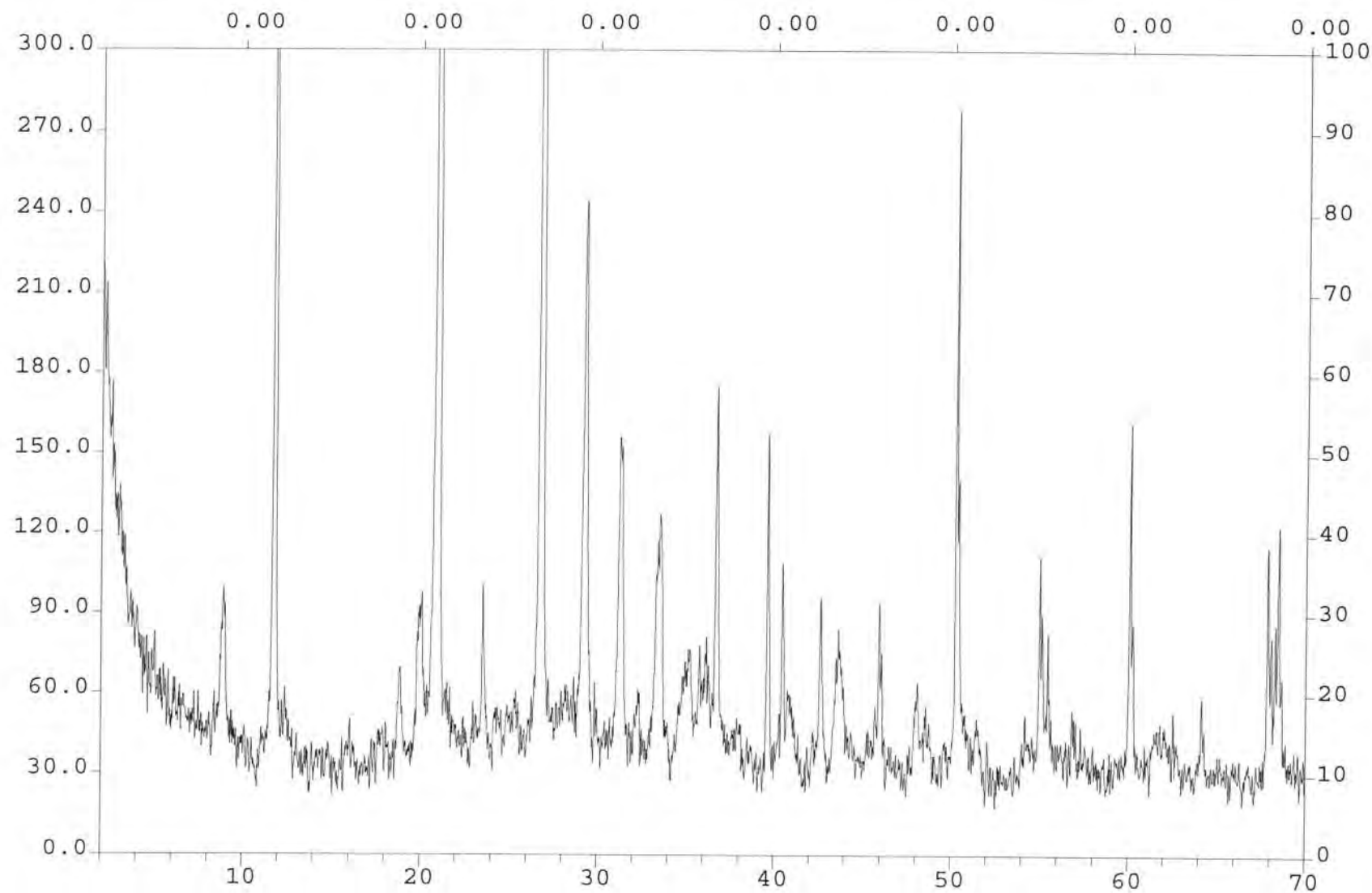
DATE: 3/12/98

TIME: 14:08

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: s262d.rd

ID: Bulk diff.

SCINTAG/USA

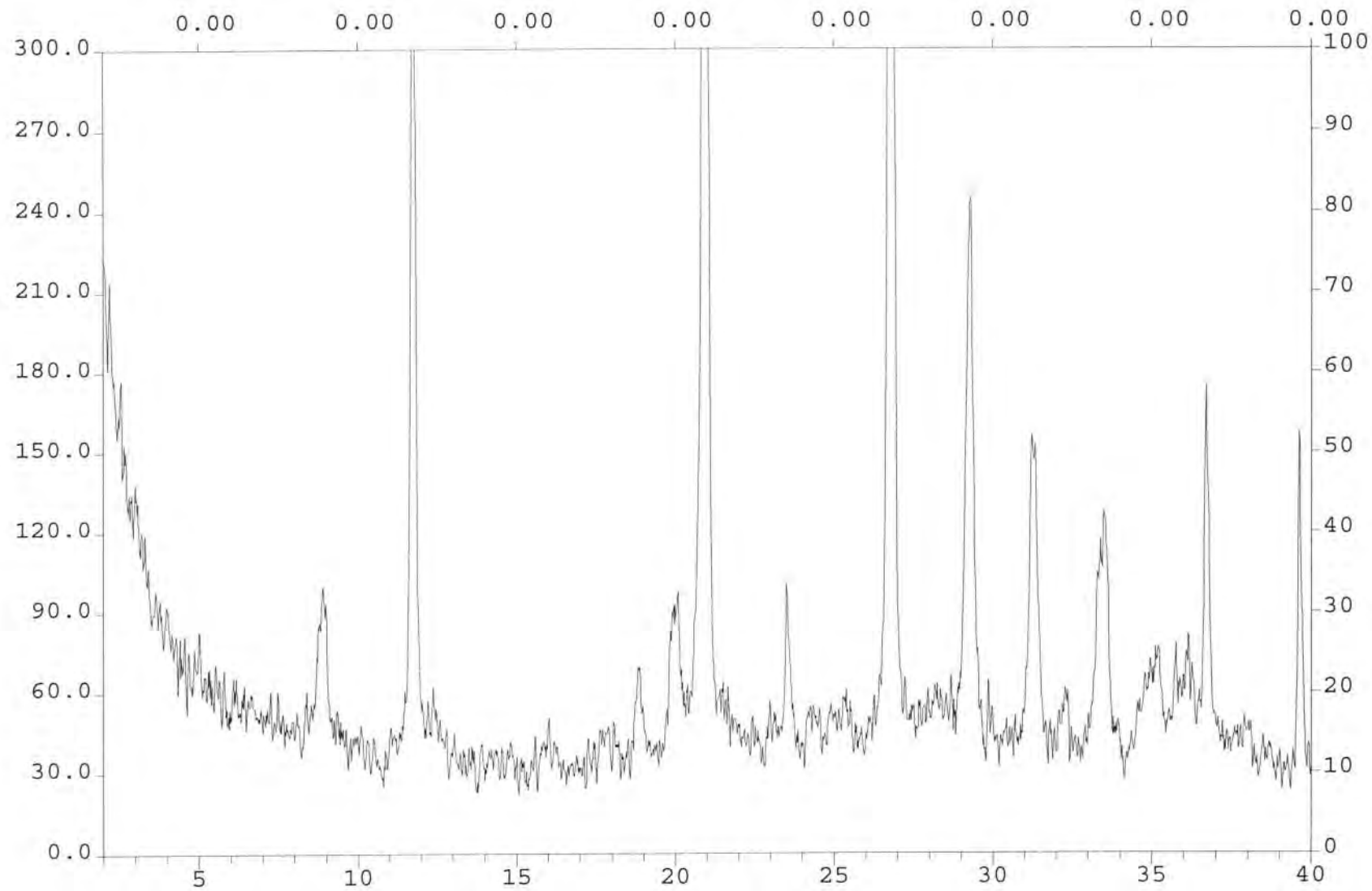
DATE: 3/12/98

TIME: 14:08

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: 52e.rd

ID: Bulk diff.

SCINTAG/USA

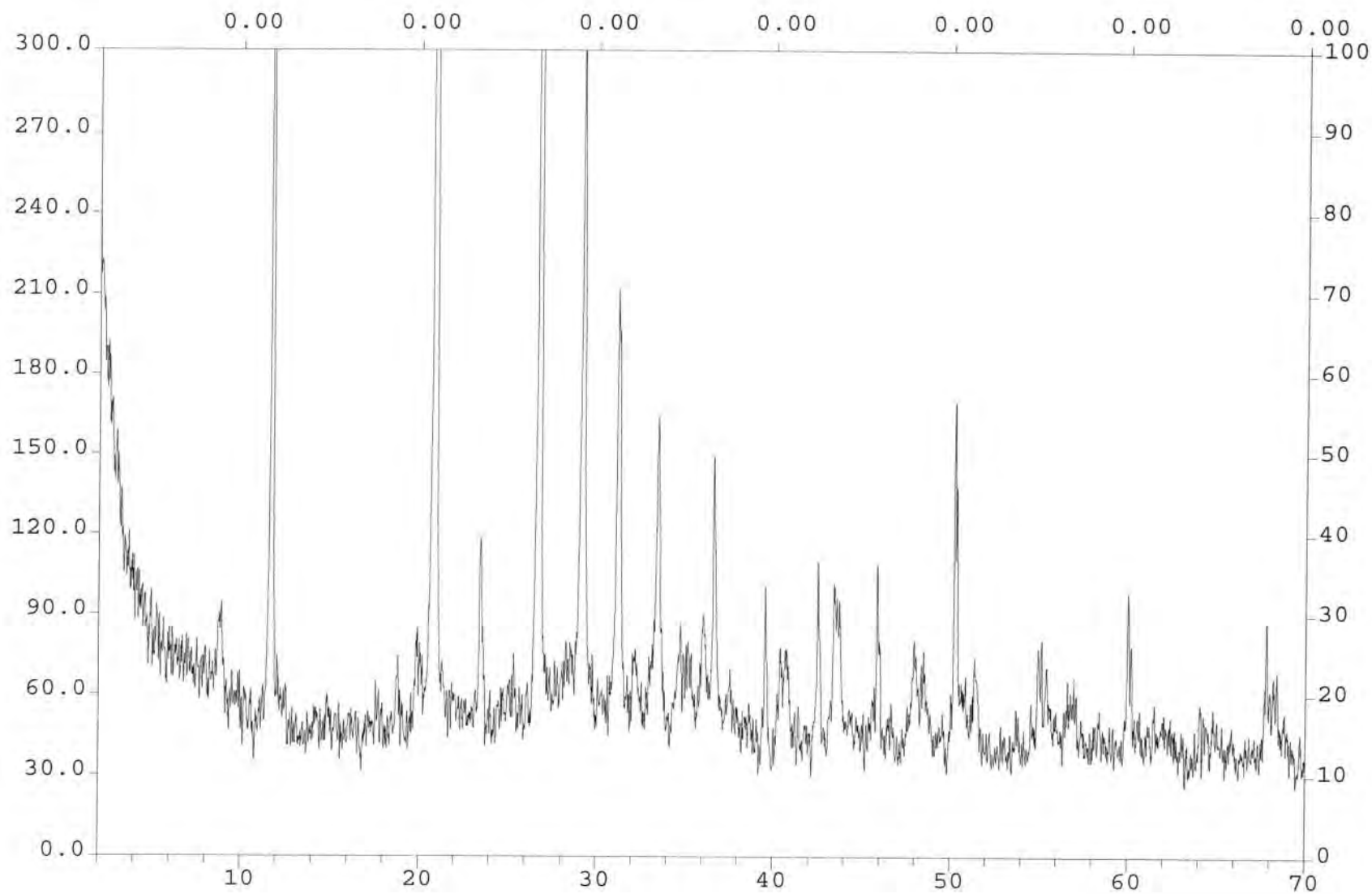
DATE: 3/12/98

TIME: 14:42

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: s262e.rd

ID: Bulk diff.

SCINTAG/USA

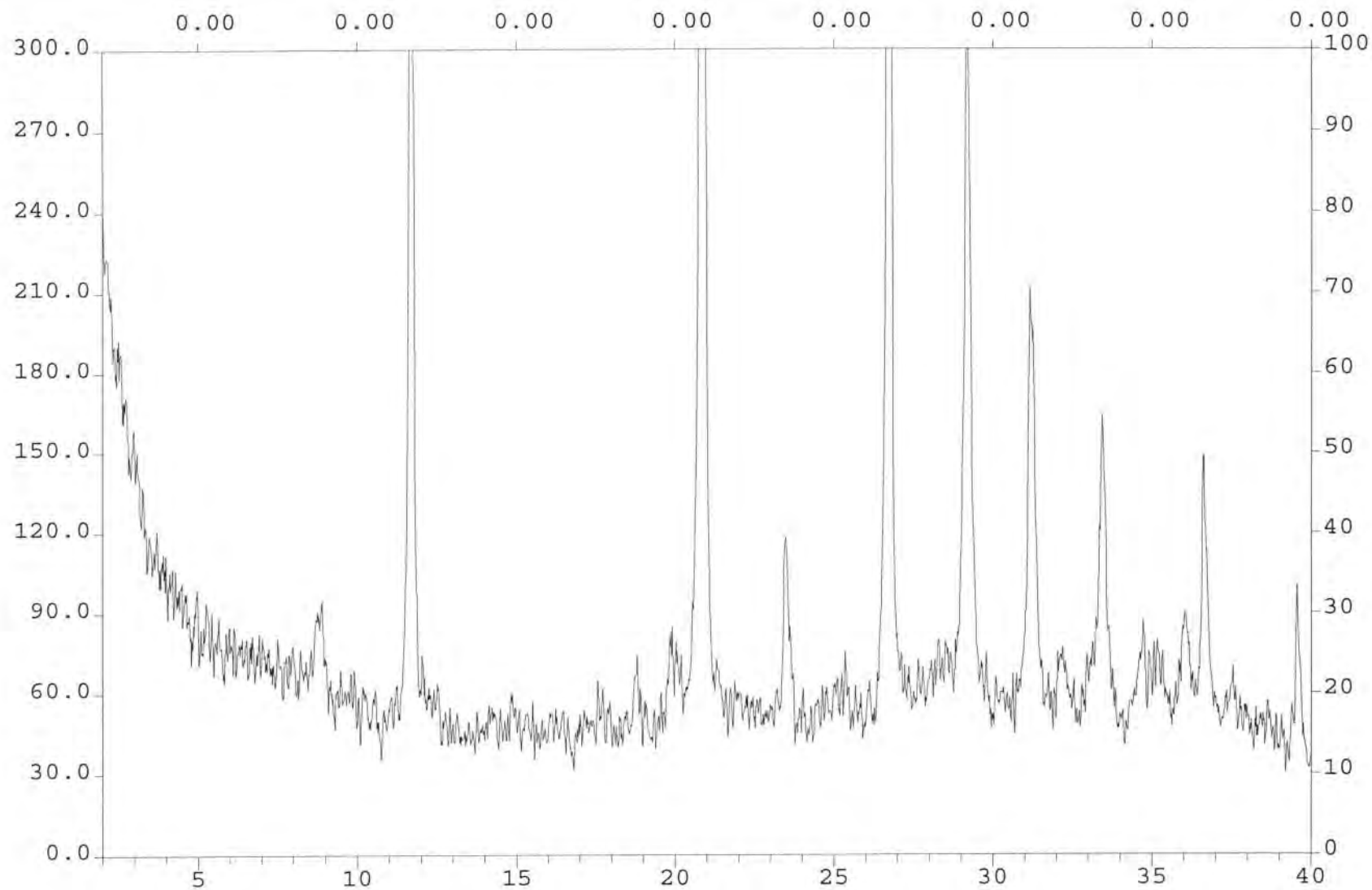
DATE: 3/12/98

TIME: 14:42

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: 2e.rd

ID: Bulk diff.

SCINTAG/USA

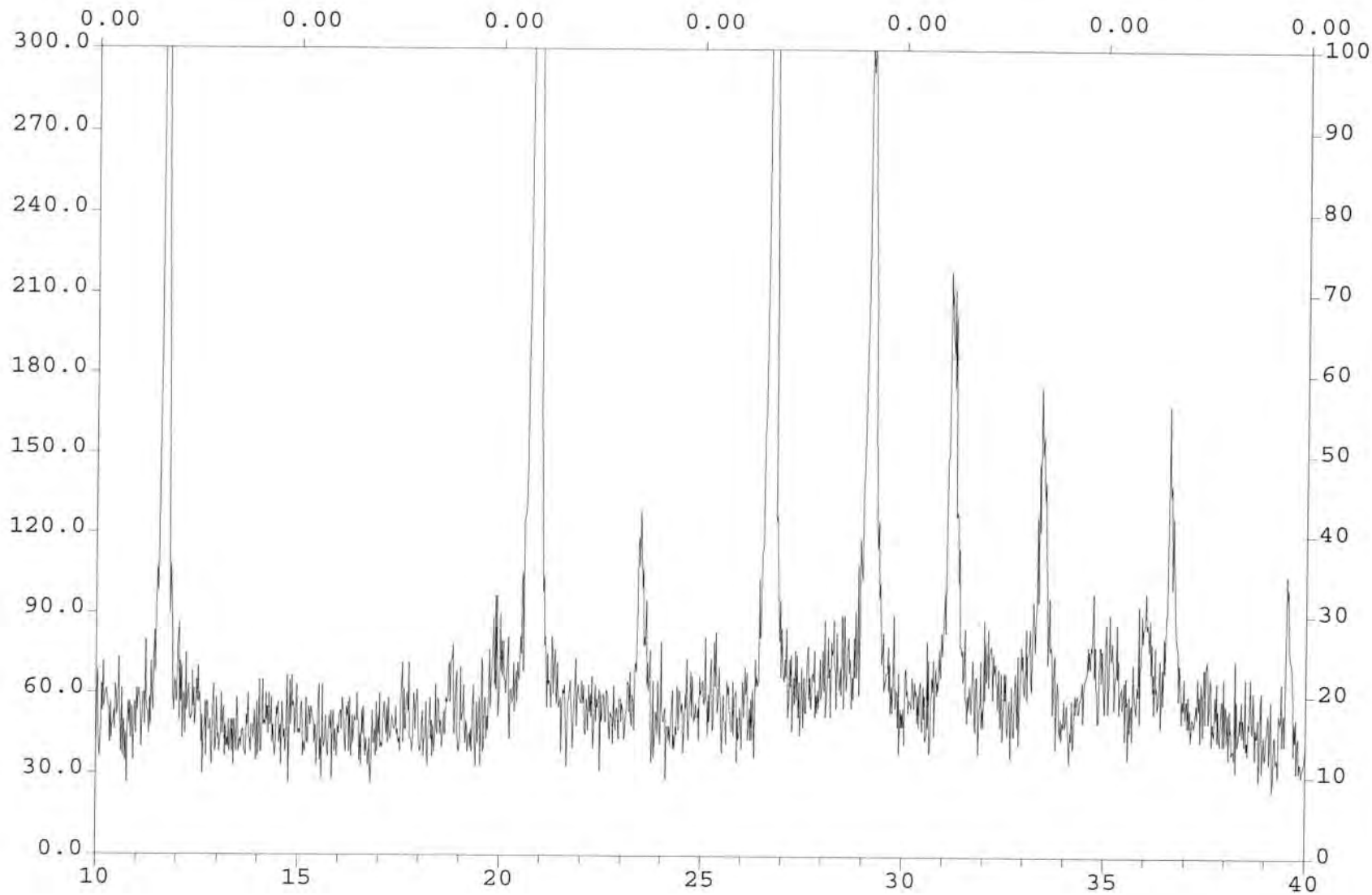
DATE: 3/12/98

TIME: 14:42

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: s262f.rd

ID: Bulk diff.

SCINTAG/USA

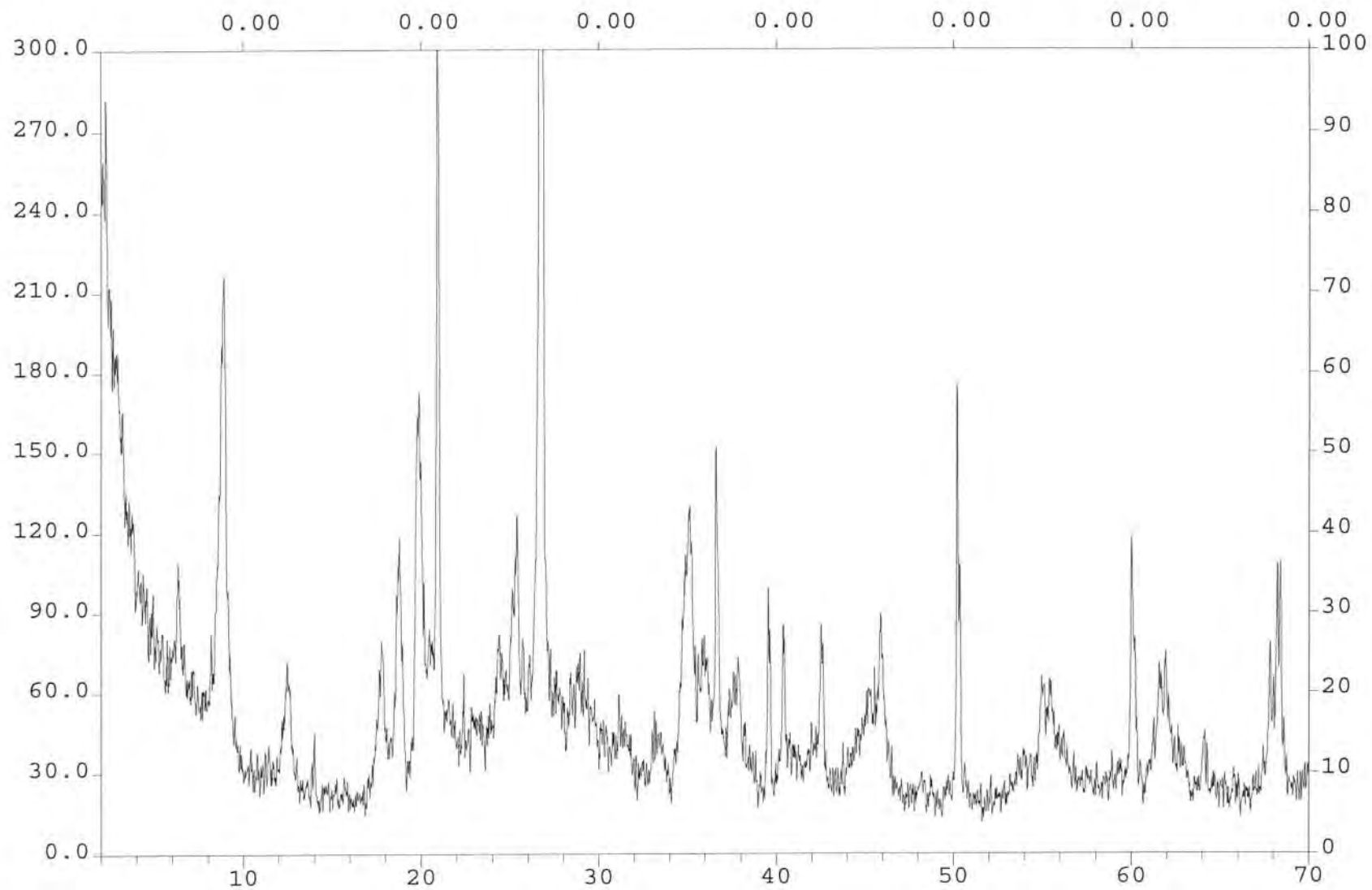
DATE: 3/12/98

TIME: 15:16

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: 2f.rd

ID: Bulk diff.

SCINTAG/USA

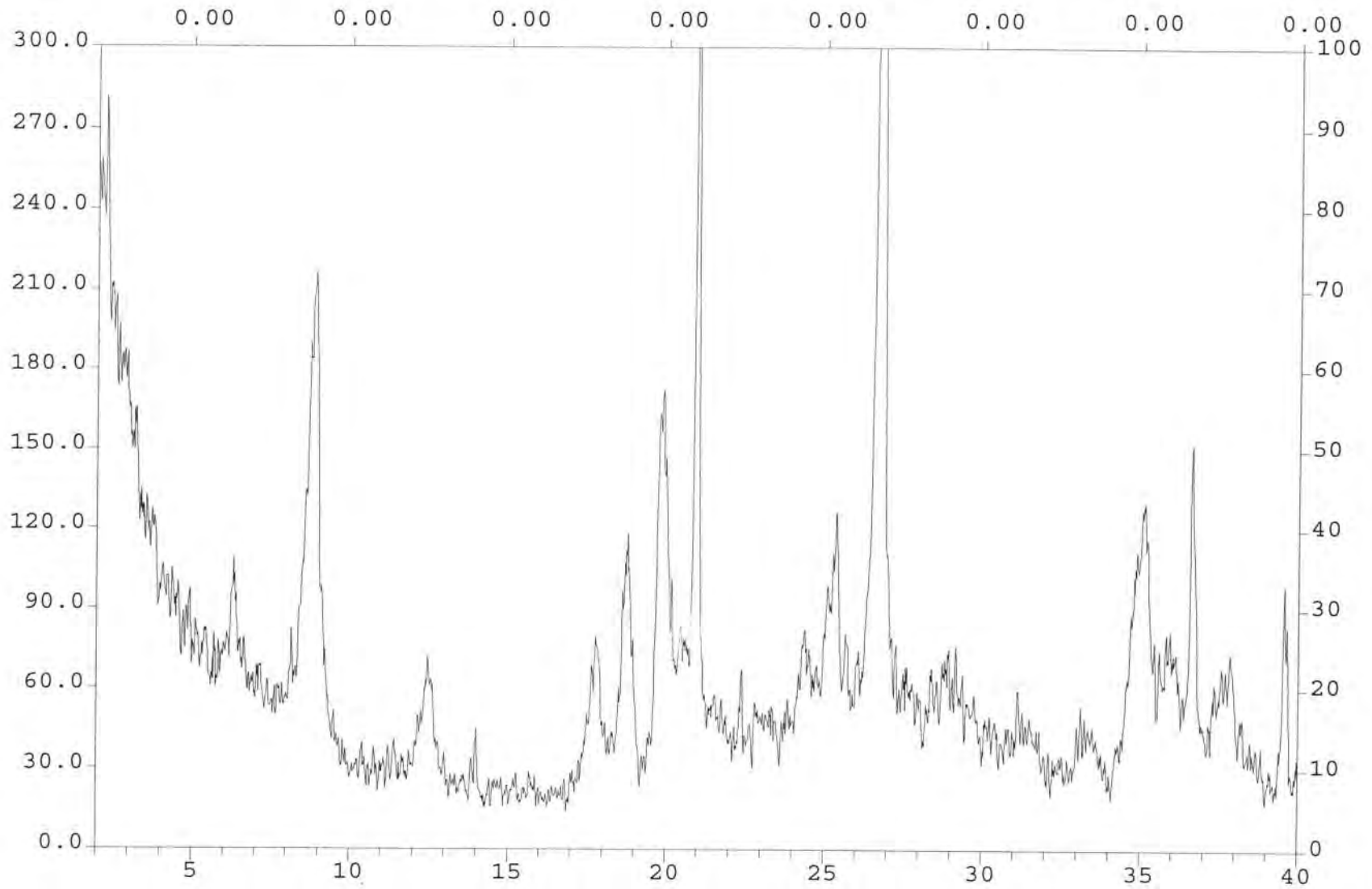
DATE: 3/12/98

TIME: 15:16

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: s262g.rd

ID: Bulk diff.

SCINTAG/USA

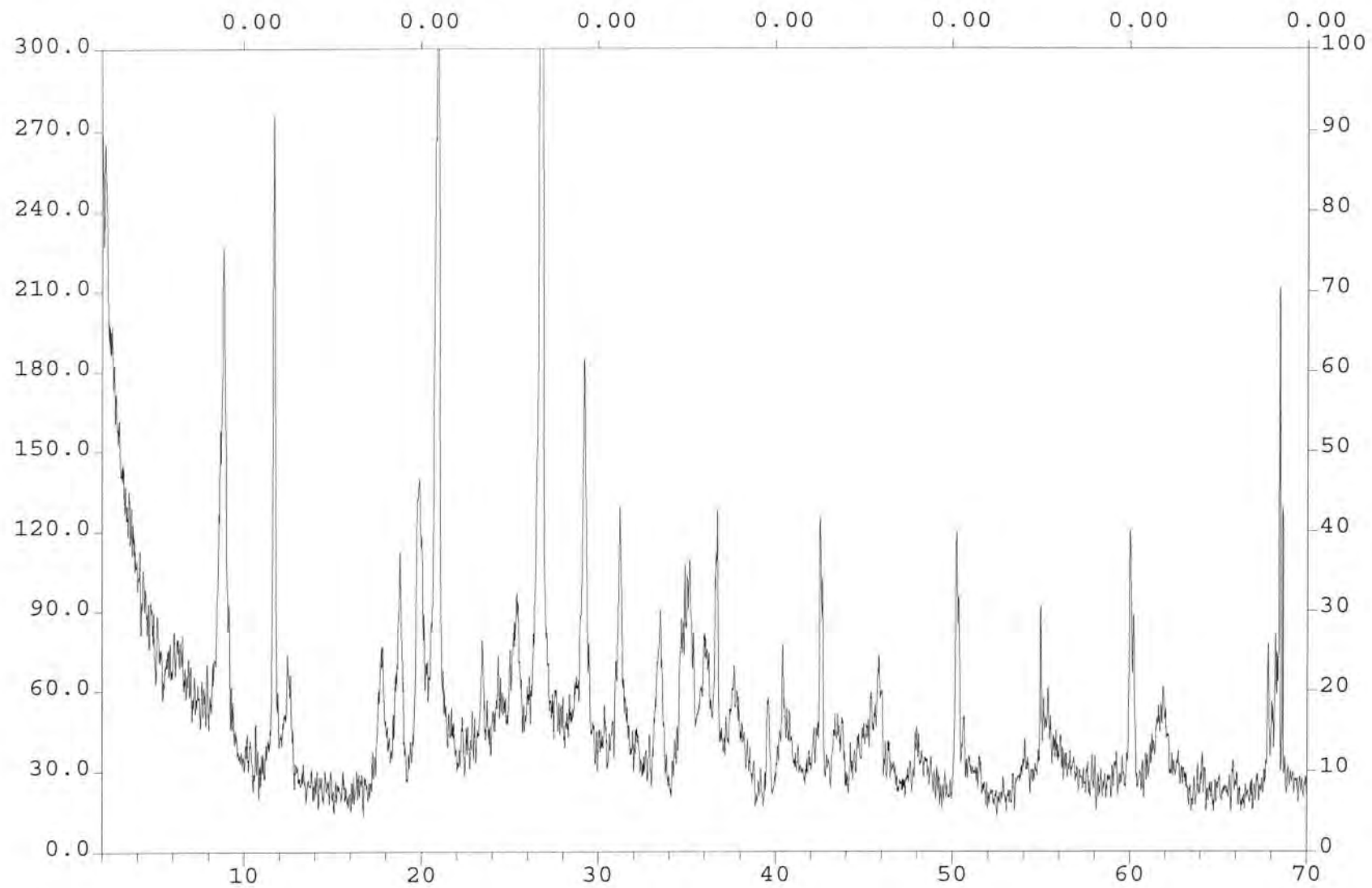
DATE: 3/12/98

TIME: 16:00

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: 12g.rd

ID: Bulk diff.

SCINTAG/USA

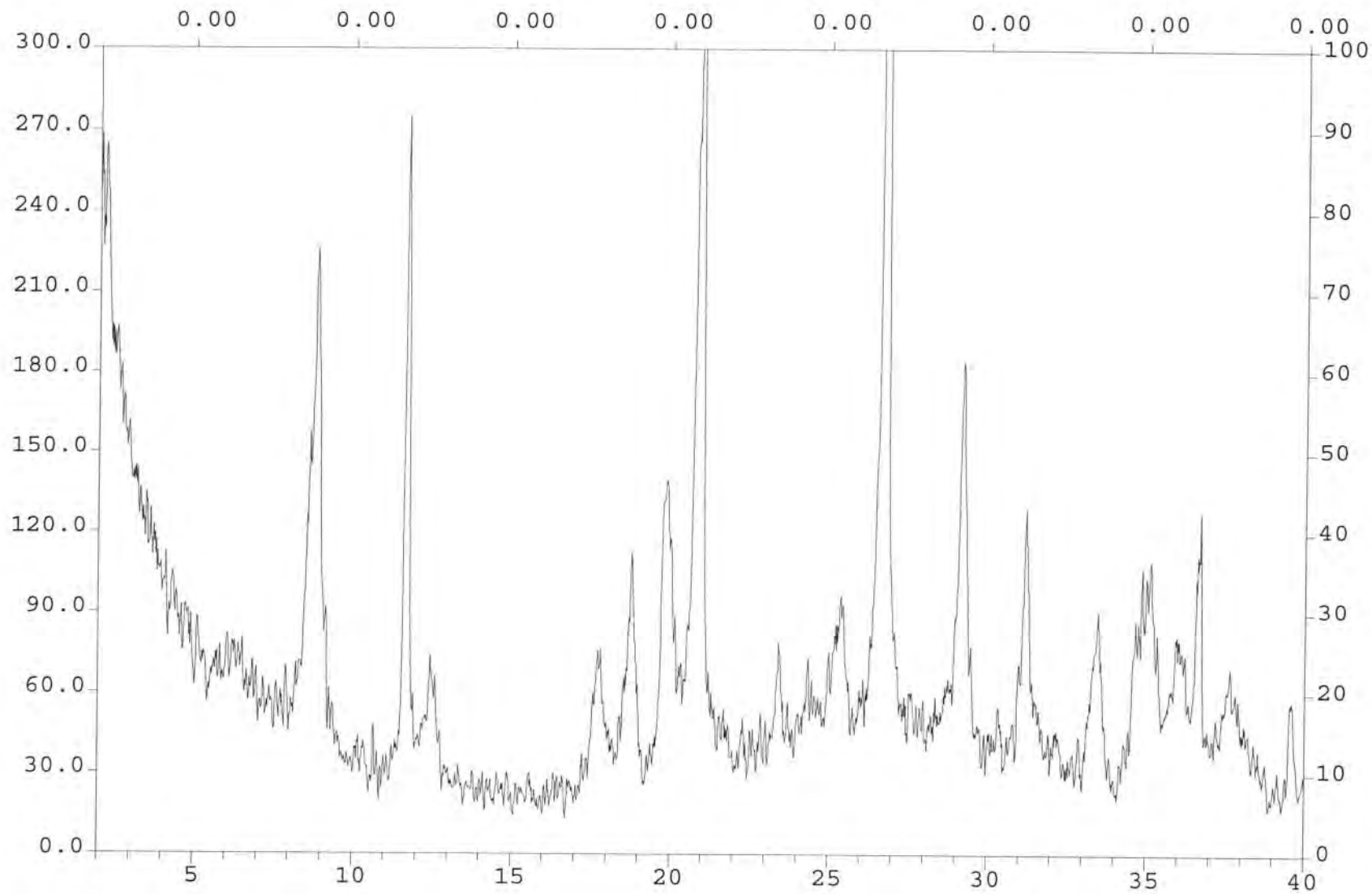
DATE: 3/12/98

TIME: 16:00

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: s262h.rd

ID: Bulk diff.

SCINTAG/USA

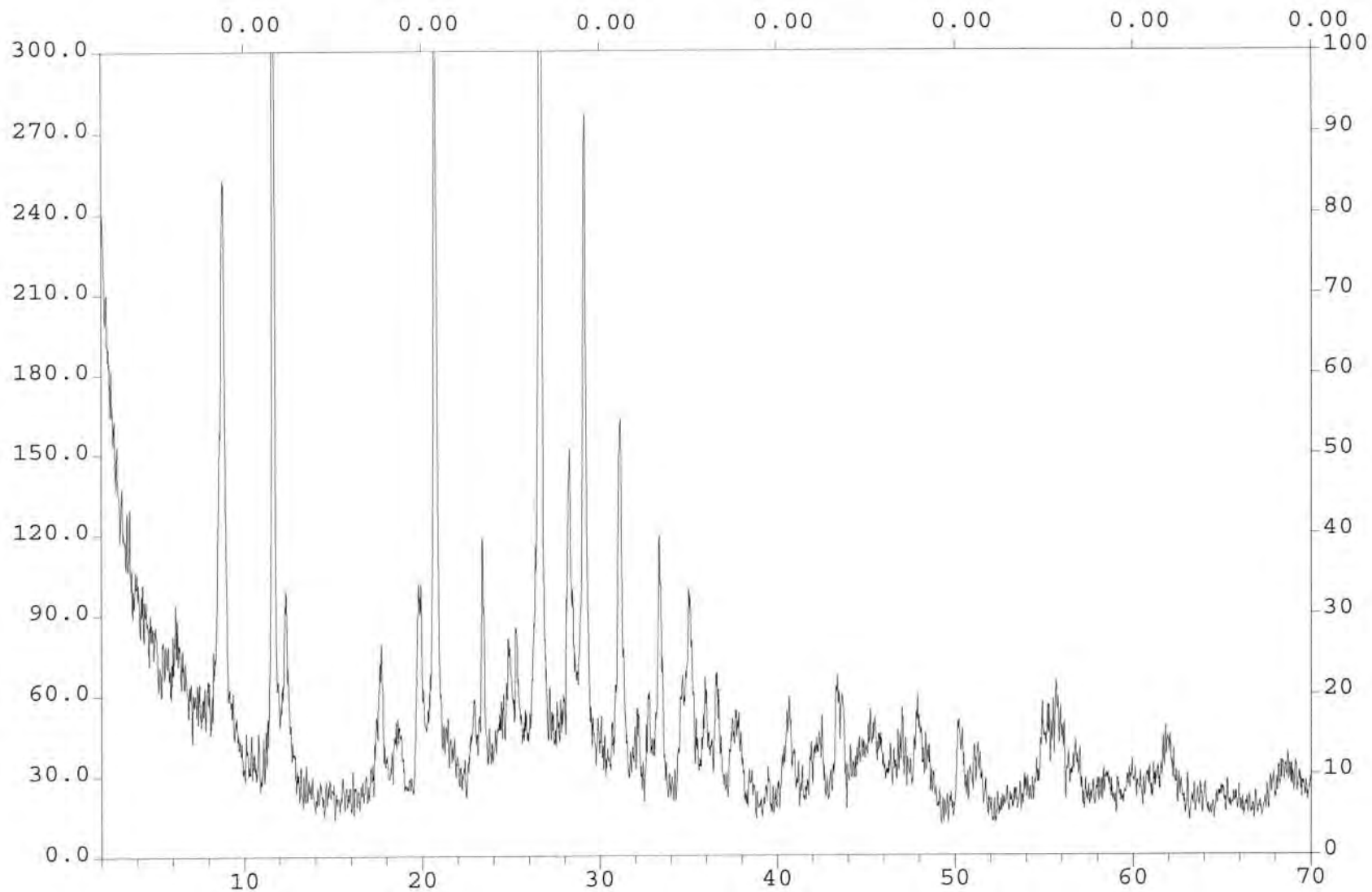
DATE: 3/12/98

TIME: 16:35

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: 52h.rd

ID: Bulk diff.

SCINTAG/USA

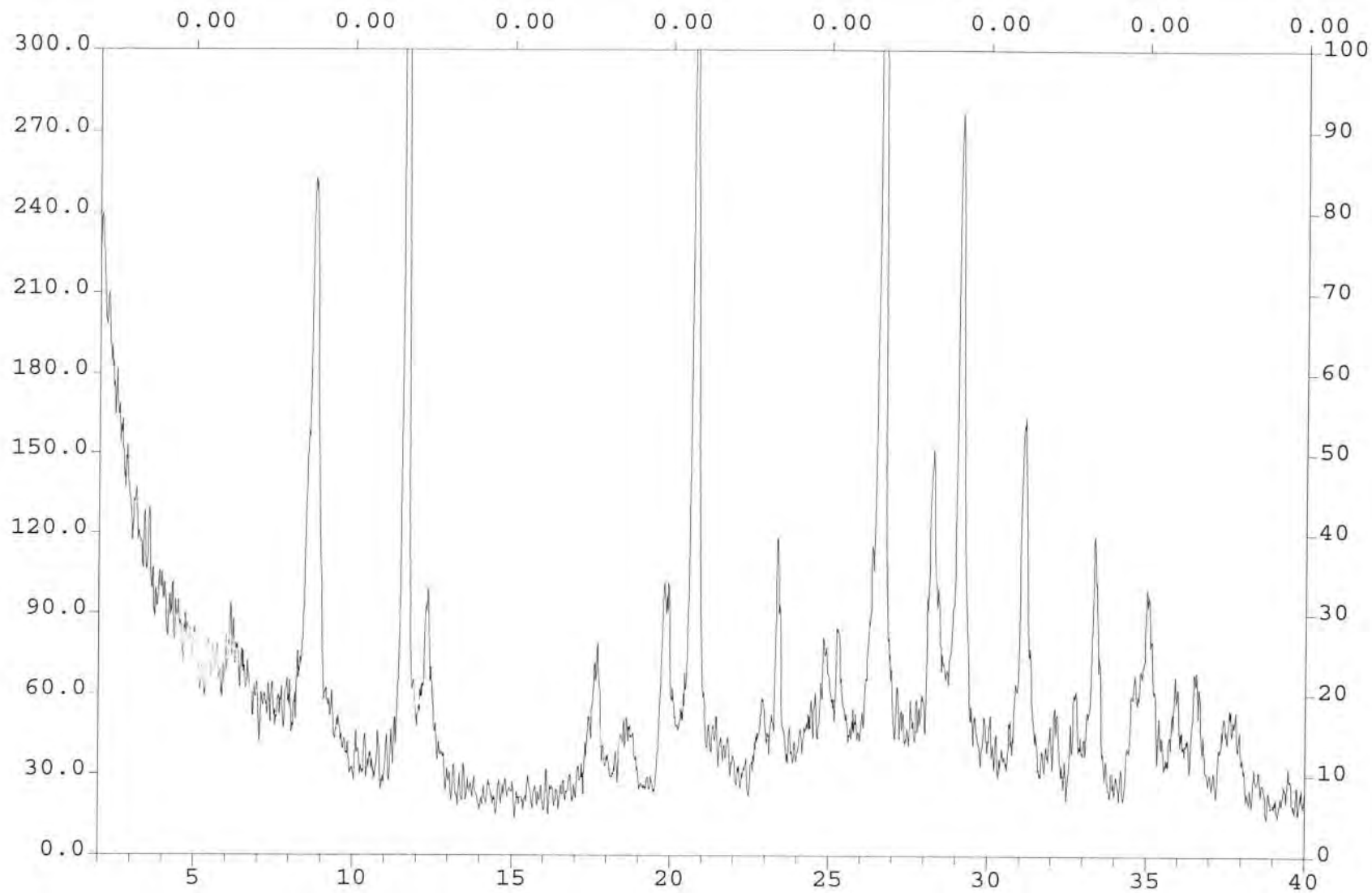
DATE: 3/12/98

TIME: 16:35

PT: -0.000

STEP: 0.020

WL: 0.00000



				d A	Int.	h k l
K Al (Si,Al) O (OH)						
0.7 2 4 10 2						
Potassium Aluminum Silicate Hydroxide				10.7	35	
Illite-1M				5.0	30	0 0 2
				4.43	100	1 1 0
				4.33	30	-1 1 1
				4.11	14	0 2 1
Rad: CuK α	Lambda: 1.5418	Filter: Ni	d-sp:			
Cutoff:	Int: Diffractometer	I/Icor: 0.7		3.66	40	-1 1 2
Ref: Brindley, G., Penn State University, University Park, Pennsylvania, USA, ICDD				3.31	35	0 0 3
Grant-in-Aid, (1977)				3.06	40	1 1 2
				2.931	16	-1 1 3
Sys: Monoclinic S.G.: C2/m (12)				2.675	12	0 2 3
a: 5.204	b: 8.950	c: 10.18	A:			
A:	B: 101.68	C:	Z: 2	2.560	85	-1 3 1
Ref: Ibid.			mp:	2.445	16	1 3 1
				2.386	25	-1 3 2
Dx: Dm: 2.60 SS/FOM: F30=3(.093,122)				2.242	12	0 4 0
				2.216	10	2 2 0
ea:	nwB:	ey:	Sign:			
Ref:			2V:	2.151	12b	-1 3 3
				2.093	8	2 2 1
				2.023	8	1 1 4
Specimen from Hungary. Mica group, dioctahedral subgroup. C.D. Cell:				1.989	12	0 0 5
a=10.180, b=8.950, c=5.204, beta=101.68, a/b=1.1374, c/b=0.5815, S.G.=A2/m				1.957	8	-1 1 5
(12). PSC: mC41.40. See original PDF Card for Graphical diffractometer trace.						
To replace 2-462 and 31-968. Volume[CD]: 464.32.				1.903	3	2 2 2
				1.820	3	0 2 5
				1.688	10	1 5 0
				1.663	12	-2 4 2
				1.631	12	-2 2 5

d A	Int.	h k l	d A	Int.	h k l	d A	Int.	h k l
1.585	4b	-2 4 3	1.292	12	1 1 7			
1.536	4b	-3 1 4						
1.496	40	3 1 2						
1.372	4b	2 2 5						
1.341	6b	1 3 6						

Strong lines: 4.43/X 2.56/9 3.66/4 3.06/4 1.50/4 10.7/4 3.31/4 5.00/3

H O)Al Si AlO (OH) 3 2 3 10 2					d Å	Int.	h k l		
Potassium Aluminum Silicate Hydroxide					10.0	90	0 0 2		
Illite-2M1					5.02	50	0 0 4		
					4.48	16	1 1 0		
					4.44	14	-1 1 1		
					3.89	8b	-1 1 3		
Rad: CoKa Lambda: 1.7902 Filter: Fe d-sp:					3.72	12	0 2 3		
Cutoff: Int: Diffractometer I/Icor:					3.46	14b	-1 1 4		
Ref: Sekino et al., Neues Jahrb. Mineral., Monatsh., 189 (1973)					3.34	100	0 0 6		
					3.20	16	1 1 4		
Sys: Monoclinic S.G.: C2/c (15)					2.988	18b	0 2 5		
a: 5.19 b: 9.00 c: 20.16 A: C:					2.867	12b	1 1 5		
A: B: 95.18 C: Z: 4 mp:					2.799	12	-1 1 6		
Ref: Ibid.					2.558	12b	1 3 1		
Dx: 2.82 Dm: 2.79 SS/FOM: F18=2(.082,148)					2.509	8	0 0 8		
					2.463	8	-1 3 3		
ea: 1.579 nwB: 1.602 ey: 1.618 Sign: - 2V: 37 deg.					2.241	4	2 2 0		
Ref: Ibid.					2.005	50	1 3 6		
Color: White					1.499	14	-3 3 1		
Specimen from Tanakami-yama pegmatite, Shiga Prefecture, Japan. Chemical analysis (wt.%): SiO2 45.67, Al2O3 36.88, MnO 0.82, K2O 8.90, H2O 6.78, F 0.64, minor Na2O, FeO, Fe2O3. Density calculated for K1 no H3O. 2M1 structure. Mica group, dioctahedral subgroup. C.D. Cell: a=20.160, b=9.000, c=5.190, beta=95.18, a/b=2.2400, c/b=0.5767, S.G.=A2/a (15). Si used as internal standard. PSC: mC84. To replace 9-334 and 15-603. Volume[CD]: 937.83.									

Strong lines: 3.34/X 10.0/9 5.02/5 2.01/5 2.99/2 4.48/2 3.20/2 4.44/1

		d Å	Int.	h k l
(Mg,Fe,Al) (Si,Al) O (OH)				
6 4 10 8				
Magnesium Aluminum Iron Silicate Hydroxide		14.2	60	0 0 1
Clinochlore-1Mia, ferroan		7.1	100	0 0 2
		4.73	40	0 0 3
		4.63	10	0 2 0
		3.55	80	0 0 4
Rad: FeKα	Lambda: 1.9373	Filter:	d-sp: D.S. -114.6	
Cutoff:	Int: Visual	I/Icor:		
Ref: Bailey, Brown, Am. Mineral., 47 819 (1962)		2.84	30	0 0 5
		2.66	40	1 1 4
		2.59	5	1 3 1
		2.55	10	-1 3 2
		2.395	60	-1 3 3
Sys: Monoclinic	S.G.: C2/m (12)			
a: 5.32	b: 9.29	c: 14.2	A:	C:
A:	B: 97.00	C:	Z: 2	mp:
Ref: Ibid.		2.270	10	1 3 3
		2.070	5	1 3 4
		2.010	30	1 1 6
Dx: 2.98 Dm:		1.890	5	1 3 5
SS/FOM: F22=1(.132,142)		1.760	5	0 0 8
ea: 1.615(4) nwB: 1.62(5) ey: 1.62(5) Sign: +/- 2V: 20-60 deg.		1.670	25	-1 5 3
Ref: Ibid.		1.570	10	0 0 9
		1.549	60	0 6 0
Color: Green, white, yellow, pink, red, brown		1.515	30	2 4 4
Specimen from Bicar mine, Michigan, USA. Composition deduced from Shirozu graphs of spacing vs. composition.		1.472	10	0 6 3
(Mg _{2.6} Fe _{2.2} Al _{1.2})Si _{2.8} Al _{1.2} O ₁₀ (OH) ₈ . Chlorite group,		1.439	5	2 2 7
tri/trioctahedral subgroup. C.D. Cell: a=14.200, b=9.290, c=5.320, beta=97.00,		1.420	30	0 6 4
a/b=1.5285, c/b=0.5727, S.G.=A2/m (12). PSC: mC72. Volume[CD]: 696.57.				

Strong lines: 7.10/X 3.55/8 14.2/6 2.40/6 1.55/6 4.73/4 2.66/4 2.84/3

		d Å	Int.	h k l
,Al) (Si,Al) O (OH)				
6 4 10 8				
Magnesium Aluminum Iron Silicate Hydroxide		14.4	60	0 0 1
Clinochlore-1M1b, ferroan		7.15	100	0 0 2
		4.79	40	0 0 3
		4.63	40	0 2 0
		3.59	70	0 0 4
Rad: FeKα	Lambda: 1.9373			
Cutoff:	Int: Visual			
Ref: Bailey, Brown, Am. Mineral., 47 819 (1963)	Filter:			
	d-sp: D.S. -114.6			
		2.87	25	0 0 5
		2.68	40	1 1 4
		2.61	15	1 3 1
		2.55	5	-1 3 2
		2.475	60	1 3 2
Sys: Monoclinic	S.G.: C2/m (12)			
a: 5.32	b: 9.29	c: 14.35	A:	C:
A:	B: 97.00	C:	Z: 2	mp:
Ref: Ibid.				
Dx: 2.92	Dm:			
	SS/FOM: F23=1(.157,144)			
ea: 1.57-1.66 nwB: 1.57-1.67 ey: 1.57-1.67 Sign: +/- 2V: 20-60 deg.				
Ref: Deer, W., Howie, R., Zussman, J., Rock Forming Minerals, 3 131				
		2.010	10	-1 3 5
		1.910	5	
		1.758	20	1 5 0
		1.740	10	-3 1 1
		1.548	60	1 5 4
Color: Green, white, yellow, pink, red, brown				
Specimen from New Britain, Connecticut, USA. Composition deduced from Shirozu graphs of spacing vs. composition. Composition deduced from Shirozu graphs of spacing vs. composition.				
(Mg _{3.13} Fe _{2.00} Al _{0.87})Si _{3.3} Al _{0.70} 10(OH) ₈ . Chlorite group,		1.515	30	0 6 2
tri/trioctahedral subgroup. C.D. Cell: a=14.350, b=9.290, c=5.320, beta=97.00,		1.478	10	0 6 3
a/b=1.5447, c/b=0.5727, S.G.=A2/m (12). PSC: mC72. Mwt: 618.86. Volume[CD]:		1.434	5	2 4 5
703.93.		1.420	10	0 6 4

Strong lines: 7.15/X 3.59/7 14.4/6 2.48/6 1.55/6 4.79/4 4.63/4 2.68/4

				d A	Int.	h k l
(Mg,Fe,Al) (Si,Al) O (OH)						
6 4 10 8						
Magnesium Iron Aluminum Silicate Hydroxide				14.1	90	0 0 1
Clinochlore-1MIb, ferrian				7.07	100	0 0 2
				4.726	30	0 0 3
				4.570	20b	1 1 0
				3.541	60	0 0 4
Rad: CoKa	Lambda: 1.7902	Filter: Fe	d-sp: D.S. -114.6			
Cutoff:	Int:	I/Icor:		2.845	30	
Ref: Gillery, Coll. of Min. Ind., Penn State Univ., University Park, Pennsylvania, USA, Private Communication				2.642	10	1 1 4
				2.576	30	1 3 1
				2.529	30	-1 3 2
Sys: Monoclinic S.G.: C2/m (12)				2.434	30	1 3 2
a: 5.307	b: 9.192	c: 14.069	A:			
A:	B: 97.17	C:	Z: 2 mp:	2.371	20	2 0 2
Ref: Ibid.				2.254	10	-2 2 2
				2.062	5	0 4 3
Dx: 2.98 Dm: 2.96 SS/FOM: F25=1(.146,176)				1.998	20	0 0 7
				1.878	10	-2 2 5
ea: 1.670	nwB: 1.685	ey: 1.685	Sign: - 2V: 0(calc.) deg			
Ref: Orcel, Bull. Soc. Fr. Mineral. Cristallogr., 50 262 (1929)				1.818	5	2 2 4
				1.745	5b	0 0 8
				1.660	5	-2 4 3
Color: Dark brown				1.563	10	3 1 3
Specimen from Nessina, Limpopo, Transvaal, South Africa. Chemical analysis				1.532	30	0 6 0
(wt.%): SiO2 25.04, Al2O3 2.27, Fe2O3 17.95, MgO 14.95, FeO 8.36, MnO						
0.08, H2O- 0.07, H2O+ 11.35. IIb structure-Bailey, Brown, Am.				1.497	10	3 3 1
Mineral., 47 819 (1962). Chlorite group, tri/trioctahedral subgroup.				1.458	5	3 3 2
C.D. Cell: a=14.069, b=9.192, c=5.307, beta=97.17, a/b=1.5306, c/b=0.5773,				1.392	10	3 1 5
S.G.=A2/m (12). PSC: mC72. Volume[CD]: 680.95.				1.349	5	-2 2 9
				1.317	5	4 0 0

d A	Int.	h k l	d A	Int.	h k l	d A	Int.	h k l
1.288	5	2 6 2						

Strong lines: 7.07/X 14.1/9 3.54/6 4.73/3 2.85/3 2.58/3 2.53/3 2.43/3

				d Å	Int.	h k l		
J,Fe) (Si,Al) O (OH)								
6 4 10 8								
Iron Magnesium Aluminum Silicate Hydroxide				14.1	35	0	0	1
Clinochlore-1MI1b, ferroan				7.07	100	0	0	2
				4.71	30	0	0	3
				4.64	2	0	2	0
				3.54	60	0	0	4
Rad: CuKa	Lambda: 1.5418	Filter: Ni	d-sp:					
Cutoff:	Int: Diffractometer	I/Icor:		2.828	15	0	0	5
Ref: Post, J., Plummer, Clays Clay Miner., 20 271 (1972)				2.597	9	-2	0	2
				2.558	6	2	0	1
				2.453	6	1	3	2
				2.387	6	-1	3	3
Sys: Monoclinic	S.G.: C2/m (12)							
a: 5.36	b: 9.28	c: 14.2	A:	C:				
A:	B: 97.15	C:	Z: 2	mp:				
Ref: McMurphy, Z. Kristallogr., Kristallgeom., Kristallphys., Kristallchem., 88 420 (1934)				2.357	1	0	0	6
				2.263	5	1	3	3
				2.070	2	1	3	4
Dx: 2.95 Dm: 2.91 SS/FOM: F26=3(.051,152)				2.020	3	0	0	7
				2.006	9	2	0	4
ea:	nwB:	ey:	Sign:	2V:				
Ref:								
				1.886	5	-2	2	5
				1.823	3	2	0	5
				1.748	1	-2	4	0
				1.727	2	-2	4	2
				1.661	3	2	0	6
Specimen from Flagstaff Hill, El Dorado County, California, USA. Chemical analysis (wt.%): SiO2 25.8, Al2O3 18.3, Fe2O3 4.1, FeO 21.3, MgO 20.3, H2O 8.7. Powder sample very loosely packed to minimize preferred orientation effect. Variety ripidolite. Chlorite group, tri/trioctahedral subgroup. C.D. Cell: a=14.200, b=9.280, c=5.360, beta=97.15, a/b=1.5302, c/b=0.5776, S.G.=A2/m (12). PSC: mC72. To replace 7-76, 7-77, 7-171 and 29-862. Volume[CD]: 700.83.				1.563	7	2	2	6
				1.5477	4	-3	3	1
				1.5100	1	0	6	2
				1.4141	7	-3	3	5
				1.4010	2	0	4	8

d Å	Int.	h k l	d Å	Int.	h k l	d Å	Int.	h k l
1.3910	6	2 0 8						

Strong lines: 7.07/X 3.54/6 14.1/4 4.71/3 2.83/2 2.60/1 2.01/1 1.56/1

				d Å	Int.	h k l
CaSO ₄ · 2H ₂ O 4 2				7.63	100	0 2 0
Calcium Sulfate Hydrate				4.283	100	0 2 1
Gypsum, syn				3.799	17	0 4 0, 1 3 0
				3.172	4	1 1 1
				3.065	75	0 4 1
Rad: CuKα1	Lambda: 1.540598	Filter: Mono.	d-sp: Diff.	2.873	45	-2 2 1
Cutoff:	Int: Diffractometer	I/Icor: 1.83		2.789	10	-1 1 2
Ref: Natl. Bur. Stand. (U.S.) Monogr. 25, 17 16 (1980)				2.732	2	1 3 1
				2.685	35	1 5 0, 2 2 0
Sys: Monoclinic	S.G.: C2/c (15)			2.597	6	-1 5 1
a: 6.2845(11)	b: 15.2079(15)	c: 5.6776(7)	A: 0.4132	2.534	2	0 6 0
A:	B: 114.09(1)	C:	Z: 4	2.495	11	-2 0 2
Ref: Ibid.			mp:	2.476	1	-1 3 2
				2.452	6	0 2 2
Dx: 2.31	Dm: 2.32	SS/FOM: F30=51(.012,49)		2.406	4	-2 4 1
ea: 1.521	nwB: 1.523	ey: 1.530	Sign: +	2.291	<1	2 4 0
Ref: Winchell, A., Elements of Optical Mineralogy, 2 157 (1951)			2V: 58 deg.	2.219	15	1 5 1
				2.142	2	0 4 2
				2.086	25	-2 4 2
Color: Colorless				2.074	15	-1 5 2, -3 1 1
Pattern taken at 25 °C. Sample prepared by adding H ₂ SO ₄ to a Ca(NO ₃) ₂				2.048	6	1 1 2
solution; the precipitate was filtered out, washed in water and bottled while				2.032	<1	1 7 0
moist; the crystals were dried immediately before use with care taken to				1.992	4	-1 7 1
prevent dehydration. Preferred orientation enhances 0k0 reflections.				1.963	3	-2 6 1
Gypsum group, gypsum subgroup. Si used as internal standard. PSC: mC48. To				1.8998	16	0 8 0, 2 6 0
replace 6-46 and validated by calculated pattern 36-432. Mwt: 172.17.						
Volume[CD]: 495.37.						

d Å	Int.	h k l	d Å	Int.	h k l	d Å	Int.	h k l
1.8795	12	2 4 1	1.5119	1	-2 8 2	1.2722	<1	1 11 1
1.8650	3	-1 1 3	1.4982	<1	1 9 1	1.2674	<1	0 12 0
1.8118	13	0 6 2	1.4947	<1	-2 6 3	1.2481	3	4 6 0, -4 0 4
1.7995	6	-2 2 3	1.4591	3	-3 7 2, 0 10 1	1.2441	2	2 10 1
1.7844	9	0 8 1	1.4392	5	-4 4 1	1.2336	3	2 8 2
1.7785	12	-2 6 2	1.4354	3	3 7 0	1.2309	2	-4 2 4, 0 12 1
1.7093	1	1 5 2	1.4278	2	2 8 1, 0 6 3			
1.6846	3	0 2 3	1.4178	3	-2 0 4			
1.6640	6	-2 4 3	1.4015	2	-4 2 3			
1.6456	4	2 6 1	1.3657	5	2 6 2, -2 10 1			
1.6209	9	-2 8 1, 1 9 0	1.3440	1	1 11 0, 2 10 0			
1.6005	1	-1 9 1	1.3324	2	-1 11 1			
1.5846	4	2 8 0	1.3262	4	-2 8 3			
1.5327	2	0 8 2	1.3234	4	-4 6 2			
1.5209	1	0 10 0, -4 2 2	1.2785	1	0 8 3			

Strong lines: 7.63/X 4.28/X 3.07/8 2.87/5 2.69/4 2.09/3 3.80/2 1.90/2

				d Å	Int.	h k l
SiO ₂						
2						
Silicon Oxide				4.257	22	1 0 0
Quartz, syn				3.342	100	1 0 1
				2.457	8	1 1 0
				2.282	8	1 0 2
				2.237	4	1 1 1
Rad: CuKα	Lambda: 1.540598	Filter: Mono.	d-sp: Diff.	2.127	6	2 0 0
Cutoff:	Int: Diffractometer	I/I _{cor} : 3.6		1.9792	4	2 0 1
Ref: Natl. Bur. Stand. (U.S.) Monogr. 25, 18 61 (1981)				1.8179	14	1 1 2
				1.8021	<1	0 0 3
				1.6719	4	2 0 2
Sys: Hexagonal	S.G.: P3221 (154)			1.6591	2	1 0 3
a: 4.9133(2)	b:	c: 5.4053(4)	A:	1.6082	<1	2 1 0
A:	B:	C:	Z: 3	1.5418	9	2 1 1
Ref: Ibid.			mp:	1.4536	1	1 1 3
				1.4189	<1	3 0 0
Dx: 2.65	Dm: 2.66	SS/FOM: F30=77(.013,31)		1.3820	6	2 1 2
ea:	nwB: 1.544	ey: 1.553	Sign: + 2V:	1.3752	7	2 0 3
Ref: Swanson, Fuyat, Natl. Bur. Stand. (U.S.), Circ. 539, 3 24 (1954)				1.3718	8	3 0 1
				1.2880	2	1 0 4
				1.2558	2	3 0 2
Color: Colorless				1.2285	1	2 2 0
Pattern taken at 25 C. Sample from the Glass Section at NBS, Gaithersburg, Maryland, USA, ground single-crystals of optical quality. Pattern reviewed by Holzer, J., McCarthy, G., North Dakota State University, Fargo, North Dakota, USA, ICDD Grant-in-Aid (1990). Agrees well with experimental and calculated patterns. O ₂ Si type. Quartz group. Also called: silica. Si used as internal standard. PSC: hP9. To replace 5-490 and validated by calculated pattern. Plus 6 additional reflections to 0.9089. Mwt: 60.08. Volume[CD]: 113.00.				1.1999	2	2 1 3
				1.1978	1	2 2 1
				1.1843	3	1 1 4
				1.1804	3	3 1 0

d Å	Int.	h k l	d Å	Int.	h k l	d Å	Int.	h k l
1.1532	1	3 1 1	1.0476	1	1 0 5	0.9873	1	3 1 3
1.1405	<1	2 0 4	1.0438	<1	4 0 1	0.9783	<1	3 0 4
1.1143	<1	3 0 3	1.0347	<1	2 1 4	0.9762	1	3 2 0
1.0813	2	3 1 2	1.0150	1	2 2 3	0.9636	<1	2 0 5
1.0635	<1	4 0 0	0.9898	1	4 0 2			

Strong lines: 3.34/X 4.26/2 1.82/1 1.54/1 2.46/1 2.28/1 1.37/1 1.38/1

				d Å	Int.	h k l		
CaSO ₄ 12H ₂ O 4 2				7.63	100	0	2	0
Calcium Sulfate Hydrate				4.283	100	0	2	1
Gypsum, syn				3.799	17	0	4	0, 1 3 0
				3.172	4	1	1	1
				3.065	75	0	4	1
Rad: CuKα	Lambda: 1.540598	Filter: Mono.	d-sp: Diff.	2.873	45	-2	2	1
Cutoff:	Int: Diffractometer	I/Icor: 1.83		2.789	10	-1	1	2
Ref: Natl. Bur. Stand. (U.S.) Monogr. 25, 17 16 (1980)				2.732	2	1	3	1
				2.685	35	1	5	0, 2 2 0
				2.597	6	-1	5	1
Sys: Monoclinic	S.G.: C2/c (15)			2.534	2	0	6	0
a: 6.2845(11)	b: 15.2079(15)	c: 5.6776(7)	A: 0.4132	2.495	11	-2	0	2
A:	B: 114.09(1)	C:	Z: 4	2.476	1	-1	3	2
Ref: Ibid.			mp:	2.452	6	0	2	2
				2.406	4	-2	4	1
Dx: 2.31	Dm: 2.32	SS/FOM: F30=51(.012,49)		2.291	<1	2	4	0
ea: 1.521	nwB: 1.523	ey: 1.530	Sign: +	2.219	15	1	5	1
Ref: Winchell, A., Elements of Optical Mineralogy, 2 157 (1951)			2V: 58 deg.	2.142	2	0	4	2
				2.086	25	-2	4	2
Color: Colorless				2.074	15	-1	5	2, -3 1 1
Pattern taken at 25 C. Sample prepared by adding H ₂ SO ₄ to a Ca(NO ₃) ₂ solution; the precipitate was filtered out, washed in water and bottled while moist; the crystals were dried immediately before use with care taken to prevent dehydration. Preferred orientation enhances 0k0 reflections.				2.048	6	1	1	2
Gypsum group, gypsum subgroup. Si used as internal standard. PSC: mC48. To replace 6-46 and validated by calculated pattern 36-432. Mwt: 172.17.				2.032	<1	1	7	0
Volume[CD]: 495.37.				1.992	4	-1	7	1
				1.963	3	-2	6	1
				1.8998	16	0	8	0, 2 6 0

d Å	Int.	h k l	d Å	Int.	h k l	d Å	Int.	h k l
1.8795	12	2 4 1	1.5119	1	-2 8 2	1.2722	<1	1 11 1
1.8650	3	-1 1 3	1.4982	<1	1 9 1	1.2674	<1	0 12 0
1.8118	13	0 6 2	1.4947	<1	-2 6 3	1.2481	3	4 6 0, -4 0 4
1.7995	6	-2 2 3	1.4591	3	-3 7 2, 0 10 1	1.2441	2	2 10 1
1.7844	9	0 8 1	1.4392	5	-4 4 1	1.2336	3	2 8 2
1.7785	12	-2 6 2	1.4354	3	3 7 0	1.2309	2	-4 2 4, 0 12 1
1.7093	1	1 5 2	1.4278	2	2 8 1, 0 6 3			
1.6846	3	0 2 3	1.4178	3	-2 0 4			
1.6640	6	-2 4 3	1.4015	2	-4 2 3			
1.6456	4	2 6 1	1.3657	5	2 6 2, -2 10 1			
1.6209	9	-2 8 1, 1 9 0	1.3440	1	1 11 0, 2 10 0			
1.6005	1	-1 9 1	1.3324	2	-1 11 1			
1.5846	4	2 8 0	1.3262	4	-2 8 3			
1.5327	2	0 8 2	1.3234	4	-4 6 2			
1.5209	1	0 10 0, -4 2 2	1.2785	1	0 8 3			

Strong lines: 7.63/X 4.28/X 3.07/8 2.87/5 2.69/4 2.09/3 3.80/2 1.90/2

(OH)	d A	Int.	h k l
Iron Oxide Hydroxide	4.98	12	0 2 0
	4.183	100	1 1 0
	3.383	10	1 2 0
Goethite	2.693	35	1 3 0
	2.583	12	0 2 1
Rad: CoKa Lambda: 1.7902 Filter: d-sp:			
Cutoff: Int: Diffractometer I/Icor:	2.527	4	1 0 1
Ref: Harrison, R. et al., Bull. Geol. Surv. G.B., 52 51 (1975)	2.489	10	0 4 0
	2.450	50	1 1 1
	2.303	1	2 0 0
Sys: Orthorhombic S.G.: Pbnm (62)	2.253	14	1 2 1
a: 4.608 b: 9.956 c: 3.0215 A: 0.4628 C: 0.3035			
A: B: C: Z: 4 mp:	2.190	18	1 4 0
Ref: Ibid.	2.089	1	2 2 0
	2.011	2	1 3 1
Dx: 4.26 Dm: 4.00 SS/FOM: F30=47(.015,41)	1.920	5	0 4 1
	1.802	6	2 1 1
ea: 2.260 nwB: 2.393 ey: 2.398 Sign: - 2V: 15(15) deg.			
Ref: Dana's System of Mineralogy, 7th Ed., I 680	1.7728	1	1 4 1
	1.7192	20	2 2 1
	1.6906	6	2 4 0
Color: Dark brown	1.6593	3	0 6 0
Specimen from Hindlow quarry, Derbyshire, England, UK (E35891). Chemical	1.6037	4	2 3 1
analysis (%): SiO2 1.84, Fe2O3 86.30, H2O (>105C) 10.79, H2O (<105C) 0.86,			
and minor MgO, CaO, CO2, and organic C. Lead nitrate used as internal	1.5637	10	1 5 1
standard (a=7.8568). Dx for Fe3.88Six(OH)4.3103.69 (x <= 0.012),	1.5614	8	1 6 0
formula from chemical analysis with impurities deducted. Opaque mineral	1.5091	8	0 0 2
optical data on specimen from Restornel, Cornwall, England, UK: R1Ro=17.5,	1.4675	2	3 2 0
RR2Re=15.6, Disp.=16, VHN=667 (mean at 100, 200, 300), Color values=1 .291,	1.4541	5	0 6 1
.296, 17.5, 2 .294, .299, 15.5, Ref.: IMA Commission on Ore Microscopy QDF,			
Diaspore group. PSC: oP16. To replace 17-536. Mwt: 88.85. Volume[CD]:			
138.62.			

d A	Int.	h k l	d A	Int.	h k l	d A	Int.	h k l
1.4207	2	1 1 2	1.3173	3	1 3 2	1.1506	1	0 8 1
1.3936	3	3 3 0	1.2921	<1	0 4 2	1.1445	1	4 1 0
1.3694	2	3 0 1	1.2654	1	3 3 1	1.1263	1	2 4 2
1.3590	3	1 7 0	1.2437	1	1 4 2			
1.3459	1	2 6 0	1.1994	1	3 4 1			

Strong lines: 4.18/X 2.45/5 2.69/4 1.72/2 2.19/2 2.25/1 4.98/1 2.58/1

				d Å	Int.	h k l		
TiO ₂								
Titanium Oxide				3.247	100	1	1	0
Rutile, syn				2.487	50	1	0	1
				2.297	8	2	0	0
				2.188	25	1	1	1
				2.054	10	2	1	0
Rad: CuKα1	Lambda: 1.54056	Filter: Mono.	d-sp:	1.6874	60	2	1	1
Cutoff:	Int: Diffractometer	I/Icor: 3.40		1.6237	20	2	2	0
Ref: Natl. Bur. Stand. (U.S.) Monogr. 25, (1969)				1.4797	10	0	0	2
				1.4528	10	3	1	0
				1.4243	2	2	2	1
Sys: Tetragonal	S.G.: P42/mnm (136)			1.3598	20	3	0	1
a: 4.5933	b:	c: 2.9592	A:	1.3465	12	1	1	2
A:	B:	C:	Z: 2	1.3041	2	3	1	1
Ref: Ibid.			mp:	[1.2739]	1	[3	2	0]
Dx: 4.25	Dm: 4.23	SS/FOM: F30=107(.009,32)		1.2441	4	2	0	2
ea: 2.9467	nwB: 2.6505	ey:	Sign: + 2V:	1.2006	2	2	1	2
Ref: Dana's System of Mineralogy, 7th Ed., I 575				1.1702	6	3	2	1
				1.1483	4	4	0	0
Color: Reddish brown				1.1143	2	4	1	0
Pattern taken at 25 C. Sample obtained from National Lead Co., South Amboy, New Jersey, USA. No impurity over 0.001%. Two other polymorphs anatase (tetragonal) and brookite (orthorhombic) converted to rutile on heating above 700 C. Optical data on specimen from Dana's System of Mineralogy, 7th Ed., I 555. Opaque mineral optical data on specimen from Sweden: R3R=20.3, Disp.=Std., VHN100=1132-1187, Ref.: IMA Commission on Ore Microscopy QDF. Pattern reviewed by Syvinski, W., McCarthy, G., North Dakota State University, Fargo, North Dakota, USA, ICDD Grant-in-Aid (1990). Agrees well with experimental and calculated patterns. Additional weak reflections [indicated by brackets] were observed. O2Ti type. Rutile group, rutile subgroup. Also called: titania. W used as internal standard. PSC: tP6. Validated by calculated pattern. Mwt: 79.90. Volume[CD]: 62.43.				1.0936	8	2	2	2
				1.0827	4	3	3	0
				1.0425	6	4	1	1
				1.0364	6	3	1	2
				1.0271	4	4	2	0
				[1.0167]	<1	[3	3	1]

d Å	Int.	h k l	d Å	Int.	h k l	d Å	Int.	h k l
0.9703	2	4 2 1	0.8892	8	2 1 3	0.8196	12	5 2 1
0.9644	2	1 0 3	0.8774	8	4 3 1	0.8120	2	4 4 0
0.9438	2	1 1 3	0.8738	8	3 3 2	0.7877	2	5 3 0
0.9072	4	4 0 2	0.8437	6	4 2 2			
0.9009	4	5 1 0	0.8292	8	3 0 3			

Strong lines: 3.25/X 1.69/6 2.49/5 2.19/3 1.62/2 1.36/2 1.35/1 0.82/1

					d A	Int.	h k l		
.sO 13.5H O 4 2									
Iron Arsenate Hydrate					12.8	100	-1	1	0
Kankite					8.78	5	0	2	0
					7.56	25	0	0	1
					7.22	20	-1	0	1
					6.97	19	1	0	1
Rad: CoKa Lambda: 1.7902 Filter: d-sp: Guinier									
Cutoff: Int: Visual I/Icor:					6.39	7	-2	2	0
Ref: Cech, F. et al., Neues Jahrb. Mineral., Monatsh., 426 (1976)					5.62	6	1	3	0
					5.36	2b	1	2	1
					5.03	11b	-2	2	1
					4.95	6	2	3	0
Sys: Monoclinic S.G.: P									
a: 18.803 b: 17.490 c: 7.633 A: 1.0751 C: 0.4364					4.764	35	-3	1	1
A: B: 92.71 C: Z: 16 mp:					4.590	5	3	1	1
Ref: Ibid.					4.525	11	-1	3	1
Dx: 2.73 Dm: 2.70 SS/FOM: F30=5(.054,123)					4.470	6	1	3	1
					4.368	13	0	4	0
ea: nwB: 1.666 ey: Sign: 2V:									
Ref: Ibid.					4.258	25	-1	4	0
					4.149	2	3	2	1
Color: Yellowish green					4.084	2	-4	0	1
Specimen from old dumps (13th to 15th century) near Kank, Kutna Hora district, Czechoslovakia. Chemical analysis (wt.%): As2O5 43.92, Fe2O3 31.84, H2O+ 13.91, H2O- 9.91; and trace amounts of SO3, CaO and insoluble.					3.969	1b	2	4	0
*Admixture of quartz.					3.807	3b	0	0	2
Si used as internal standard. PSC: mP264. Mwt: 257.82. Volume[CD]: 2507.42.					3.697	20b	1	4	1
					3.484	7b	2	4	1
					3.414	13b	1	2	2
					3.345*	16	-4	3	1
					3.250	13	5	1	1

d A	Int.	h k l	d A	Int.	h k l	d A	Int.	h k l
3.187	16b	3 0 2	2.553	20	6 3 1	2.161	4	-2 4 3
3.061	3	-2 3 2	2.520	20	0 1 3	2.141	5	-5 1 3
3.004	4	3 2 2	2.426	5b	2 0 3	2.126	5	4 2 3
2.948	7	6 2 0	2.374	9	0 7 1	2.053	4	4 6 2
2.904	11	-6 1 1	2.346	3	8 0 0	2.025	3	-2 5 3
2.854	8	4 1 2	2.297	5	3 1 3	2.002	6	-3 8 1
2.763	11b	6 3 0	2.281	9	-4 0 3			
2.734	7	-5 0 2	2.261	7	-4 1 3			
2.683	7	7 0 0	2.229	5b	4 5 2			
2.630	30	-6 3 1	2.187	4	5 6 1			

Strong lines: 12.8/X 4.76/4 2.63/3 7.56/3 4.26/3 7.22/2 3.70/2 2.55/2

				d Å	Int.	h k l		
FeAsO 12H ₂ O 4 2				5.609	80	1	1	1
Iron Arsenate Hydrate				5.164	6	0	2	0
Scorodite				5.018	35	0	0	2
				4.513*	10	0	1	2
				4.472	100b	2	0	0, 1 2 0
Rad: CuKα1	Lambda: 1.540562	Filter: Mono.	d-sp: Diff.	4.089	30	2	0	1, 1 2 1
Cutoff:	Int: Diffractometer	I/Icor:		4.033	4	1	1	2
Ref: Blanchard, F., Dept. of Geology, University of Florida, Gainesville, Florida, USA, ICDD Grant-in-Aid, (1986)				3.800	30	2	1	1
				3.383	7	2	2	0
Sys: Orthorhombic S.G.: Pcab (61)				3.339	12	1	2	2
a: 8.9516(7)	b: 10.3273(9)	c: 10.0419(7)	A:	3.178	90	2	1	2
A:	B:	C:	Z: 8 mp:	3.060	45	1	3	1
Ref: Ibid.				2.999	35	1	1	3
Dx: 3.30 Dm: 3.31 SS/FOM: F30=46(.013,49)				2.758	10	3	1	1
				2.708	4	1	3	2
ea: 1.888	nwB: 1.895	ey: 1.915	Sign: + 2V: 58 deg.	2.682	25	2	0	3, 1 2 3
Ref: Dana's System of Mineralogy, 7th Ed., II 765 (1951)				2.596	35	2	1	3
				2.582	30	3	2	0, 0 4 0
Color: Light green				2.510	20	0	0	4
Specimen from Gold Hill, Tooele County, Utah, USA. Analysis (wt.%): Fe2O3				2.501	25	3	2	1
34.13, As2O5 48.42, H2O+ 15.73, MgO 0.01, CaO 0.38, FeO 0.84, insol 0.42				2.440	1	0	1	4
Dana's System of Mineralogy, 7th Ed., II 765 (1951). X-ray				2.379	1	2	2	3
emission analysis (under SEM): Fe, As with minor to traces of Ca, Cu, Si and				2.354	1	1	1	4
Zn(?). Calculated pattern confirms indexing, Hawthorne, F., Acta				2.318	9	1	3	3
Crystallogr., Sec. B, 32 2891-2892 (1976) for crystal structure.				2.297	2	0	4	2
Refractive indices for, chemically, a very similar material (Japan) Variscite								
group, variscite subgroup. C.D. Cell: a=10.042, b=10.327, c=8.952, a/b=0.9724,								
c/b=0.8668, S.G.=Pbca (61).								
*Not always resolved from 4.472.								
&Not always resolved from 2.0047.								
Si used as internal standard. PSC: oP96. To replace 18-654, 19-603 and								
26-778. Mwt: 230.80. Volume[CD]: 928.33.								

d Å	Int.	h k l	d Å	Int.	h k l	d Å	Int.	h k l
2.257	3	0 2 4	1.7244	1	1 5 3	1.4709	1	5 4 0
2.238	6	4 0 0, 2 4 0	1.7205	<1	0 6 0	1.4607	2	6 1 1
2.225	2	1 4 2	1.6909	3	1 6 0	1.4527	3	4 5 2
2.202	3	3 3 1	1.6730	6	0 0 6	1.4450	2	3 1 6
2.186	8	1 2 4, 4 0 1	1.6678	8	5 2 1, 4 4 1	1.4405	3	1 7 1
2.177	4	3 1 3	1.6643	11	5 1 2	1.4198	1	0 6 4
2.142	6	2 1 4	1.6497	7	0 1 6, 4 1 4	1.4033	4	1 1 7, 5 2 4
2.115	5	2 3 3	1.6449	4	3 1 5	1.3825	<1	4 5 3
2.054	5	4 2 0	1.6359	4	2 5 3	1.3710	1	4 3 5, 2 5 5
2.044	4	4 0 2, 2 4 2	1.6245	2	1 1 6	1.3659	3	2 0 7, 1 2 7
2.0101&	7	4 2 1	1.6179	1	2 3 5	1.3520	2b	2 6 4, 4 6 1
2.0047	13b	4 1 2	1.6067	2	2 6 0	1.3424	2	5 3 4
1.9939	2	1 4 3	1.6021	3	4 4 2, 1 6 2	1.3346	2	1 7 3
1.9792	2	1 3 4	1.5855	6	3 2 5	1.3209	<1	6 3 2
1.9529	4	3 4 0	1.5679	3	1 2 6	1.3097	2	1 3 7
1.9254	1	1 1 5	1.5607	2	1 4 5	1.2994	2b	0 5 6, 4 5 4
1.9100	2	0 5 2	1.5496	2	2 1 6	1.2937	2	5 2 5, 4 4 5
1.8892	1	3 1 4	1.5415	1	3 4 4	1.2812	3	6 4 1
1.8689	1	1 5 2	1.5143	9	3 5 3, 5 3 2	1.2672	1b	5 4 4, 1 8 1
1.8598	2	4 0 3, 2 4 3	1.5089	2	1 6 3	1.2485	1	2 5 6
1.8441	4	2 5 1	1.5000	3b	2 2 6, 3 3 5	1.2412	2	7 2 0
1.8316	4	1 2 5, 4 1 3	1.4946	3	4 0 5	1.2317	2	7 2 1, 5 6 1
1.8002	6	3 2 4, 0 4 4	1.4916	2	6 0 0, 3 6 0	1.2103	1	3 3 7
1.7569	7	4 3 2, 2 5 2	1.4844	1	1 3 6	1.2081	1b	1 2 8, 2 4 7
1.7499	1	4 2 3	1.4754	7	6 0 1, 3 6 1	1.1974	2	6 0 5, 3 6 5

d A	Int.	h k l	d A	Int.	h k l	d A	Int.	h k l
1.897	1	6 1 5, 1 6 6	1.1313	<1	5 7 1, 6 3 5	1.1058	1b	4 7 4, 8 1 1
1.1764	<1	3 8 1	1.1284	1	4 6 5, 7 3 3	1.0944	1	2 4 8, 4 0 8
1.1660	1	7 3 2	1.1201	<1	6 6 1			
1.1520	<1	5 3 6	1.1126	1	5 1 7, 7 2 4			
1.1374	<1	6 5 3	1.1103	1	5 7 2			

Strong lines: 4.47/X 3.18/9 5.61/8 3.06/5 5.02/4 3.00/4 2.60/4 4.09/3

				d A	Int.	h k l
Al SO (OH) 136H O						
4 4 10 2						
Aluminum Sulfate Hydroxide Hydrate				12.6	100	0 0 1
Hydrobasaluminite				8.08	50	-1 1 0
				6.18	70	1 1 1
				5.29	70	2 0 1
				4.70	70	1 2 0
Rad:	Lambda:	Filter:	d-sp:			
Cutoff:	Int:	I/Icor:		4.23	60	1 2 1
Ref: Hollingsworth, Bannister, Mineral. Mag., 29 1 (1950)				4.00	60	-1 2 2
				3.73	70	-4 0 1
				3.43	50	1 1 3
				3.21	30	-1 3 1
Sys: Monoclinic S.G.: P						
a: 14.911	b: 9.993	c: 13.640	A: 1.4921 C: 1.3650	3.07	70	1 3 1
A:	B: 112.4	C:	Z: 4 mp:	2.83	40	-4 1 4
Ref: Clayton, T., Mineral. Mag., 43 931 (1980)				2.57	50	-1 1 5
				2.41	50	-6 1 2
Dx: 3.62 Dm: SS/FOM: F30=1(.036,886)				2.25	50	0 2 5
ea:	nwB:	ey:	Sign: 2V:			
Ref:				2.22	30	-5 3 2
				2.10	60	3 4 1
				2.06	30	-7 0 4
Color: White				1.96	40	0 4 4
A fully hydrated plastic mineral from Lodge Pit, Irchester, Northamptonshire, England, UK. PSC: mP548. Mwt: 1022.60. Volume[CD]: 1879.08.				1.835	60	-8 0 4
				1.793	50	-7 3 2
				1.729	40	-4 5 0
				1.680	10	2 5 3
				1.625	60	-9 1 4
				1.560	5	5 5 1

d A	Int.	h k l	d A	Int.	h k l	d A	Int.	h k l
1.500	30	-4 6 0						
1.445	50	-8 4 5						
1.408	10	1 4 7						
1.382	10	-9 1 8						
1.349	10	0 2 9						

Strong lines: 12.6/X 6.18/7 5.29/7 4.70/7 3.73/7 3.07/7 4.23/6 4.00/6

SO (OH) 14H O 4 4 10 2				d Å	Int.	h k l
Aluminum Sulfate Hydroxide Hydrate				9.387	100	-1 0 1
Basaluminite				7.338	12	1 0 1
				5.917	35	1 1 1
				5.323	18	2 1 0
				4.732	58	0 1 2
Rad: CuKα1	Lambda: 1.54051	Filter: Mono.	d-sp: Guinier			
Cutoff:	Int: Densitometer	I/Icor:		4.685	36	-2 0 2
Ref: Farkas, L., Ph.D. Thesis, Budapest, Hungary, Private Communication, (1980)				4.540	27	0 2 1
				4.419	15	2 1 1
				3.927	16	-3 1 1
				3.871	18	-2 2 1
Sys: Monoclinic	S.G.: P					
a: 12.954(5)	b: 10.004(6)	c: 11.064(8)	A: 1.2949	C: 1.1060		
A:	B: 104.10(6)	C:	Z: 4	mp:		
Ref: Ibid.				3.689	50	-1 0 3
				3.616	28	3 0 1
				3.456	19	-1 1 3
				3.441	27	2 1 2
				3.400	11	3 1 1
Dx: 2.13	Dm: 2.12	SS/FOM: F30=15(.014,149)				
ea:	nwB: 1.519	ey:	Sign: 2V:			
Ref: Hollingworth, S., Bannister, F., Mineral. Mag., 29 1 (1950)				3.225	12	1 3 0
				3.185	5	0 3 1
				2.955	13	2 2 2
				2.875	24	[-2 2 3]
				2.835	22	
Color: White						
Optical data on specimen from Irchester, Northamptonshire, England, UK. Also called: felsobanyaite. KCl used as internal standard. PSC: mP164. To replace 8-64 and 24-7. Mwt: 446.12. Volume[CD]: 1390.61.				2.721	33	2 1 3
				2.690	25	1 3 2
				2.661	11	4 2 0
				2.554	5	3 2 2
				2.502	19	1 0 4

d Å	Int.	h k l	d Å	Int.	h k l	d Å	Int.	h k l
2.462	40	4 0 2	1.8874	44	-6 2 3	1.4380	62	8 2 1
2.439	20	0 3 3	1.8427	21	-7 0 2	1.4176	25	-5 2 7
2.391	7	4 1 2	1.8013	9	4 1 4	1.1119	22	-9 0 8
2.301	13	-5 2 1	1.7807	4	-5 3 4			
2.275	39	2 0 4	1.7737	26	6 3 0			
2.245	7	5 2 0	1.6226	36	-3 4 5			
2.195	40	3 2 3	1.6069	6	-1 3 6			
2.087	16	-6 1 2	1.4850	14	-7 4 1			
2.073	30	4 1 3	1.4673	21	-3 4 6			
2.036	20	-6 0 3	1.4549	27	0 4 6			

Strong lines: 9.39/X 1.44/6 4.73/6 3.69/5 1.89/4 2.46/4 2.20/4 2.28/4

				d Å	Int.	h k l
Fe O						
2 3						
Iron Oxide				3.684	30	0 1 2
Hematite, syn				2.700	100	1 0 4
				2.519	70	1 1 0
				2.292	3	0 0 6
				2.207	20	1 1 3
Rad: CuKα1 Lambda: 1.540598 Filter: Mono. d-sp: Diff.						
Cutoff: Int: Diffractometer I/Icor: 2.4				2.0779	3	2 0 2
Ref: Natl. Bur. Stand. (U.S.) Monogr. 25, 18 37 (1981)				1.8406	40	0 2 4
				1.6941	45	1 1 6
				1.6367	1	2 1 1
				1.6033	5	1 2 2
Sys: Rhombohedral (Hex) S.G.: R-3c (167)						
a: 5.0356(1) b: c: 13.7489(7) A: C: 2.7303				1.5992	10	0 1 8
A: B: C: Z: 6 mp: 1350-1360 deg.				1.4859	30	2 1 4
Ref: Ibid.				1.4538	30	3 0 0
Dx: 5.27 Dm: 5.26 SS/FOM: F30=69(.011,39)				[1.4138]	<1	[1 2 5]
				1.3497	3	2 0 8
ea: 2.94 nwB: 3.22 ey: Sign: - 2V:						
Ref: Dana's System of Mineralogy, 7th Ed., I 529 (1944)				1.3115	10	1 0 10
				1.3064	6	1 1 9
				1.2592	8	2 2 0
				1.2276	4	3 0 6
				1.2141	2	2 2 3
Color: Dark reddish brown						
Pattern taken at 25 C. Sample from Pfizer, Inc., New York, New York, USA,				1.1896	5	1 2 8
heated at 800 C for 3 days. CAS no.: 1309-37-1. Opaque mineral optical data				1.1632	5	0 2 10
on specimen from Elba, RIR0=30.2, RR2Re=26.1, Disp.=16, VHN=1038 (mean at				1.1411	7	1 3 4
100, 200, 300), Color values=1 .299, .309, 29.8, 2 .299, .309, 25.7, Ref.:				1.1035	7	2 2 6
IMA Commission on Ore Microscopy QDF. Pattern reviewed by Syvinski, W.,				1.0768	2	0 4 2
McCarthy, G., North Dakota State University, Fargo, North Dakota, USA, ICDD						
Grant-in-Aid (1990). Agrees well with experimental and calculated patterns.						
Additional weak reflection [indicated by brackets] was observed. Al2O3 type.						
Corundum group, corundum subgroup. Also called: burnt ochre. Also called:						
colcothar. Also called: rouge. Ag used as internal standard. PSC: HR10. To						
replace 13-534 and validated by calculated pattern 24-72. Mwt: 159.69.						
Volume[CD]: 301.93.						

d Å	Int.	h k l	d Å	Int.	h k l	d Å	Int.	h k l
1.0557	7	2 1 10	0.9081	5	1 3 10			
1.0428	<1	1 1 12	0.8998	1	3 0 12			
1.0393	3	4 0 4	0.8954	3	2 0 14			
0.9892	4	3 1 8	0.8789	6	4 1 6			
0.9715	<1	2 2 9	0.8648	1	2 3 8			
0.9606	5	3 2 4	0.8543	3	4 0 10			
0.9581	4	0 1 14	0.8436	5	1 2 14			
0.9516	5	4 1 0	0.8392	3	3 3 0			
0.9318	2	4 1 3	0.8089	4	3 2 10			
0.9206	2	0 4 8	0.8014	4	2 4 4			

Strong lines: 2.70/X 2.52/7 1.69/5 1.84/4 3.68/3 1.49/3 1.45/3 2.21/2

					d Å	Int.	h k l
e (SO) (OH)							
3 4 2 6							
Potassium Iron Sulfate Hydroxide					5.93	45	1 0 1
Jarosite, syn					5.72	25	0 0 3
					5.09	70	0 1 2
					3.65	40	1 1 0
					3.55	4	1 0 4
Rad: CoKa Lambda: 1.7902 Filter: d-sp: Guinier							
Cutoff: Int: Densitometer I/Icor:					3.11	75	0 2 1
Ref: Smith, Plessey Company, Limited, Caswell, Towcaster, Northants, UK, Private Communication					3.08	100	1 1 3
					3.02	6	0 1 5
Sys: Rhombohedral (Hex) S.G.: R-3m (166)					2.965	15	2 0 2
a: 7.29 b: c: 17.16 Å: C: 2.3539					2.861	30	0 0 6
A: B: C: Z: 3 mp:							
Ref: Ibid.					2.542	30	0 2 4
					2.368	4	2 1 1
Dx: 3.16 Dm: 2.91 SS/FOM: F30=20(.038,40)					2.302	12	1 2 2
					2.287	40	1 0 7
					1.977	45	3 0 3
ea: 1.715 nwB: 1.820 ey: Sign: 2V:							
Ref: Dana's System of Mineralogy, 7th Ed., II					1.937	10	0 2 7
					1.909	8	0 0 9
Color: Yellow, brown					1.825	45	2 2 0
Heated 170 C for 24 hours in sealed tube. Fe2(SO4)3 + K2SO4 + H2SO4.					1.776	6	2 0 8
Occurs as mineral at Meadow Valley 1, Pioche, Nevada, USA, with a=7.304,					1.738	6	2 2 3
c=17.268, S.G.=R-3m (166), Dx=3.158, Kato, T., Miura, Mineral. J. Japan,							
8 419 (1977). Alunite group, alunite subgroup. PSC: hR26. To replace					1.717	6	3 1 2
10-443. Mwt: 500.80. Volume[CD]: 789.77.					1.690	2	1 1 9
					1.656	2	1 0 10
					1.621	6	1 3 4
					1.595	6	1 2 8

d Å	Int.	h k l	d Å	Int.	h k l	d Å	Int.	h k l
1.572	4	4 0 1	1.412	4	3 0 9			
1.560	6	3 1 5	1.399	4	2 0 11			
1.552	6	0 4 2	1.379	4	4 1 0			
1.536	20	2 2 6	1.338	12	4 1 3			
1.507	20	0 2 10	1.326	2	4 0 7			
1.480	8	4 0 4	1.314	2	2 2 9			
1.442	4	3 2 1	1.287	2	1 0 13			
1.432	4	0 4 5						
1.428	4	2 3 2						
1.423	4	1 3 7						

Strong lines: 3.08/X 3.11/8 5.09/7 5.93/5 1.98/5 1.83/5 3.65/4 2.29/4

		d A	Int.	h k l
Ni (AsO) 1H O 3 4 2 2				
Nickel Arsenate Hydrate		11.0	10	1 0 0
		6.36	70	0 1 0
		4.57	60	1 0 1
		3.711	70	2 0 1
		3.672	70	3 0 0
Rad:	Lambda:	Filter:	d-sp:	
Cutoff:	Int: Visual	I/Icor:		
Ref: Palazzi, M., Guerin, Bull. Soc. Chim. Fr., I119 (1978)		3.206	100	2 1 1
		3.183	60	3 1 0
		2.964	10	3 0 1
		2.754	70	4 0 0
		2.612	50	1 2 1
Sys: Orthorhombic S.G.: P2221 (17)				
a: 11.02	b: 6.37	c: 5.02	A:	C:
A:	B:	C:	Z: 2	mp:
Ref: Ibid.		2.527	10	4 1 0
		2.508	90	0 0 2
		2.448	10	1 0 2
Dx: 4.448 Dm: 4.440 SS/FOM: F30=30(.016,63)		2.416	90	4 0 1
		2.334	70	0 1 2
ea:	nwB:	ey:	Sign:	2V:
Ref:		2.258	40	4 1 1
		2.203	10	5 0 0
		2.148	40	2 1 2
Made by heating Ni3(AsO4)2·8H2O in a sealed tube at 200 C.		2.072	20	3 0 2
Co3(AsO4)2·H2O type. C.D. Cell: a=6.370, b=11.020, c=5.020, a/b=0.5780,		2.018	10	5 0 1
c/b=0.4555. PSC: oP32. Mwt: 471.95. Volume[CD]: 352.39.				
		1.971	10	3 1 2
		1.923	20	5 1 1
		1.855	60	4 0 2
		1.841	60	2 3 1
		1.781	80	4 1 2

d A	Int.	h k l	d A	Int.	h k l	d A	Int.	h k l
1.725	10	6 0 1	1.618	60	0 1 3	1.468	10	1 2 3
1.705	10	5 2 1	1.603	10	5 1 2	1.461	10	3 4 0
1.680	10	4 3 0	1.591	50	6 2 0	1.444	10	6 1 2
1.665	70	6 1 1	1.554	70	2 1 3	1.430	60	4 0 3
1.655	10	1 0 3	1.502	10	7 0 1	1.396	10	4 1 3

Strong lines: 3.21/X 2.51/9 2.42/9 1.78/8 6.36/7 3.71/7 3.67/7 2.75/7

	d A	Int.	h k l
1,Mg) (AsO) 18H O 3 4 2 2			
Magnesium Nickel Arsenate Hydrate	7.929	35	1 1 0
Annabergite, magnesian	6.676	100	0 2 0
	4.924	10	2 0 0
	4.571	4	0 0 1
	4.364	30	-1 1 1
Rad: CuK α Lambda: 1.5418 Filter: Ni d-sp: Diff.			
Cutoff: Int: Diffractometer I/Icor:	4.046	10	1 3 0
Ref: Giuseppetti, G., Tadini, Bull. Mineral., 105 333 (1982)	3.964	5	2 2 0
	3.887	20	-2 0 1
	3.639	3	1 1 1
Sys: Monoclinic S.G.: C2/m (12)	3.333	30	0 4 0
a: 10.211(6) b: 13.335(3) c: 4.728(3) A: C:			
A: B: 104.97 C: Z: 2 mp:	3.203	95	-1 3 1
Ref: Ibid.	2.988	45	2 0 1
	2.759	10	2 4 0
Dx: 3.08 Dm: 3.11 SS/FOM: F30=11(.041,66)	2.724	30	2 2 1
	2.695	40	0 4 1
ea: nwB: ey: Sign: 2V:			
Ref:	2.642	20	3 3 0
	2.531	15	-2 4 1
	2.447	14	-4 0 1
Color: Light yellowish green	2.308	35	-1 5 1
Specimen from Laurium, Greece. Microprobe analysis (wt.%): NiO 30.80, MgO 4.04, As ₂ O ₅ 39.00, H ₂ O (by difference) 26.03, minor FeO, trace CoO:	2.223	10	2 4 1, 0 6 0
(Ni _{2.2} Mg _{0.7} Fe _{0.1})(AsO ₄) ₂ ·8H ₂ O. Dm, on cabrerite from Laurium, Greece, by Des Cloizeaux, A., Damour, Bull. Soc. Fr. Mineral. Cristallogr., 1 75 (1978). Validated by a calculated pattern.	2.174	15	1 5 1
Vivianite group, vivianite subgroup. C.D. Cell: a=10.084, b=13.335, c=4.728, beta=101.96, a/b=0.7562, c/b=0.3546, S.G.=I2/m (12). PSC: mC74. To replace 34-162. Volume[CD]: 621.93.	2.070	12	3 5 0
	2.026	4	2 6 0
	1.998	3	0 6 1
	1.973	3	-4 4 1

d A	Int.	h k l	d A	Int.	h k l	d A	Int.	h k l
1.943	5	5 1 0	1.760	8	-1 7 1			
1.904	7	1 3 2	1.665	45	0 8 0			
1.879	15	[0 4 2]	1.650	15	5 1 1, 2 4 2			
1.828	2	-5 3 1	1.601	7	-5 5 1, -2 6 2			
1.781	2	2 6 1, 3 5 1	1.556	3	5 3 1			

Strong lines: 6.68/X 3.20/X 2.99/5 1.67/5 2.70/4 7.93/4 2.31/4 4.36/3

				d Å	Int.	h k l		
Ni (AsO) 18H O 3 4 2 2				7.91	33	1	1	0
Nickel Arsenate Hydrate				6.66	100	0	2	0
Annabergite, syn				4.919	11	2	0	0
				4.562	4	-1	0	1
				4.363	20	0	1	1
Rad: CuKα1 Lambda: 1.540598 Filter: Mono. d-sp: Diff.				4.044	6	1	3	0
Cutoff: Int: Diffractometer I/Icor: 1.00				3.954	8	2	2	0
Ref: Natl. Bur. Stand. (U.S.) Monogr. 25, 19 60 (1982)				3.879	16	1	0	1
				3.765	3	-1	2	1
				3.639	8	-2	1	1
Sys: Monoclinic S.G.: I2/m (12)				3.347	5	1	2	1
a: 10.054(2) b: 13.303(3) c: 4.7159(10) A: 0.7558 C: 0.3545				3.326	4	0	4	0
A: B: 102.10(2) C: Z: 2 mp:				3.198	43	0	3	1
Ref: Ibid.				2.982	52	-3	0	1
Dx: 3.22 Dm: 3.07 SS/FOM: F30=57(.012,44)				2.756	12	2	4	0
ea: 1.622 nwB: 1.658 ey: 1.687 Sign: - 2V: 84 deg.				2.721	30	-3	2	1
Ref: Dana's System of Mineralogy, 7th Ed.				2.687	21	-1	4	1
				2.635	14	3	3	0
Color: Light yellow-green				2.568	1	1	5	0
Pattern taken at 25 C. CAS no.: 54469-74-1. The sample was prepared at NBS,				2.523	8	1	4	1
Gaithersburg, Maryland, USA. A solution of 2 grams Ni(NO3)2·6H2O in 1 liter				2.440	17	3	0	1
H2O was added dropwise to a solution of 2g Na2HAsO4 in 1 1/2 liters of warm				2.321	10	-1	1	2
H2O. The combined solution was held at 70 to 80 C for 3 weeks. The crystals				2.304	16	4	2	0
were filtered off and washed with H2O and C2H5OH. Vivianite group,				2.217	3	0	6	0
vivianite subgroup. Si used as internal standard. PSC: mC74. To replace				2.178	8	0	2	2
11-625. Mwt: 598.06. Volume[CD]: 616.73.						-2	5	1

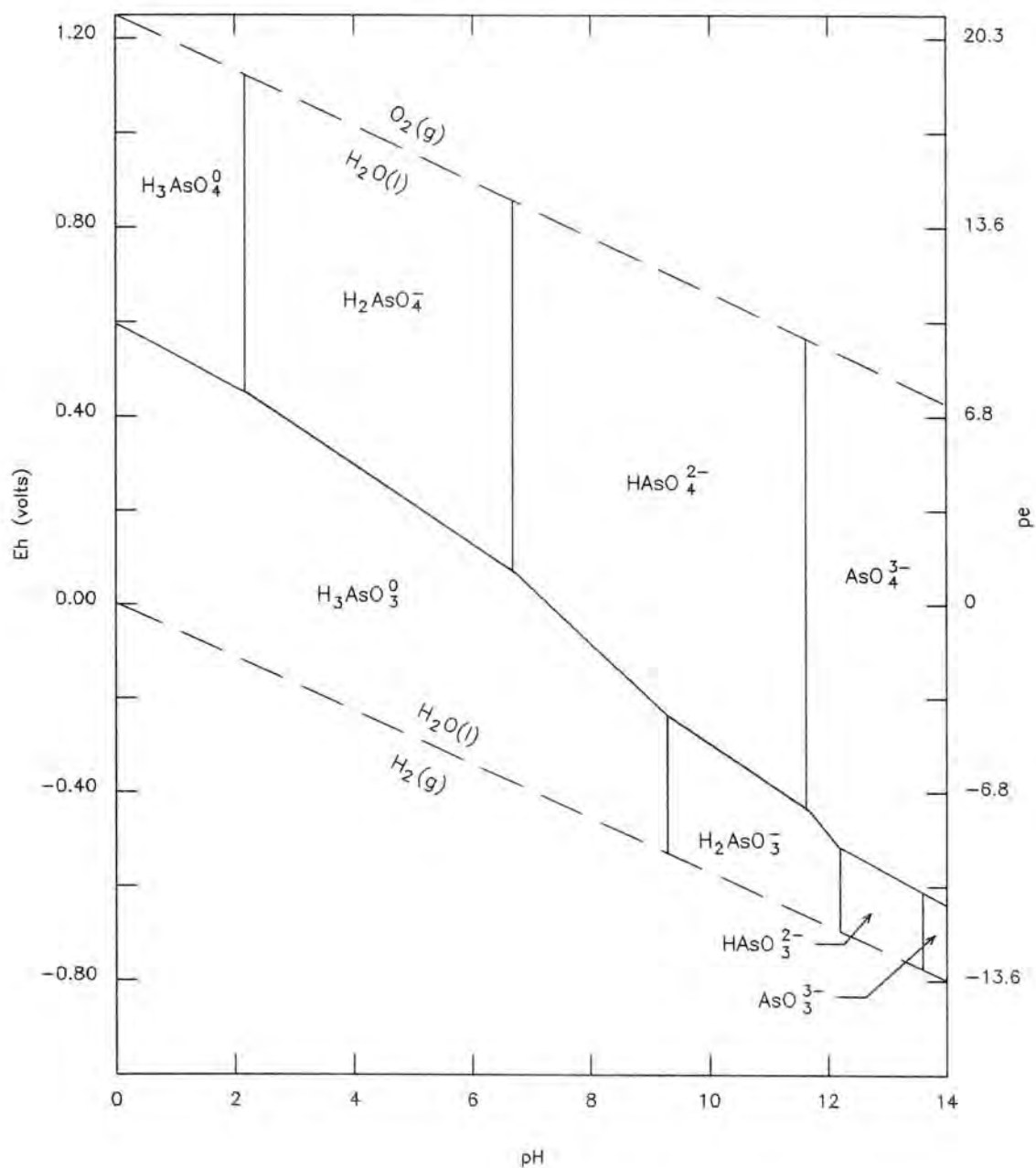
d Å	Int.	h k l	d Å	Int.	h k l	d Å	Int.	h k l
2.155	1	-2 2 2	1.8240	3	4 3 1	1.5909	4	6 2 0
2.102	1	-4 3 1	1.7756	2	-4 5 1	1.5807	2	5 5 0
2.079	7	-3 1 2	1.7572	3	0 7 1	1.5519	2	-2 1 3, -6 3 1
2.066	8	3 5 0	1.6915	1	-5 4 1	1.5281	3	1 8 1, -1 2 3
2.021	1	2 6 0	1.6713	8	1 5 2	1.5191	2	-3 0 3
1.992	2	-1 6 1	1.6629	10	0 8 0	1.5028	3	5 4 1
1.9678	3	3 4 1	1.6505	11	-3 5 2	1.4902	5	4 2 2
1.9463	6	5 1 0	1.6405	11	3 6 1	1.4791	4	-1 7 2
1.9322	6	1 3 2	1.6066	4	3 3 2			
1.9006	9	-3 3 2	1.6002	5	4 5 1			

Strong lines: 6.66/X 2.98/5 3.20/4 7.91/3 2.72/3 2.69/2 4.36/2 2.44/2

(AsO)				d A	Int.	h k l
3	4	2				
Nickel Arsenate				5.75	40	0 0 1
				5.06	5	2 0 0
				4.79	5	0 2 0
Xanthiosite				4.48	10	2 1 0
				4.32	60	1 2 0
Rad: CuK α Lambda: 1.5418 Filter:				d-sp: D.S. -114.6		
Cutoff: Int: Visual I/Icor:				4.02	5	
Ref: Davis, Hey, Kingsbury, Mineral. Mag., 35 72 (1965)				3.90	50	-2 0 1
				3.70	30	2 0 1
				3.67	50	0 2 1
Sys: Monoclinic S.G.: P21/a (14)				3.57	5	-2 1 1
a: 10.174(5)	b: 9.548(2)	c: 5.766(1)	A: 1.0656	C: 0.6039		
A:	B: 92.98	C:	Z: 4	mp:		
Ref: Ibid.				3.46	80	2 1 1
				3.42	5	1 2 1
				3.32	5	
Dx: 5.39 Dm: 5.37 SS/FOM: F30=7(.071,60)				3.19	50	3 1 0
				3.13	5	
ea: nwB: ey: Sign: 2V:				3.03	50	-2 2 1
Ref:				2.956	5	
				2.923	30	2 2 1
Color: Yellow				2.862	5	-3 1 1
0 assigned because of poor fit between given cell and d-values. Specimen from				2.784	5	0 3 1
Johanngeorgenstadt, Saxony, Germany. PSC: mP52. Mwt: 453.94. Volume[CD]:						
559.36.				2.748	80	0 1 2
				2.678	80	1 3 1
				2.621	60	1 1 2
				2.576	5	-2 0 2
				2.529	100	-3 2 1

d A	Int.	h k l	d A	Int.	h k l	d A	Int.	h k l
2.466	10	0 2 2	1.944	30	2 3 2	1.589	10	3 5 1
2.410	30	2 3 1	1.913	20	-4 1 2	1.582	5	6 1 1
2.373	20	2 1 2	1.873	5b	5 2 0	1.570	10	-4 0 3
2.305	10	-4 1 1	1.850	30	5 1 1	1.544	60	2 3 3
2.243	10	4 2 0	1.831	5	3 4 1	1.527	60	-4 5 0
2.215	30	4 1 1	1.813	20	0 5 1	1.521	5	-1 6 1
2.204	10	0 4 1	1.784	20	0 2 3	1.504	30	-3 3 3
2.185	5	2 2 2	1.732	10	4 2 2	1.492	60	-4 2 3
2.153	10	1 4 1	1.708	10	-2 2 3	1.487	5	-4 5 1
2.130	40	3 3 1	1.678	30	-5 1 2	1.461	10	2 6 1
2.100	10	-1 3 2	1.664	20	3 5 0	1.436	60	7 1 0
2.069	10	1 3 2	1.645	20	0 3 3	1.426	50	4 2 3
2.033	10	-3 2 2	1.631	20	-1 3 3			
1.995	5	-2 3 2	1.619	30	5 3 1			
1.986	40	4 3 0	1.605	5	4 3 2			

Strong lines: 2.53/X 3.46/8 2.75/8 2.68/8 4.32/6 2.62/6 1.54/6 1.53/6



JOB NO: HCl-1722	DATE: 4/1/98
BY: JJM	DRAWING: EHPH-FIG
CHKD:	PLOT: EHPH7

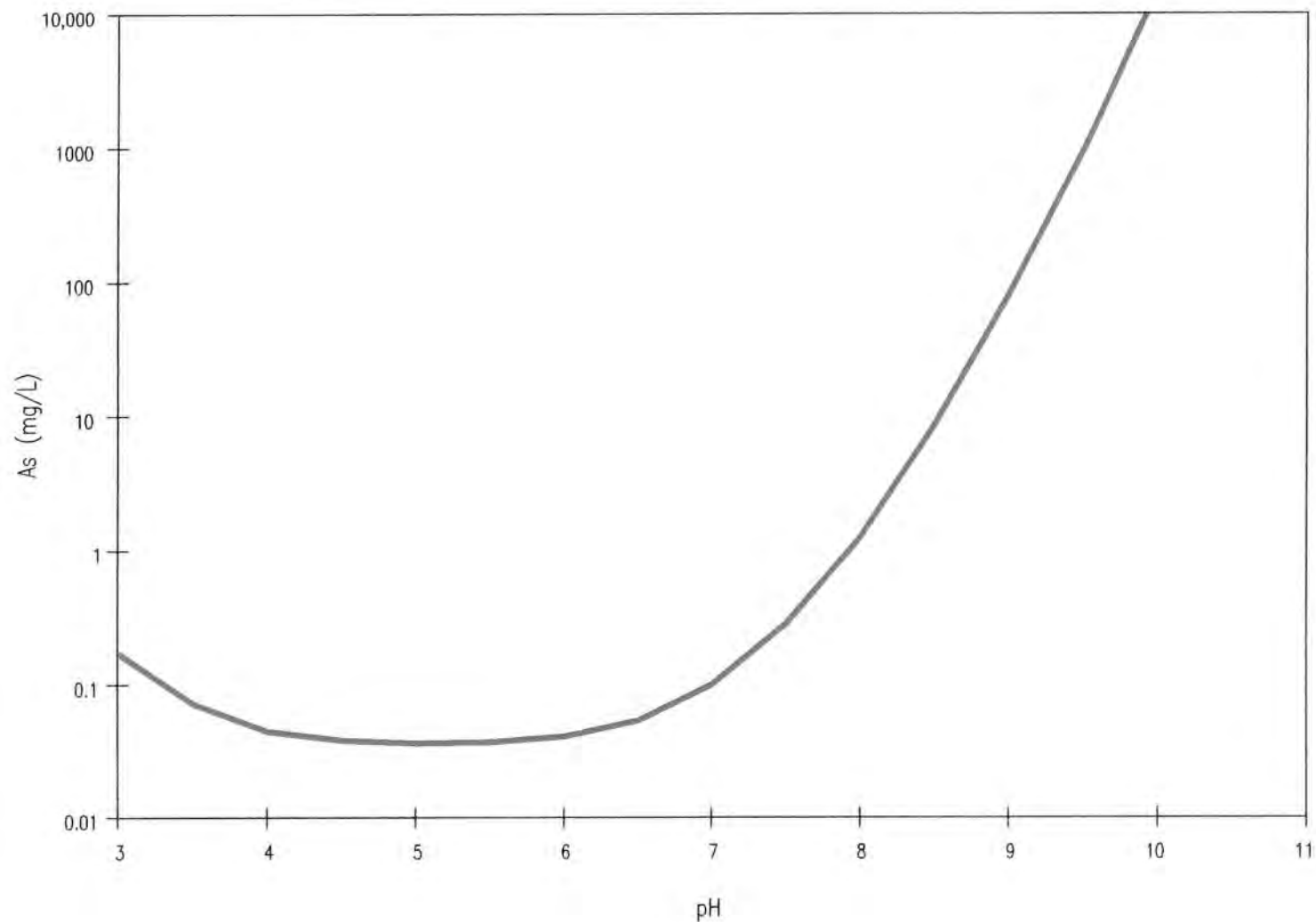
HCI HYDROLOGIC
CONSULTANTS, INC.

Eh-pH diagram for aqueous species
in the As-O₂-H₂O system at 25°C.

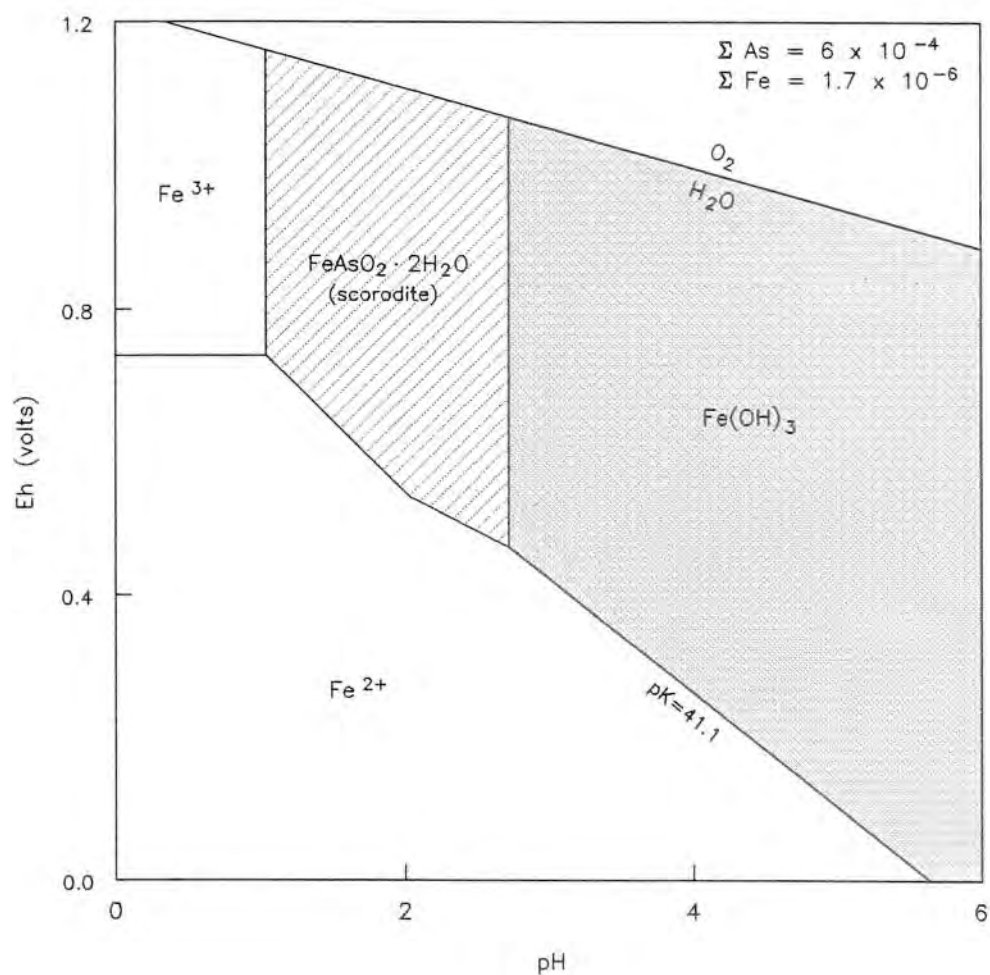
APPENDIX 3

FIGURE

1



APPENDIX 3



APPENDIX 3

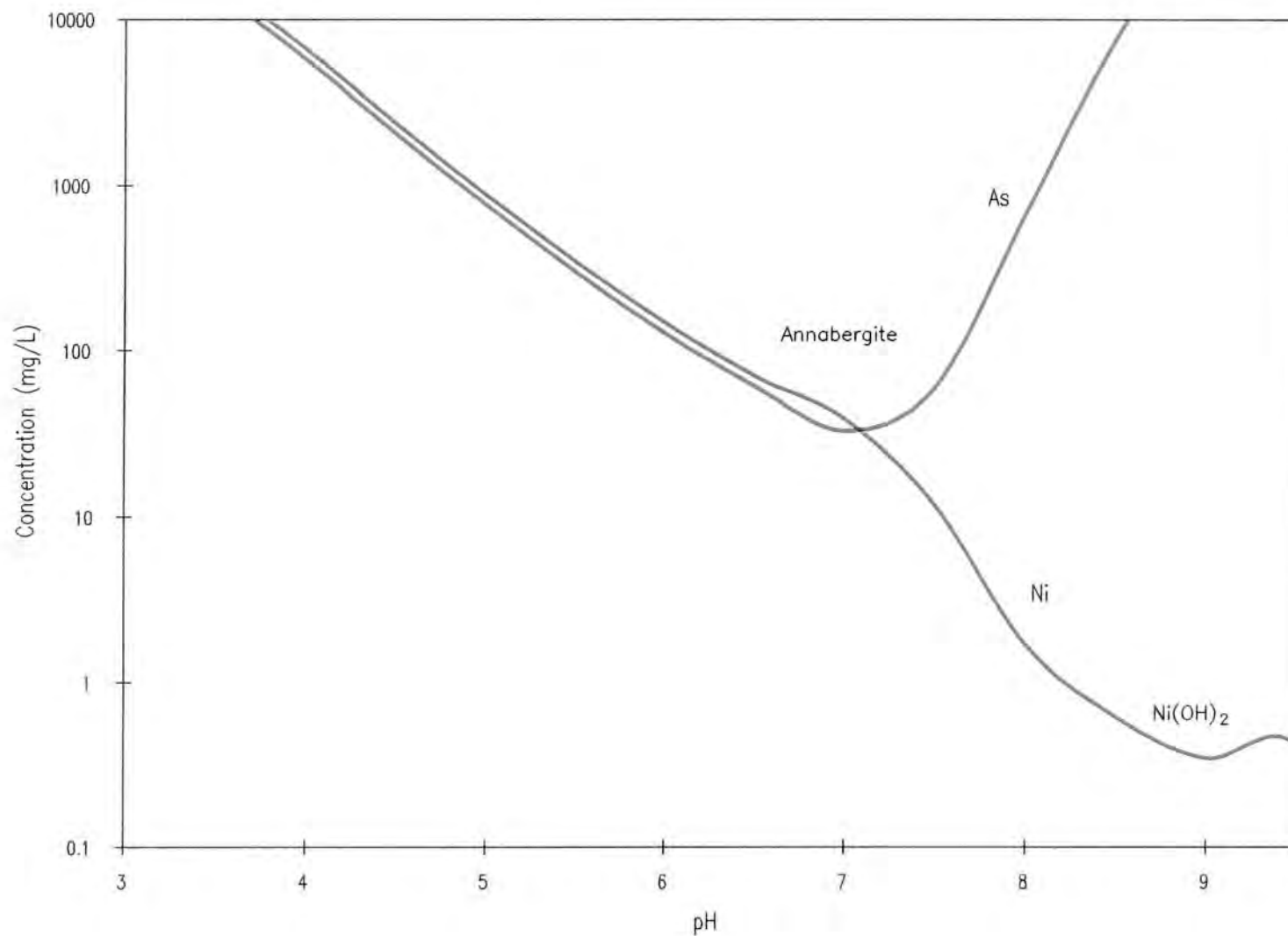
JOB NO: HCl-1722	DATE: 4/1/98
BY: JJM	DRAWING: EHPH-FIG
CHKD:	PLOT: EHPH3

Constructed using raw data from Krause and Ettel (1988, Amer. Mineralogist 73, 850)

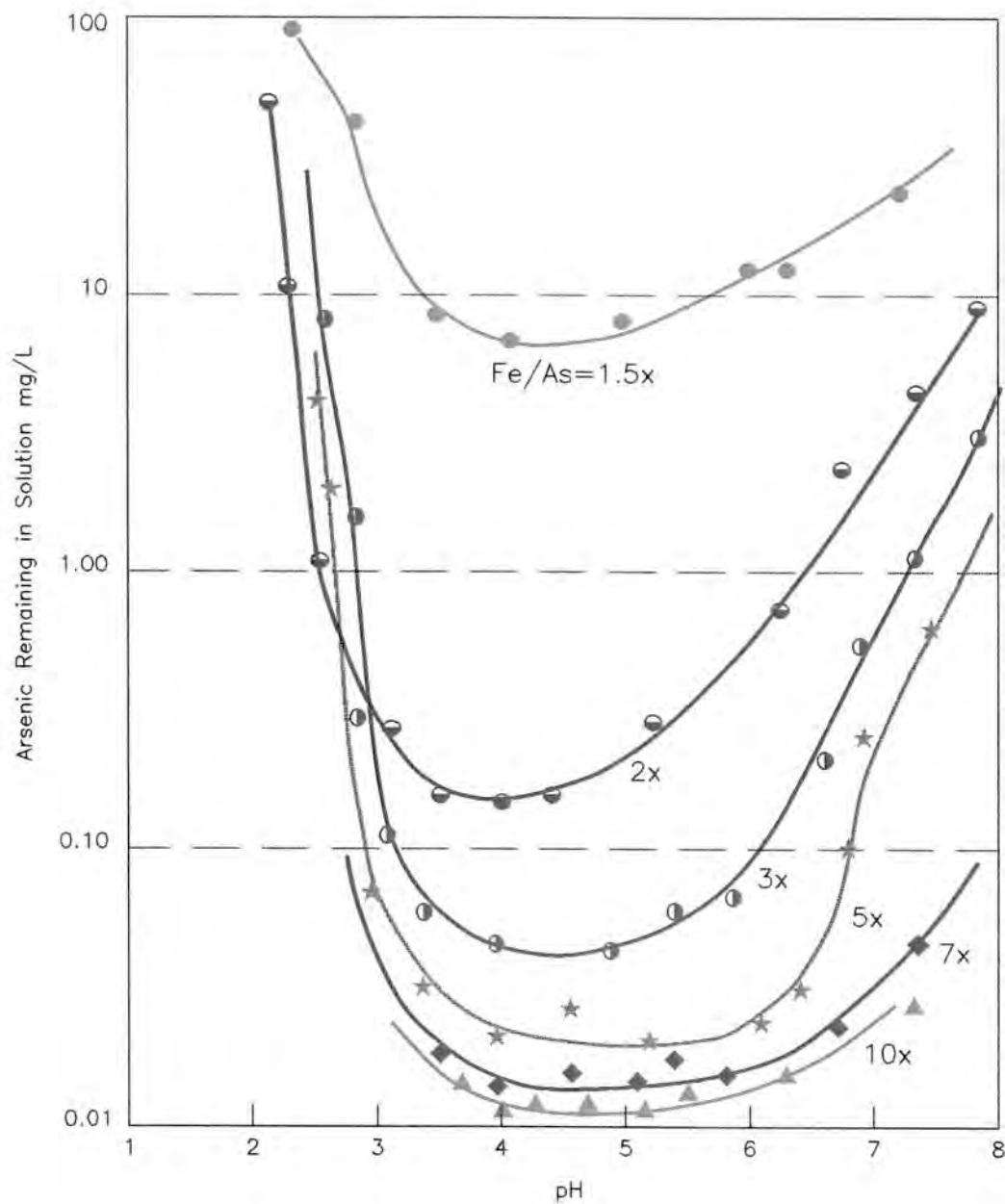
HCI HYDROLOGIC
CONSULTANTS, INC.

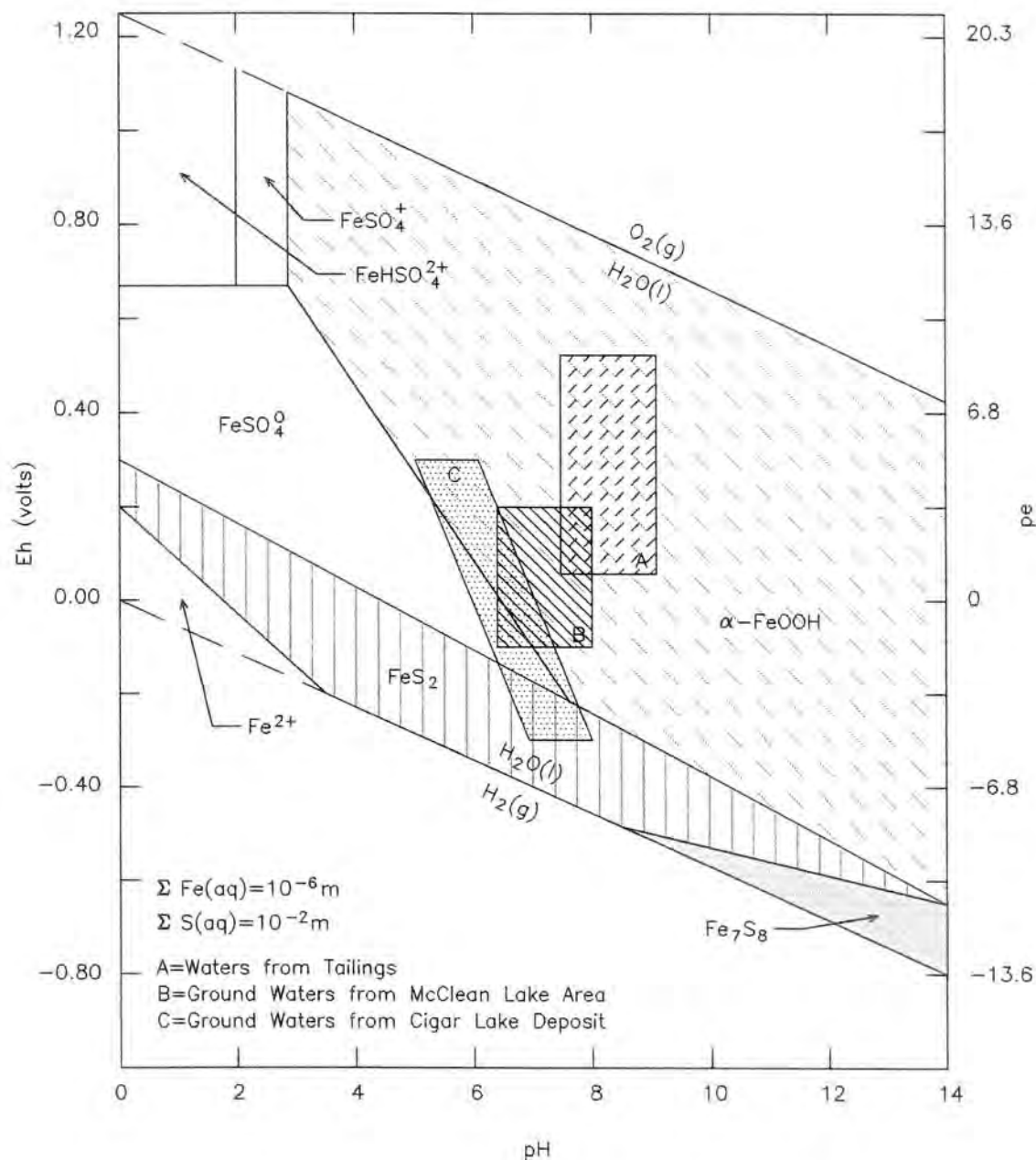
**Eh-pH Diagram for the Fe-O₂-As(V)-H₂O System
at 25°C and 1 Bar Pressure**

FIGURE
3



APPENDIX 3





APPENDIX 3

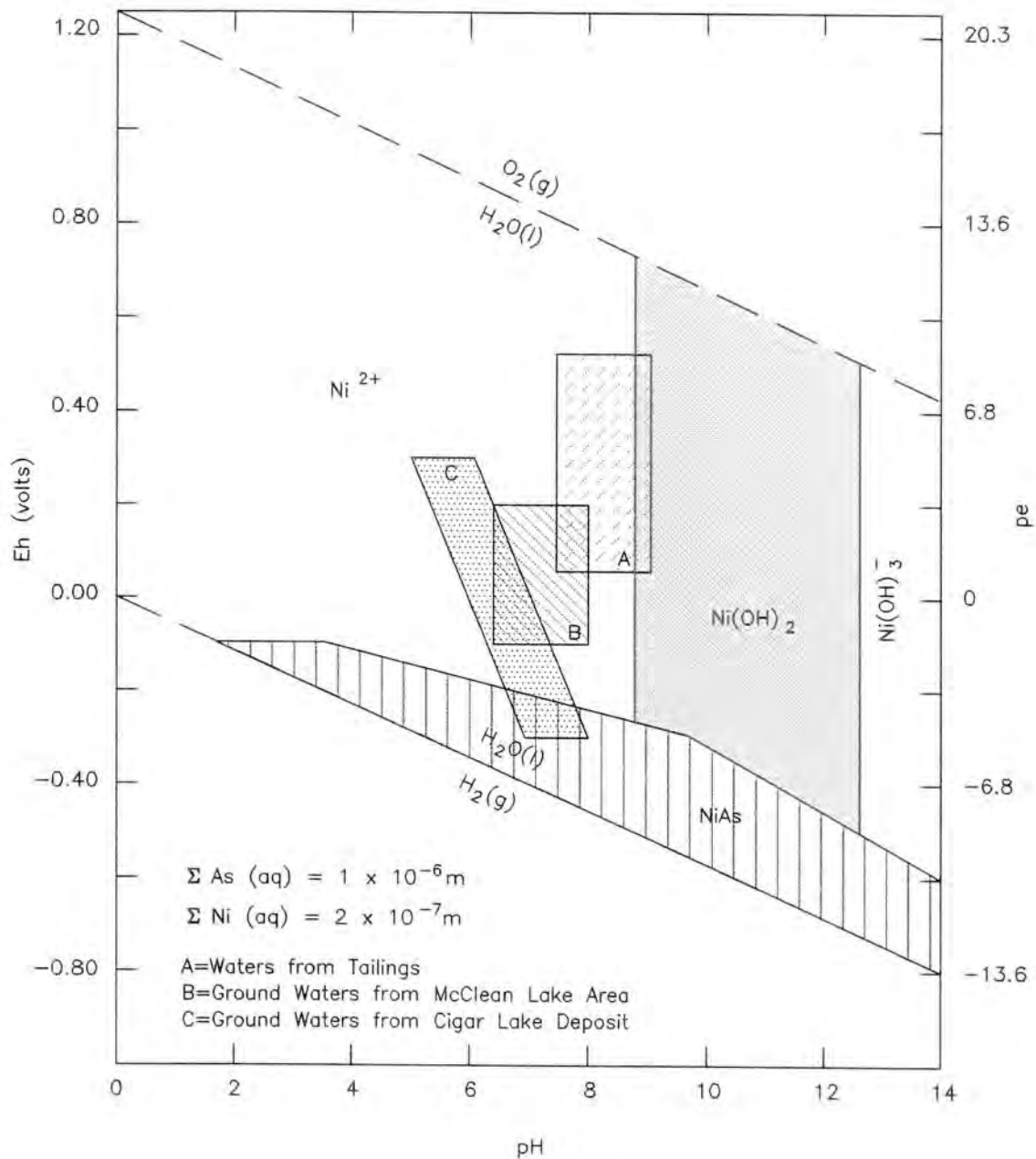
Eh-pH diagram for the system Fe-S-O₂-H₂O at 25°C showing the stability fields of goethite ($\alpha\text{-FeOOH}$), pyrite (FeS_2) and pyrrhotite (Fe_7S_8). Also plotted are measured Eh and pH values of JEB tailings raffinate, ground waters from the McClean Lake area (Section 3.3) and ground waters from the Cigar Lake deposit (Cramer and Smellie, 1994)

FIGURE

6

JOB NO: HCI-1722	DATE: 4/14/98
BY: JJM	DRAWING: EHPH-FIG
CHKD:	PLOT: EHPH4

HCI HYDROLOGIC
 CONSULTANTS, INC.

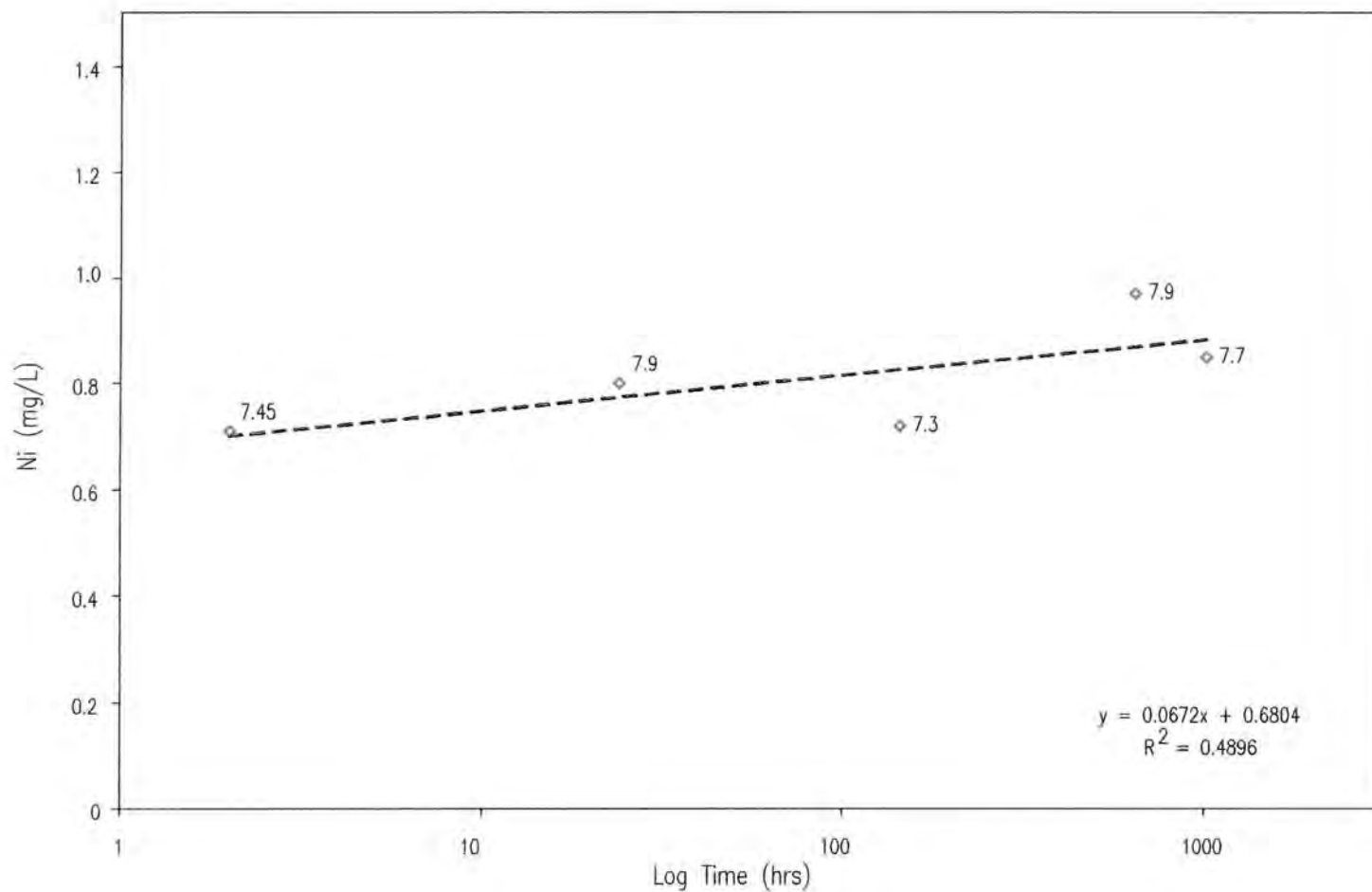


Eh-pH diagram for the system Fe-S-O₂-H₂O at 25°C showing the stability fields of niccolite (NiAs). Also plotted are measured Eh and pH values of JEB tailings raffinate, ground waters from McClean Lake area and ground waters from the Cigar Lake deposit (Cramer and Smellie, 1994).

APPENDIX 3

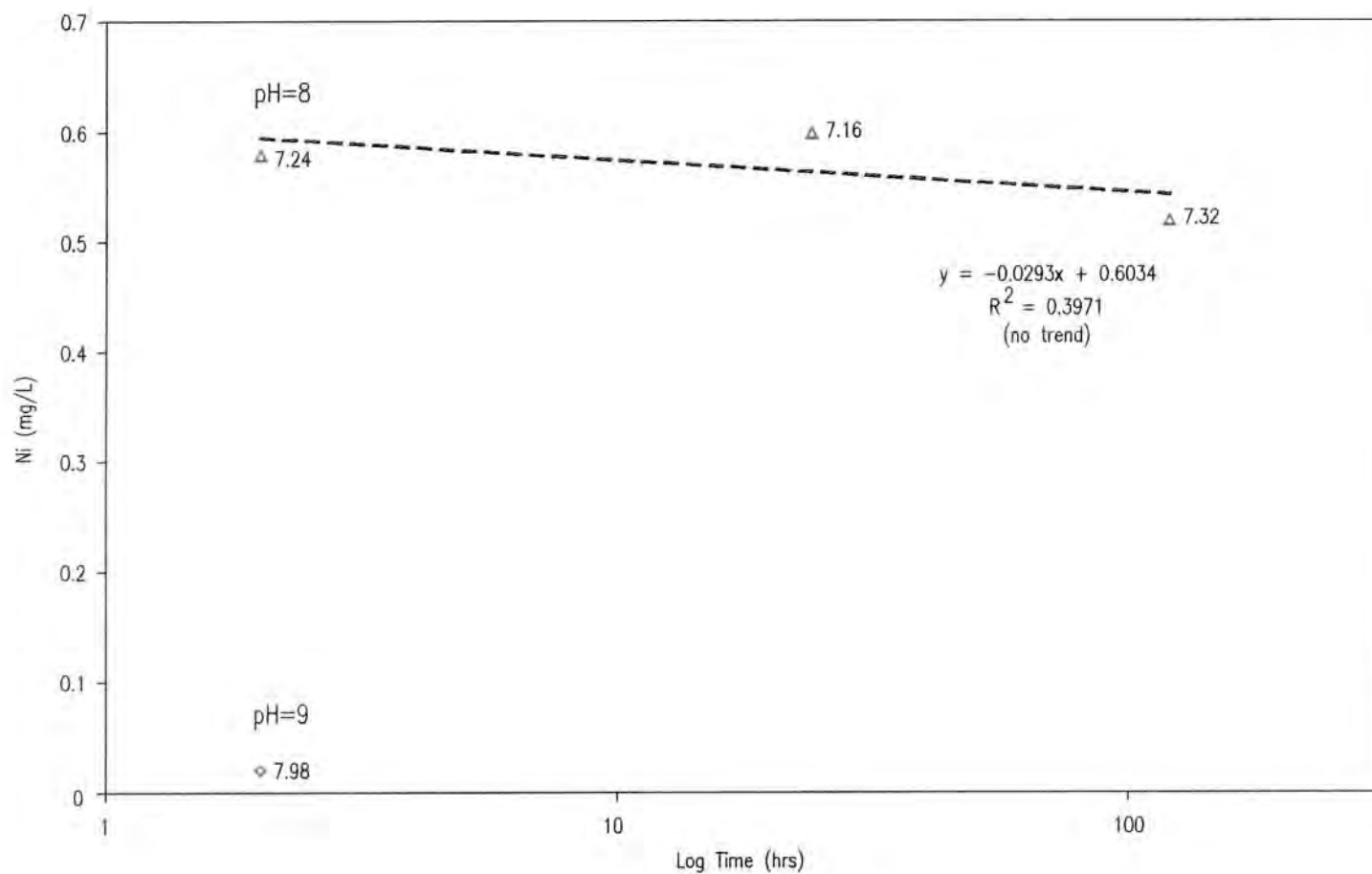
FIGURE

7



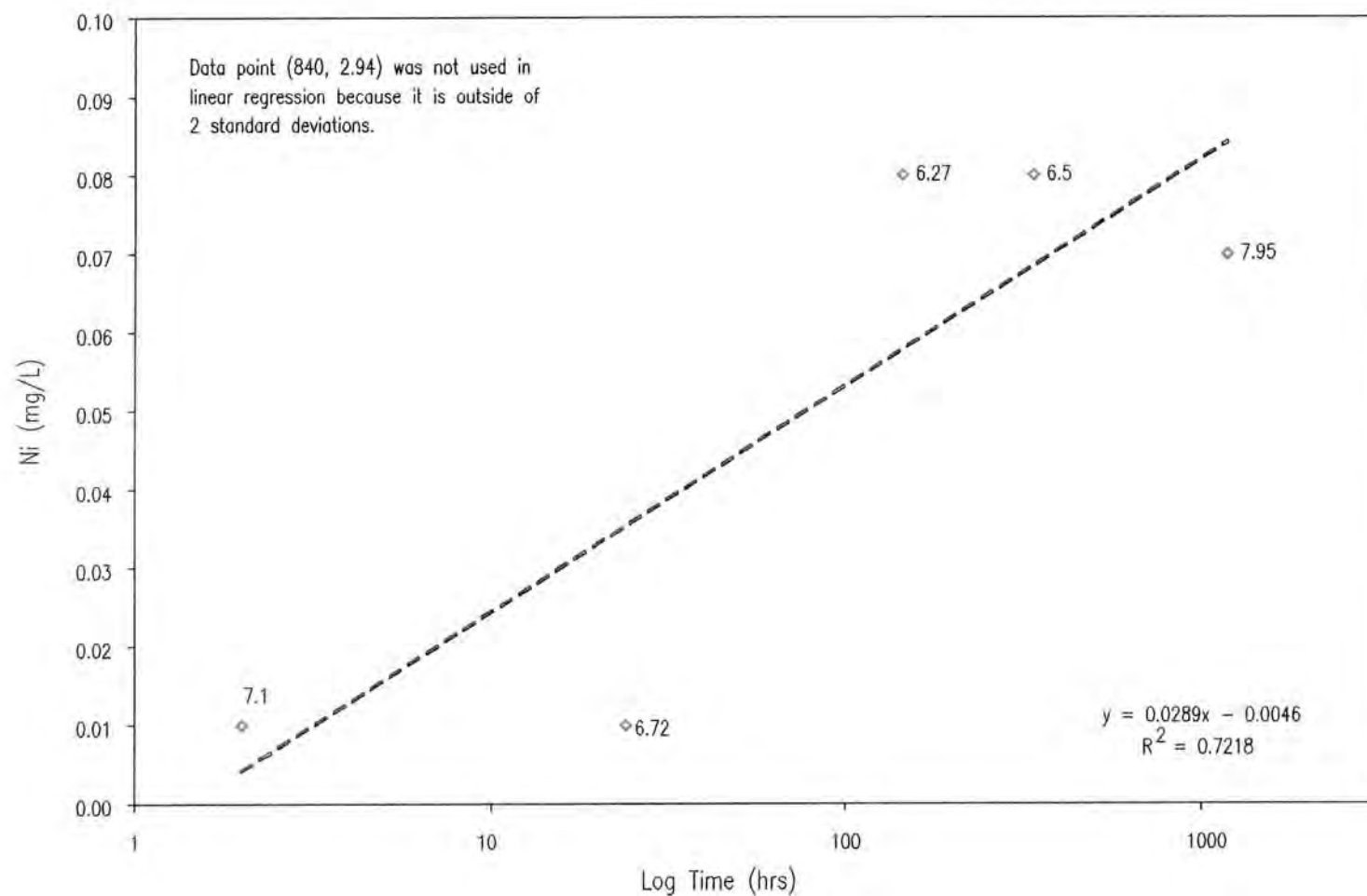
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



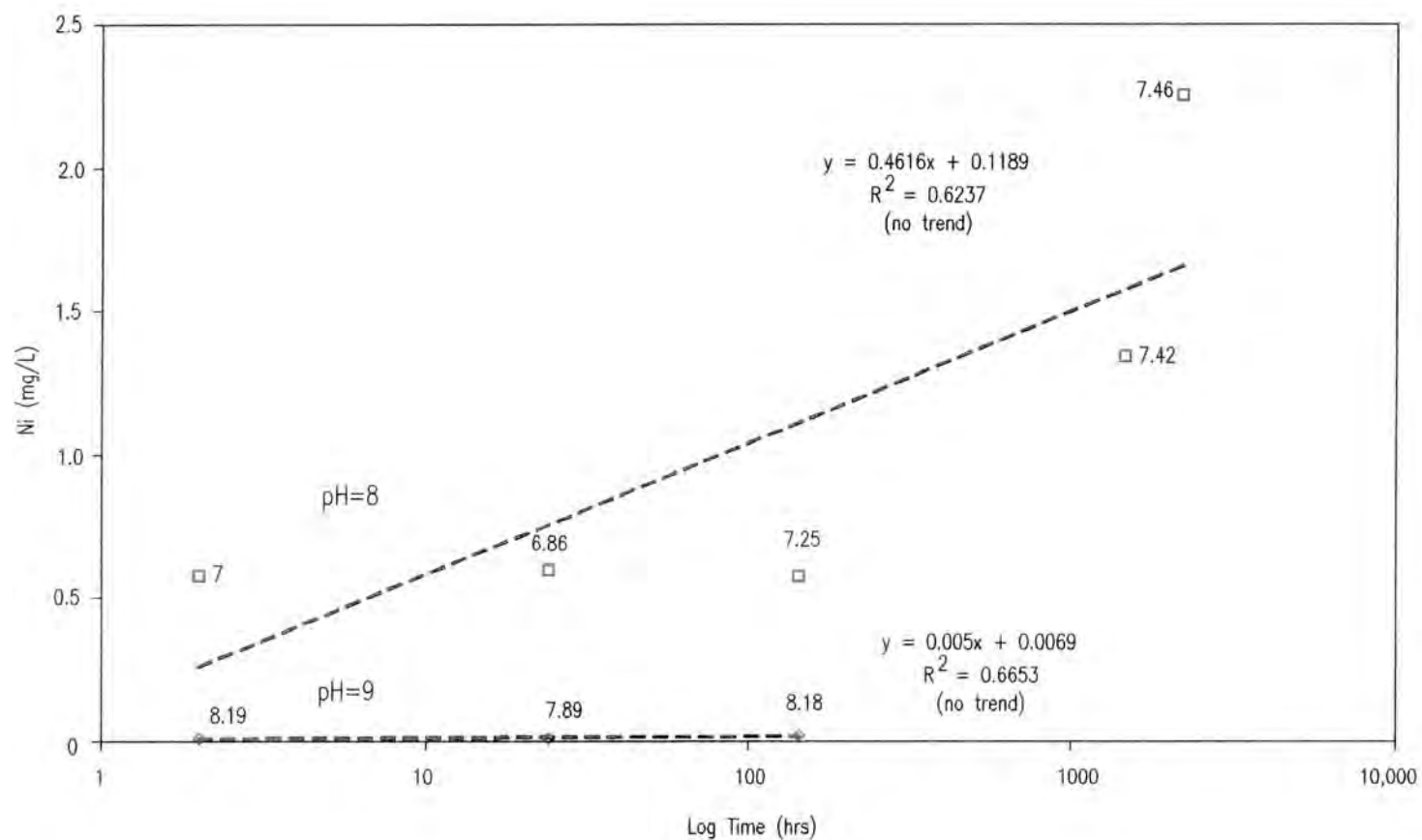
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



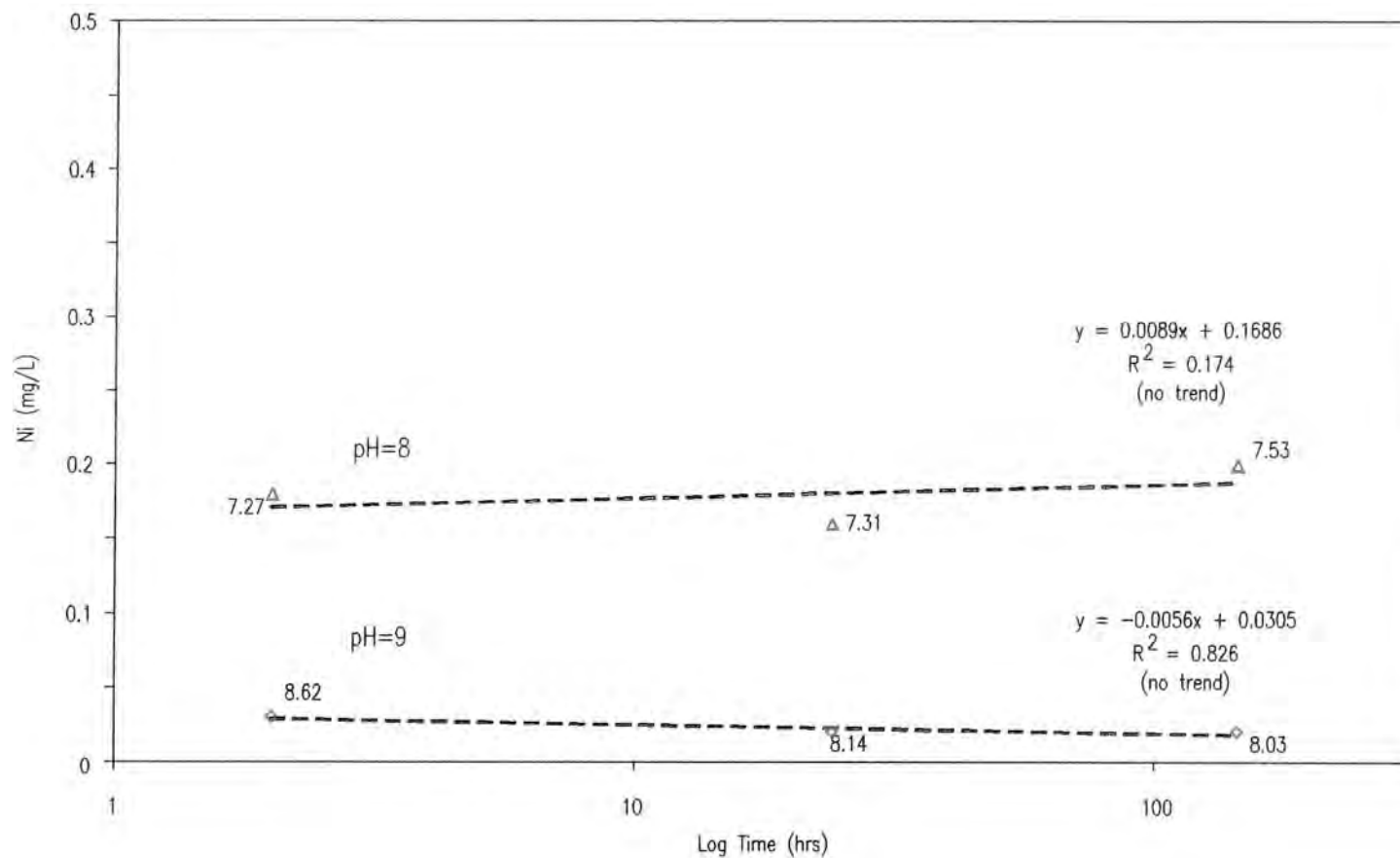
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



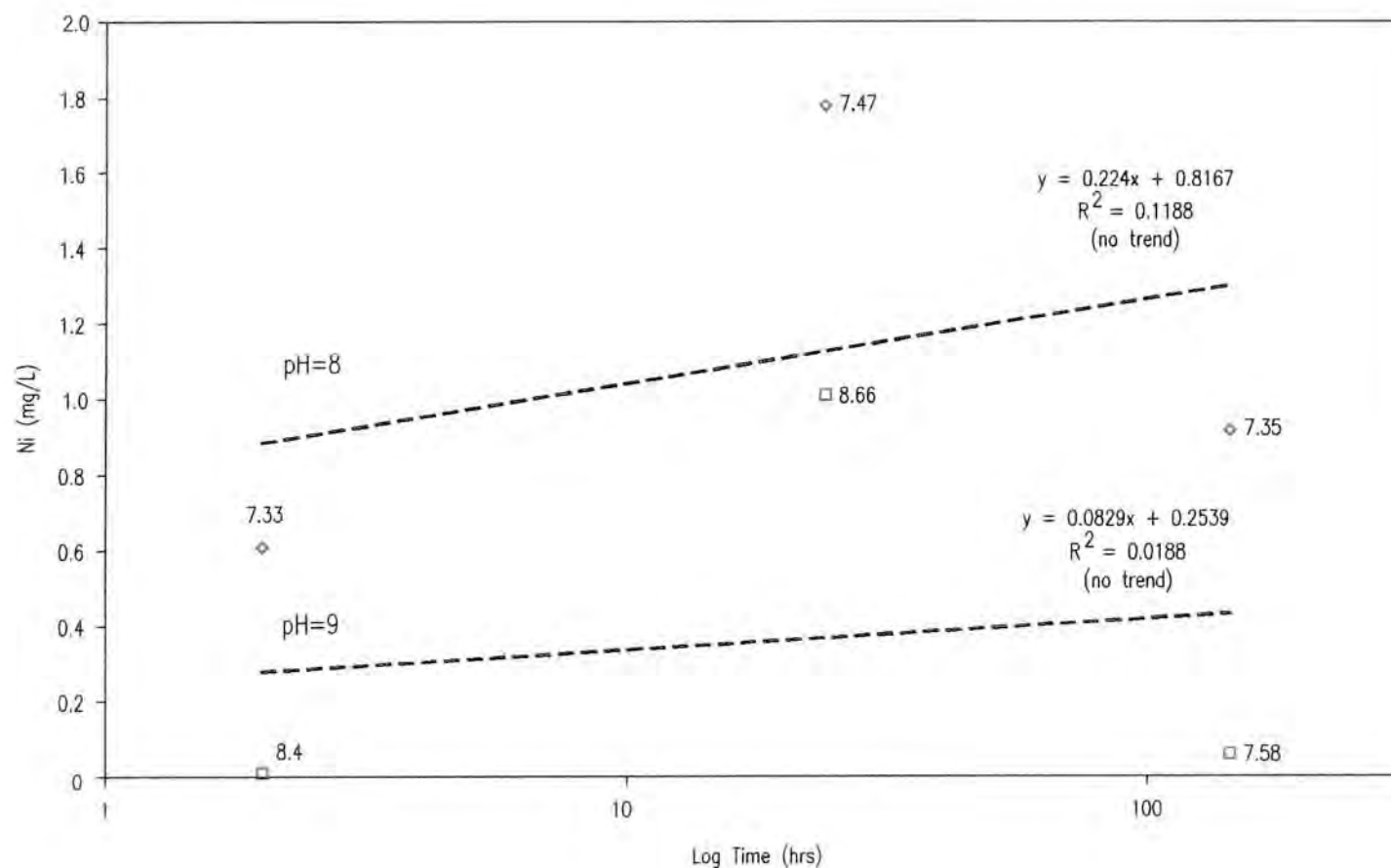
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



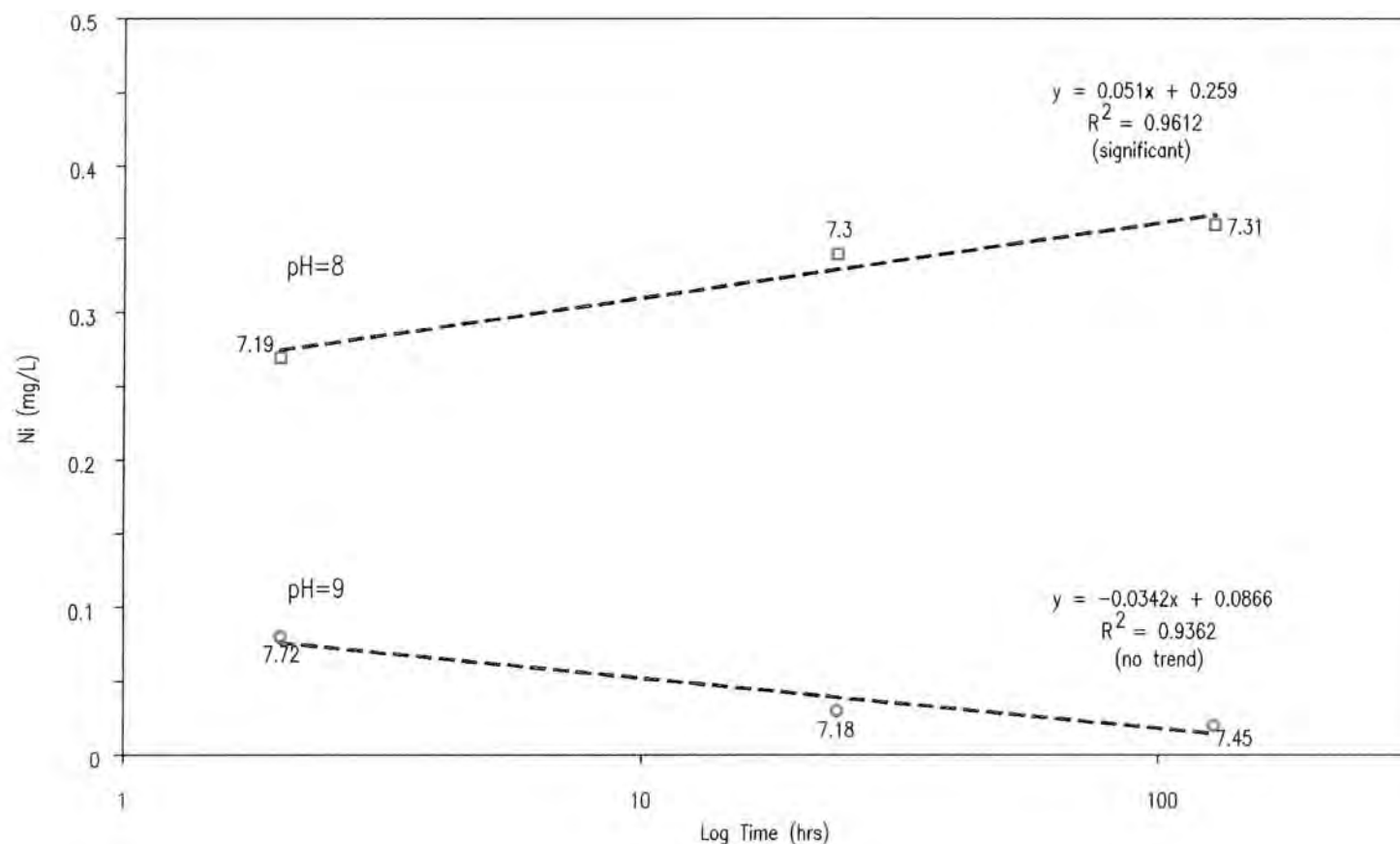
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



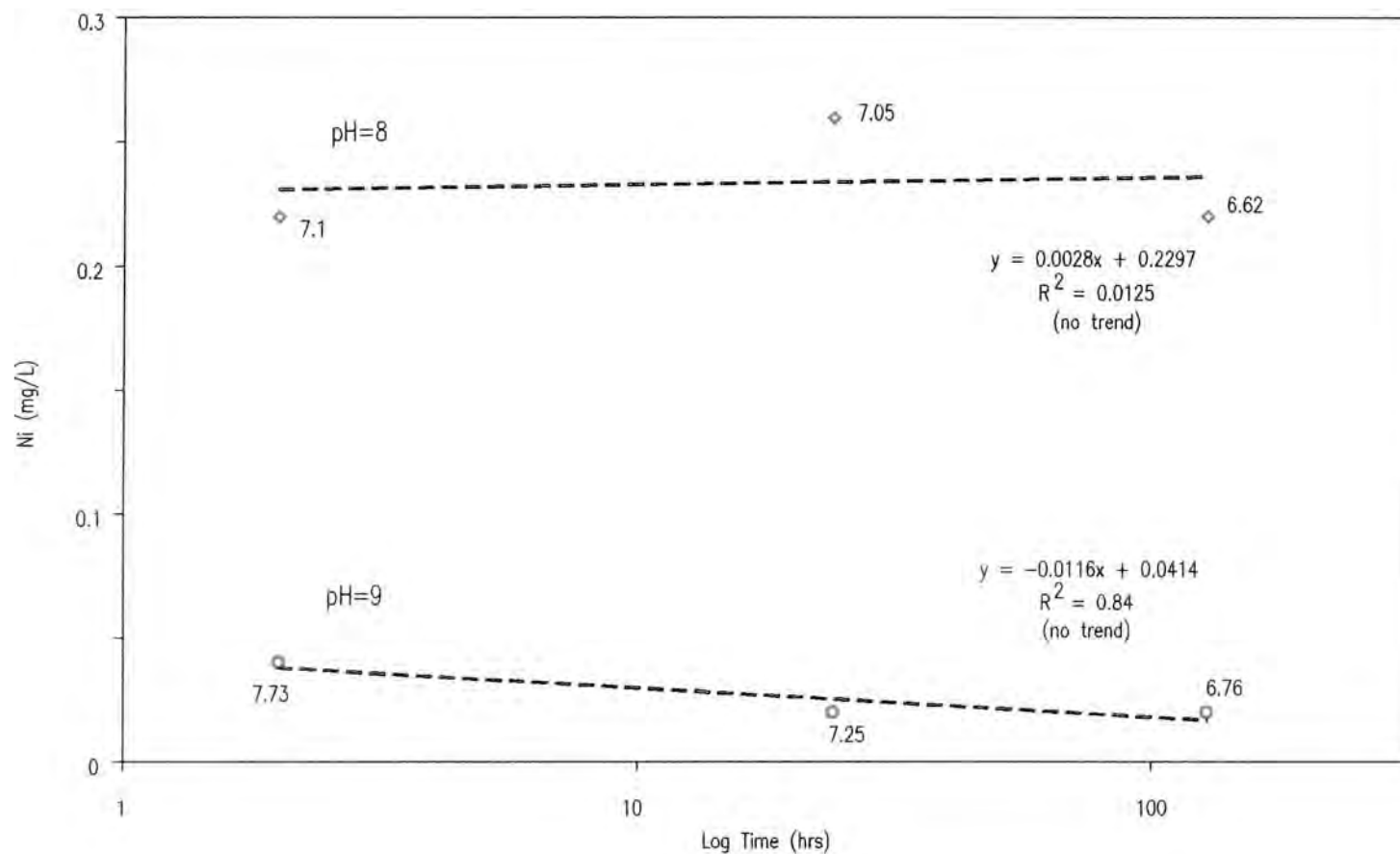
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



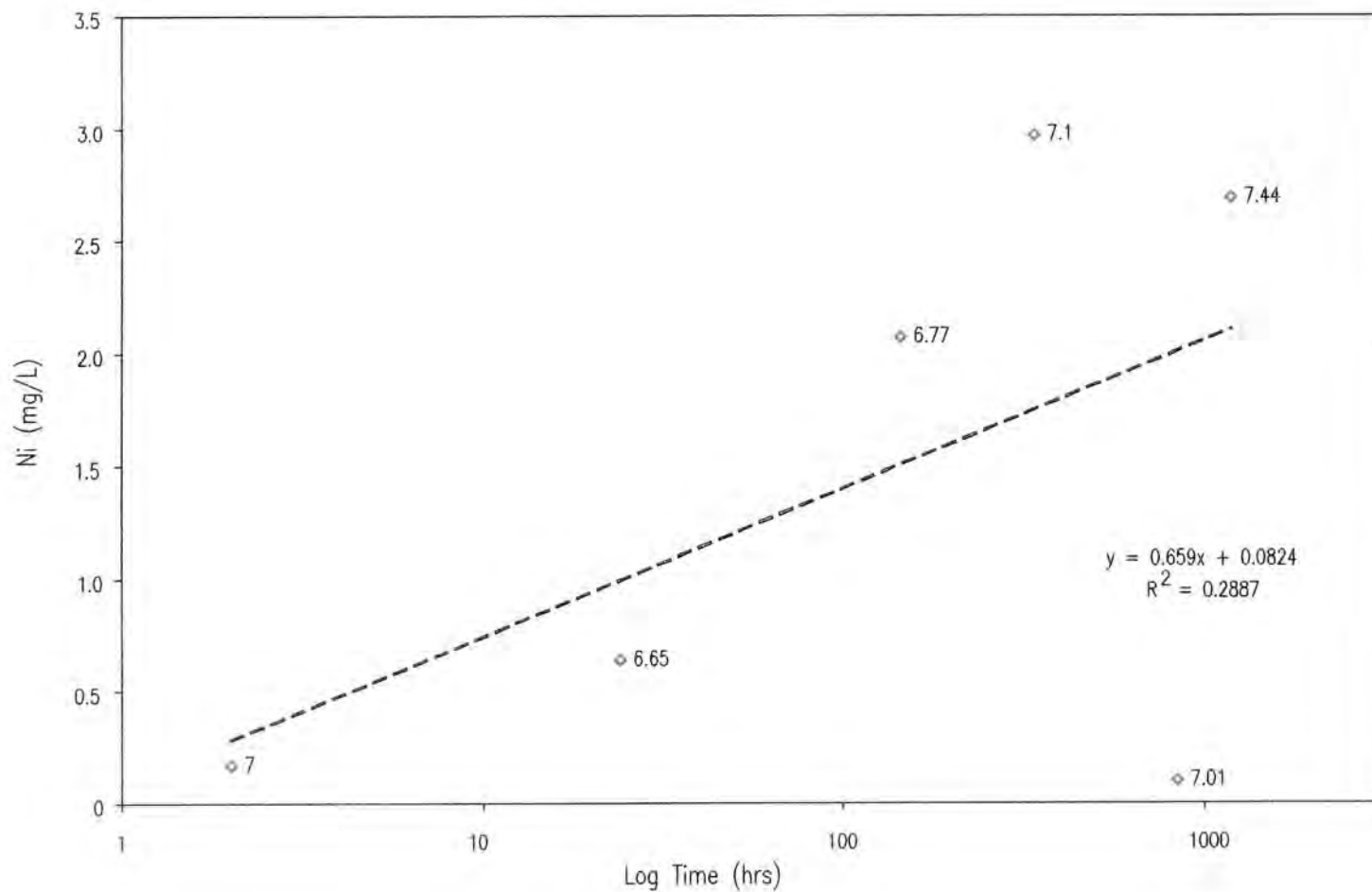
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



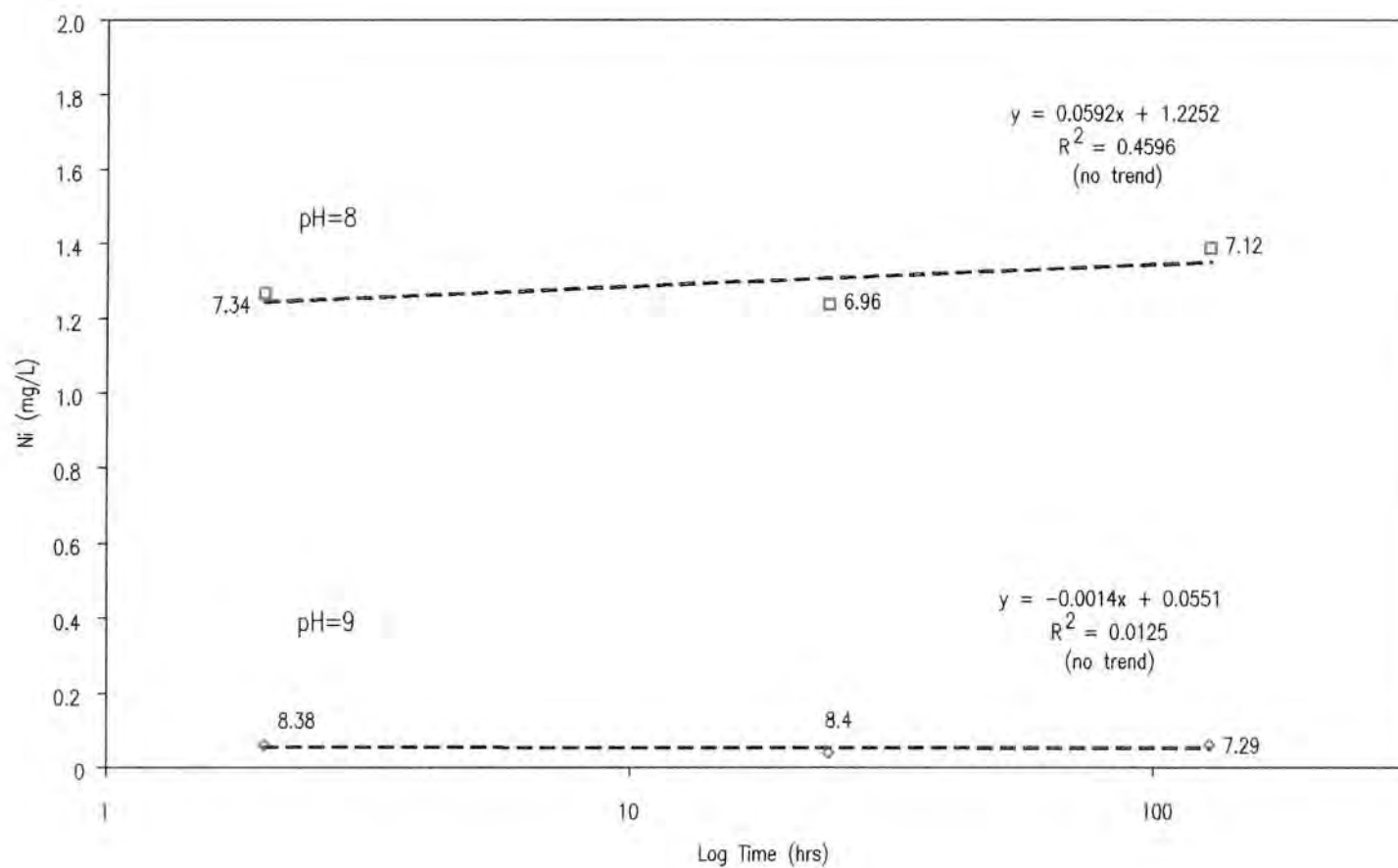
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



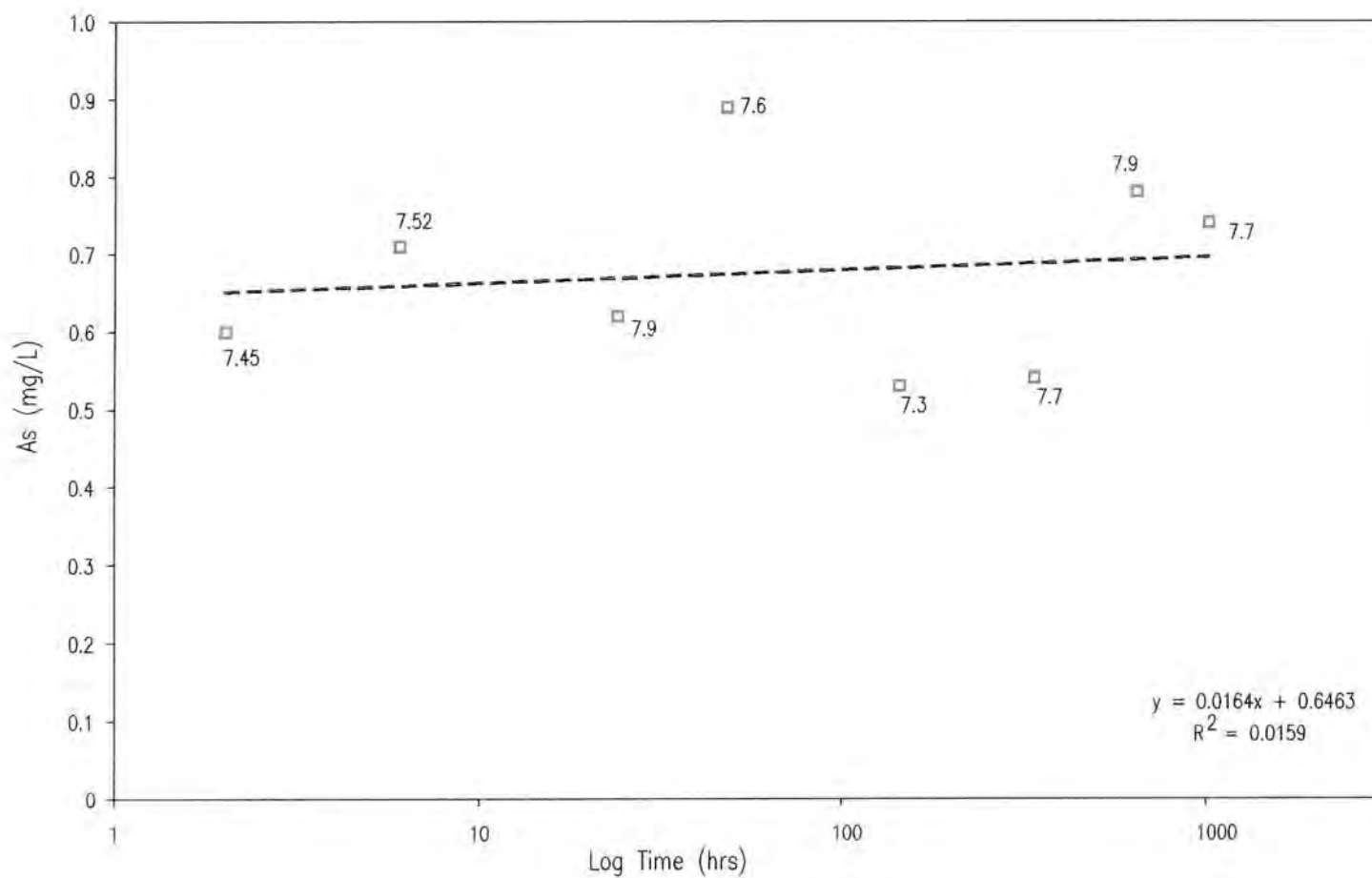
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APPENDIX 3



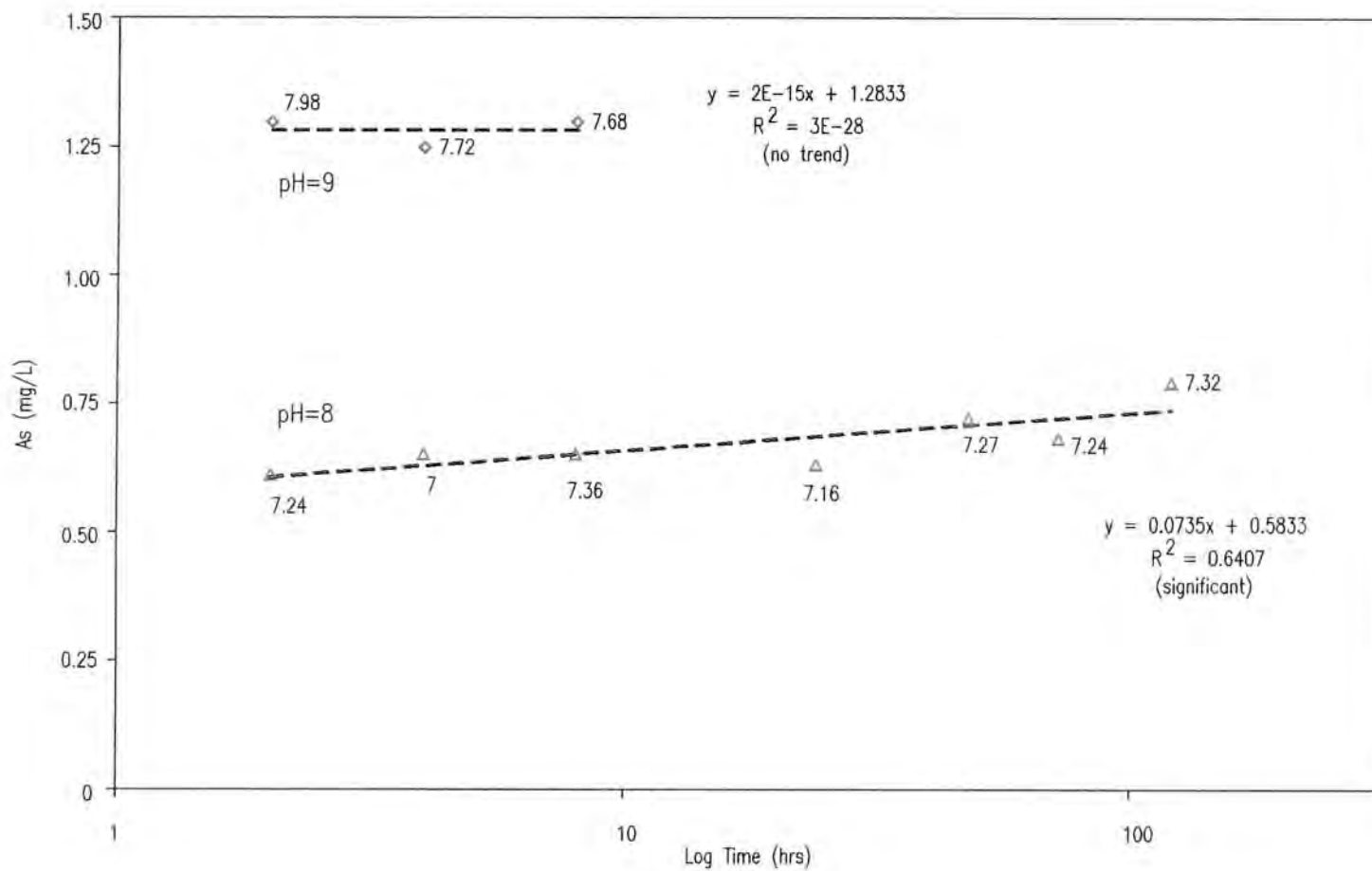
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



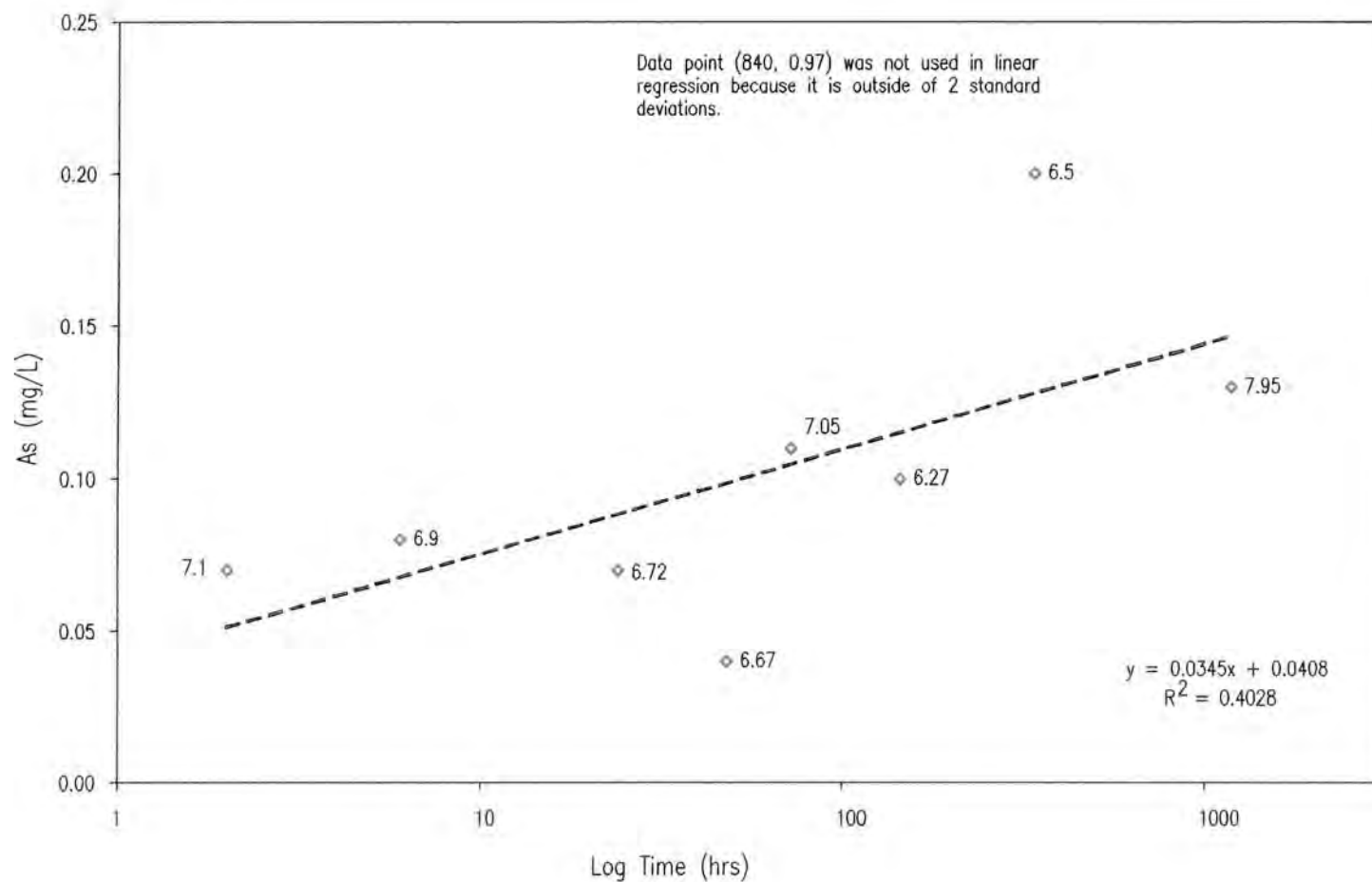
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



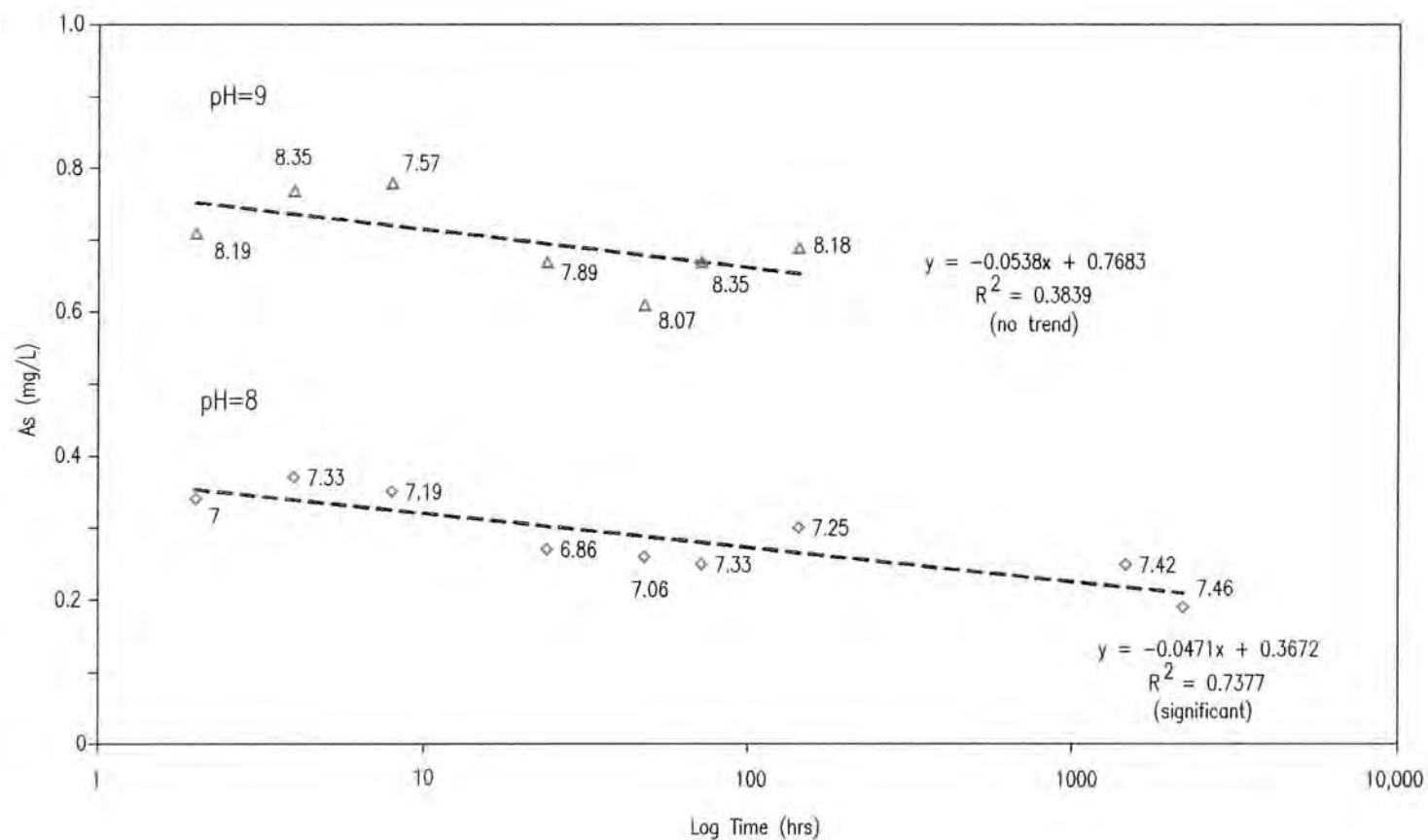
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



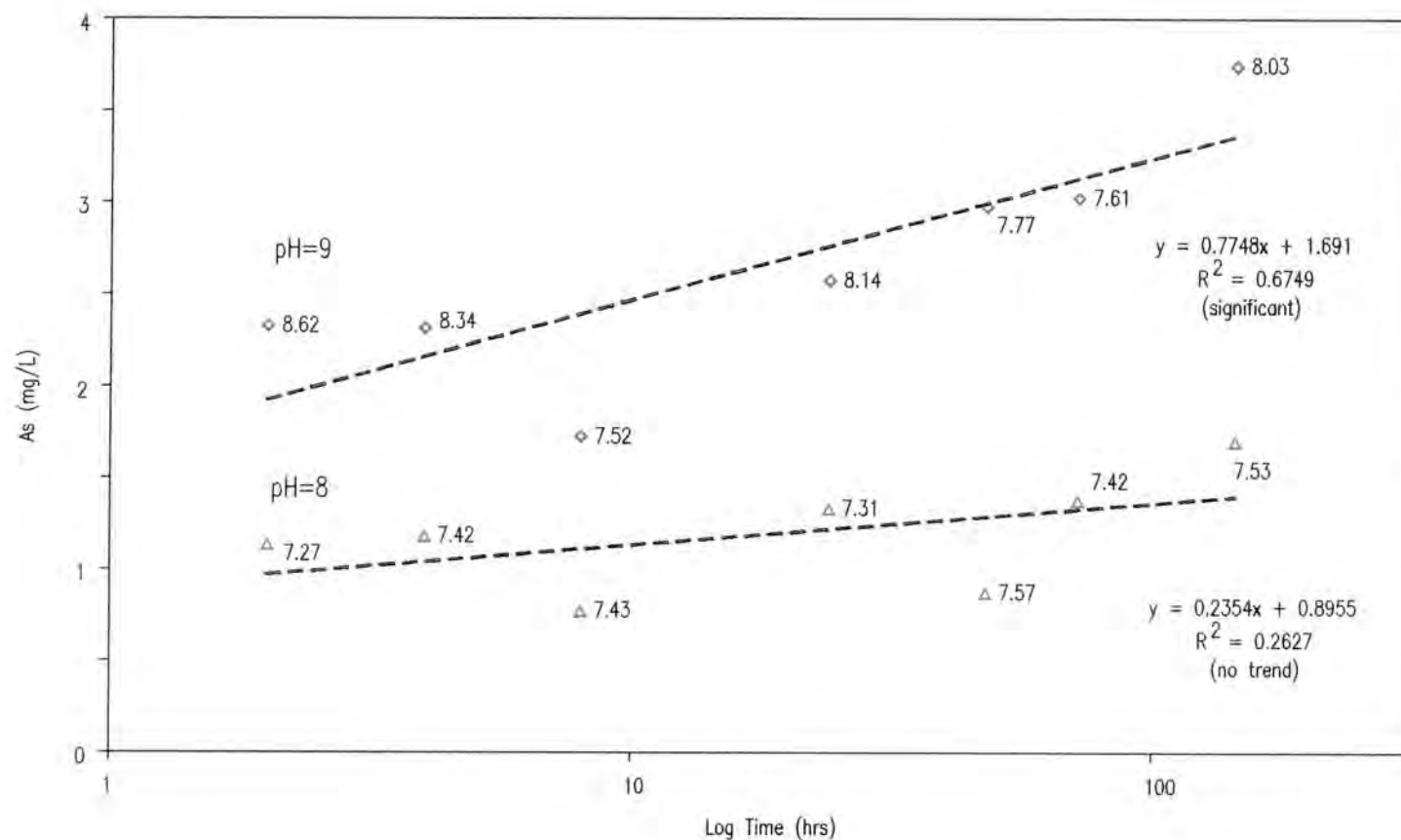
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



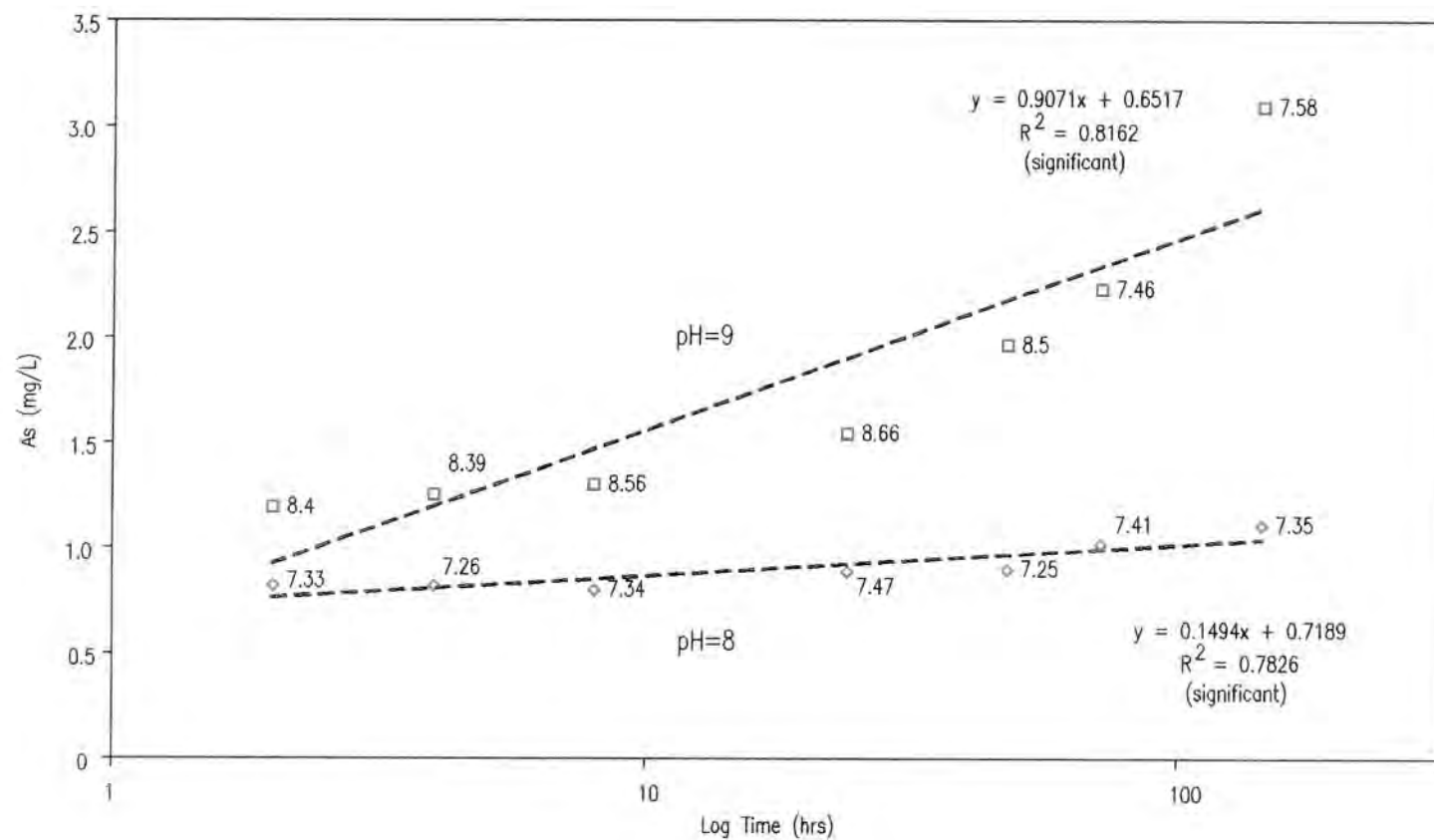
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APPENDIX 3



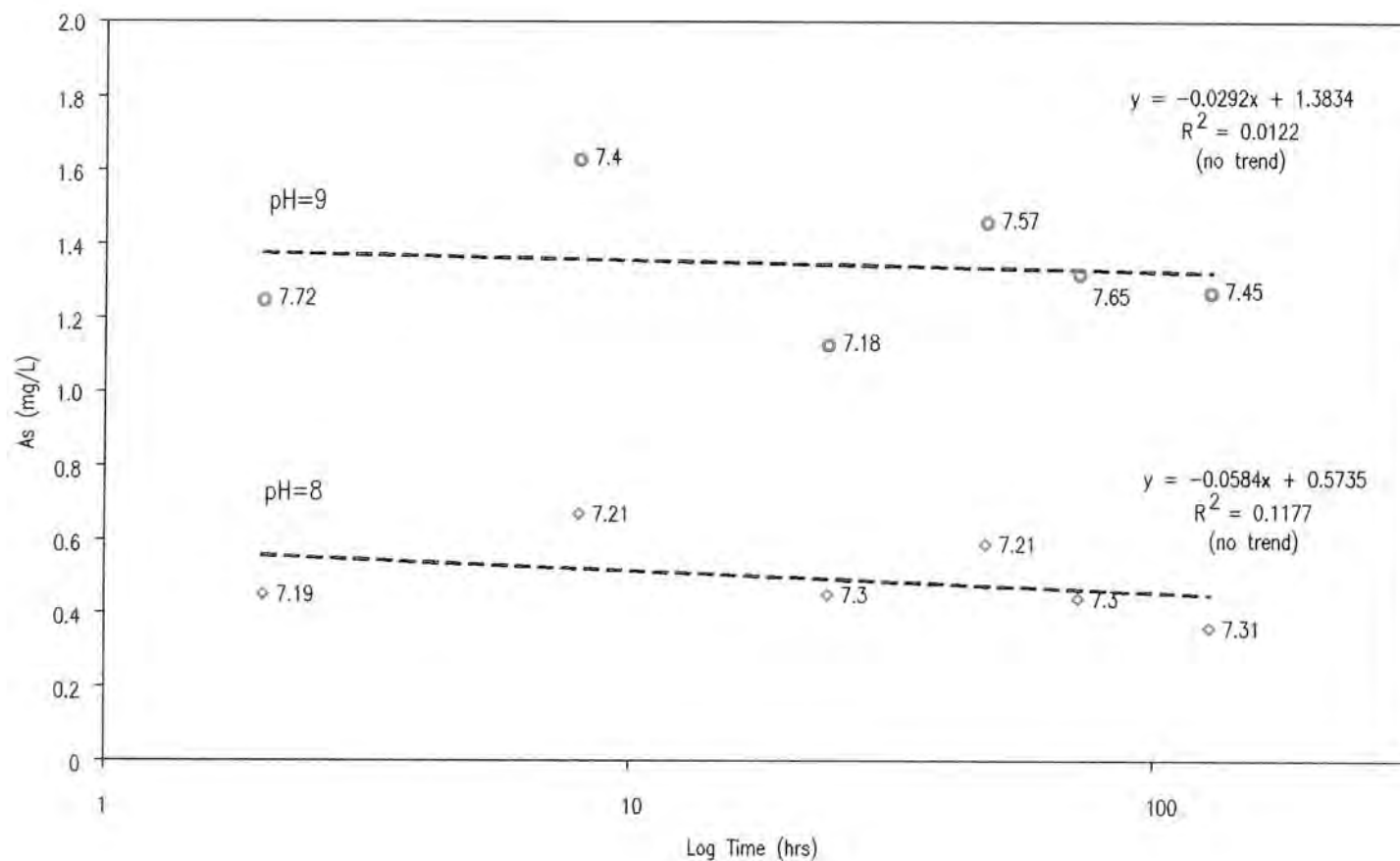
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



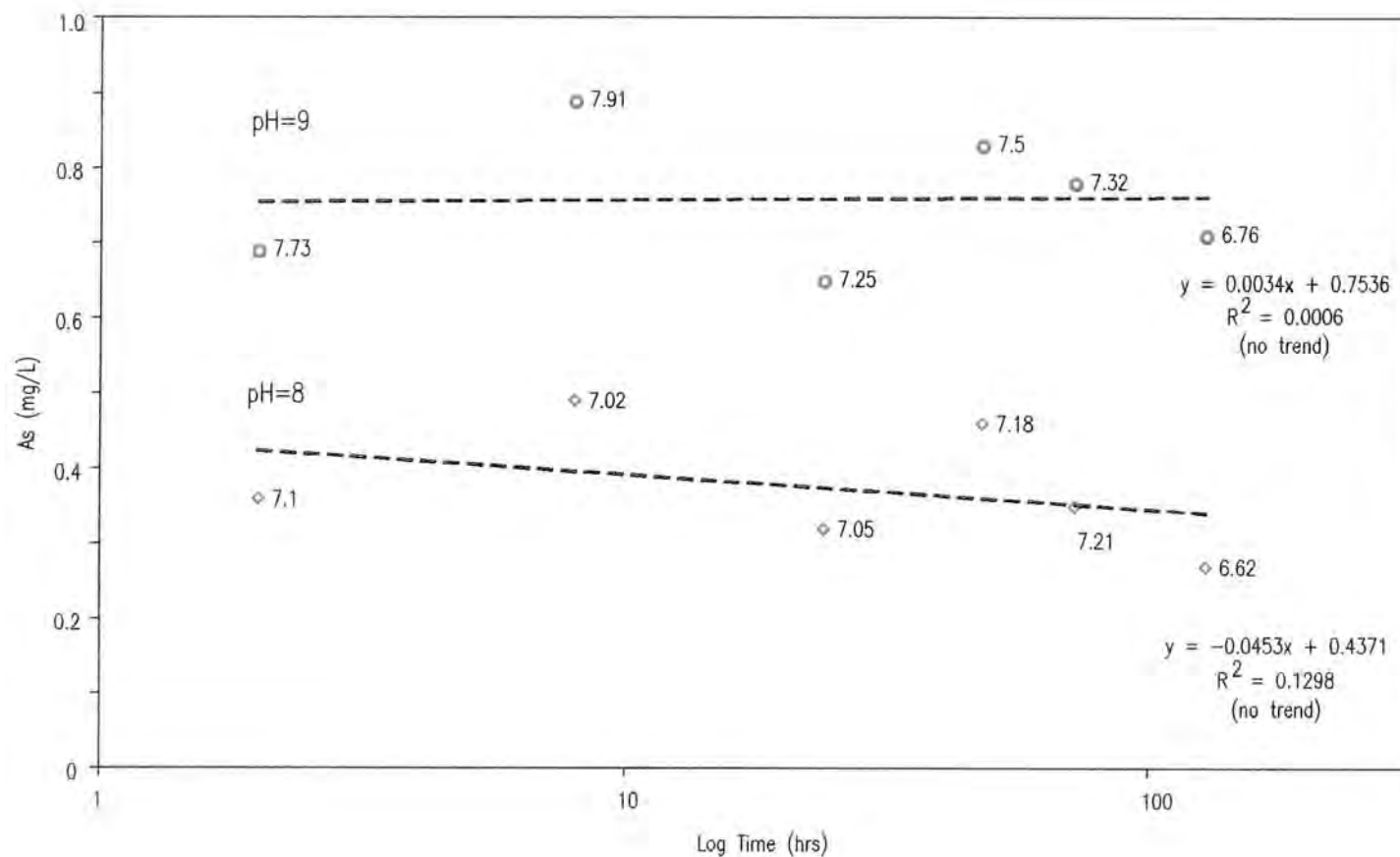
NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



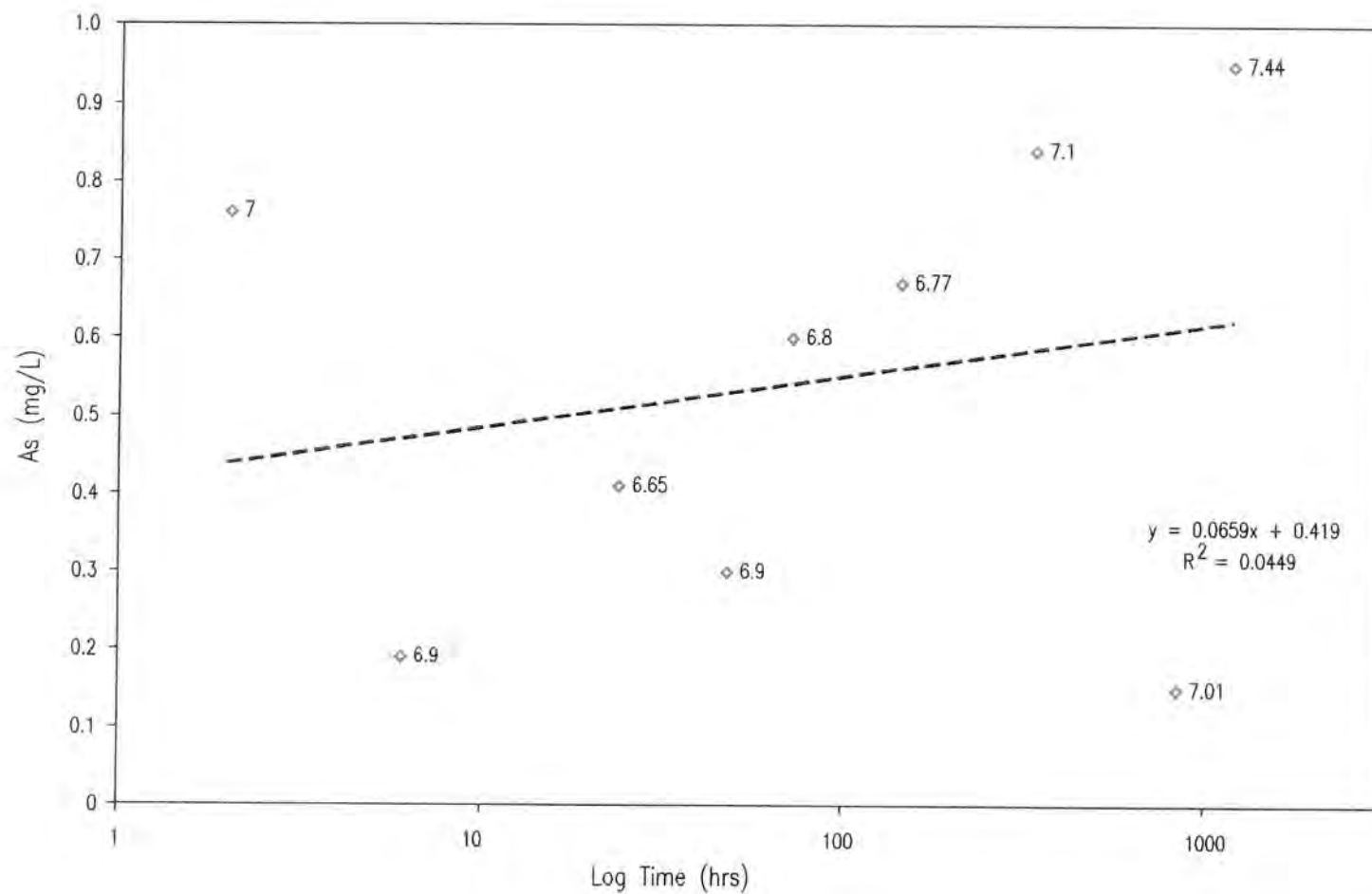
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APPENDIX 3



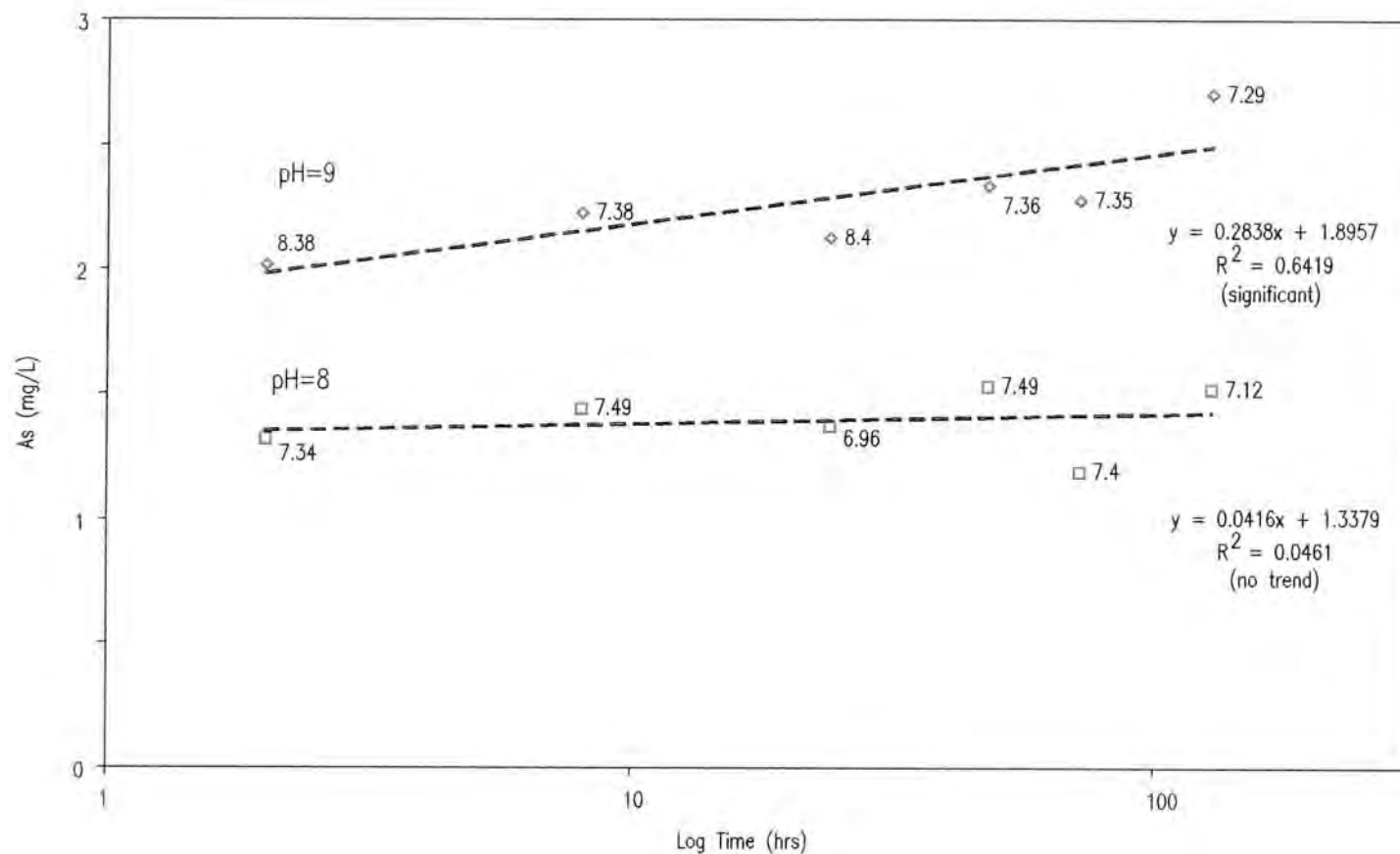
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APPENDIX 3



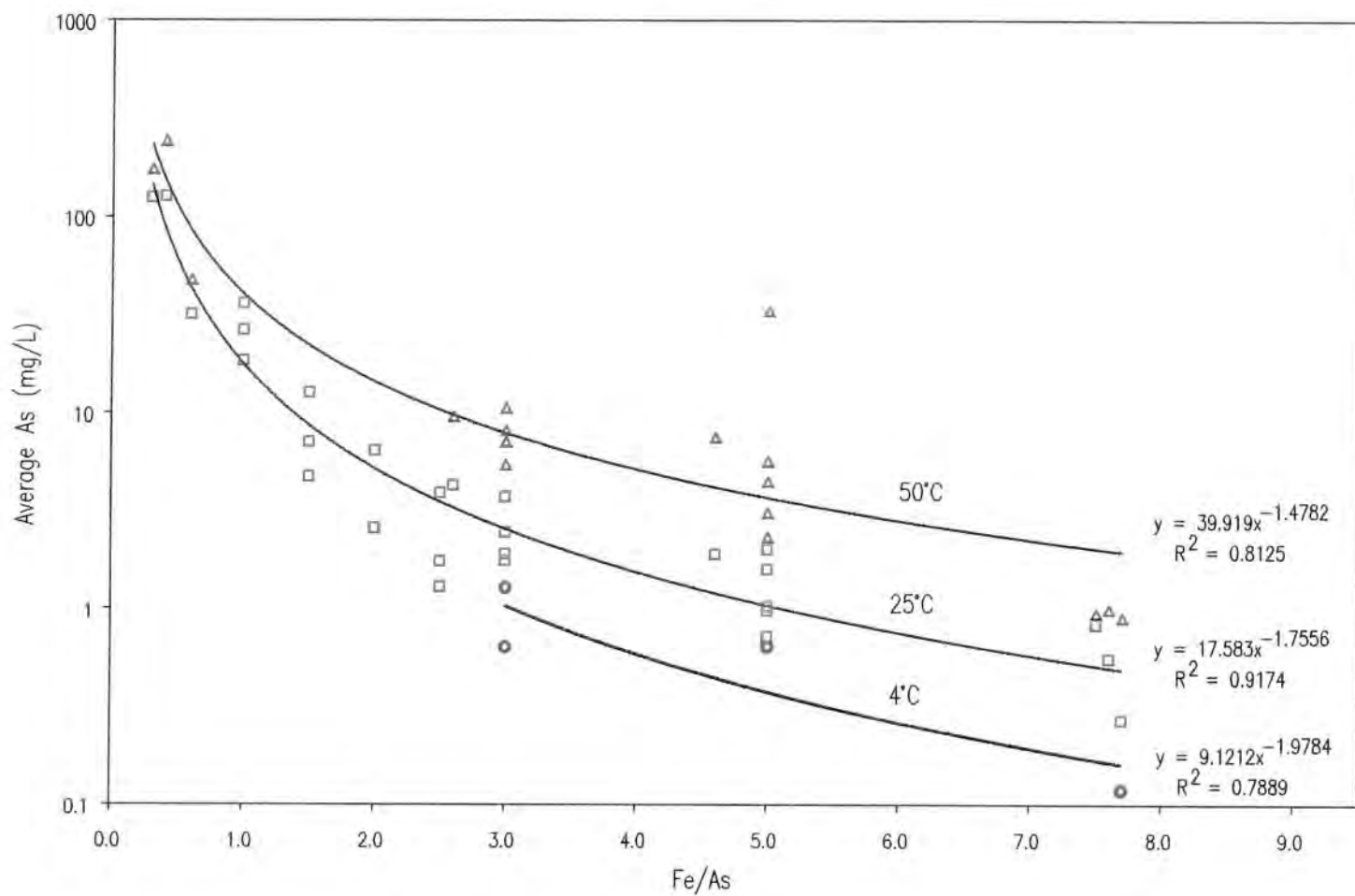
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APPENDIX 3

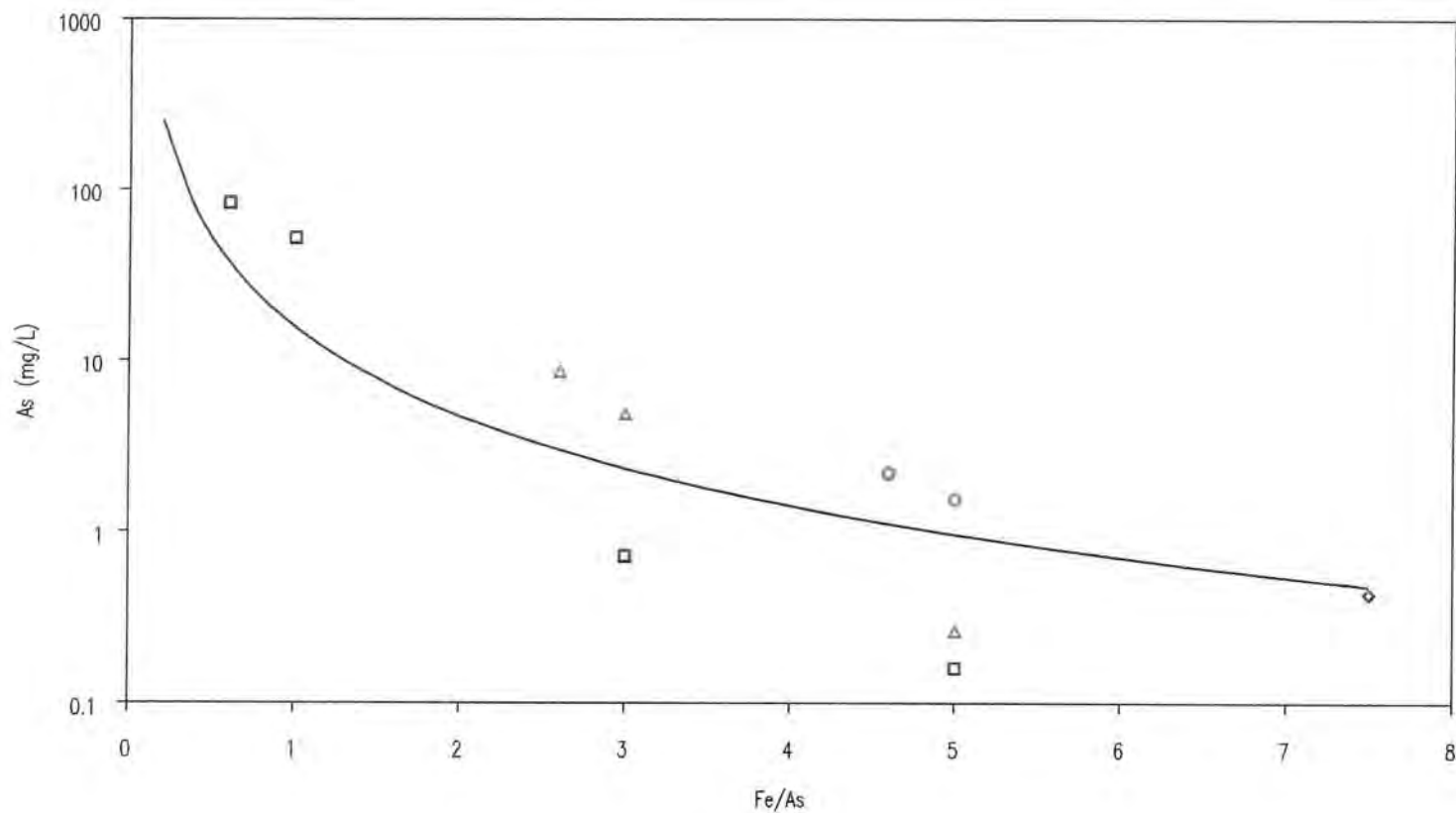


NOTE: ALSO SHOWN ARE EQUATIONS FOR LINEAR REGRESSIONS OF THE DATA, AND MEASURED pH VALUES FOR EACH DATA POINT.

APPENDIX 3



APPENDIX 3



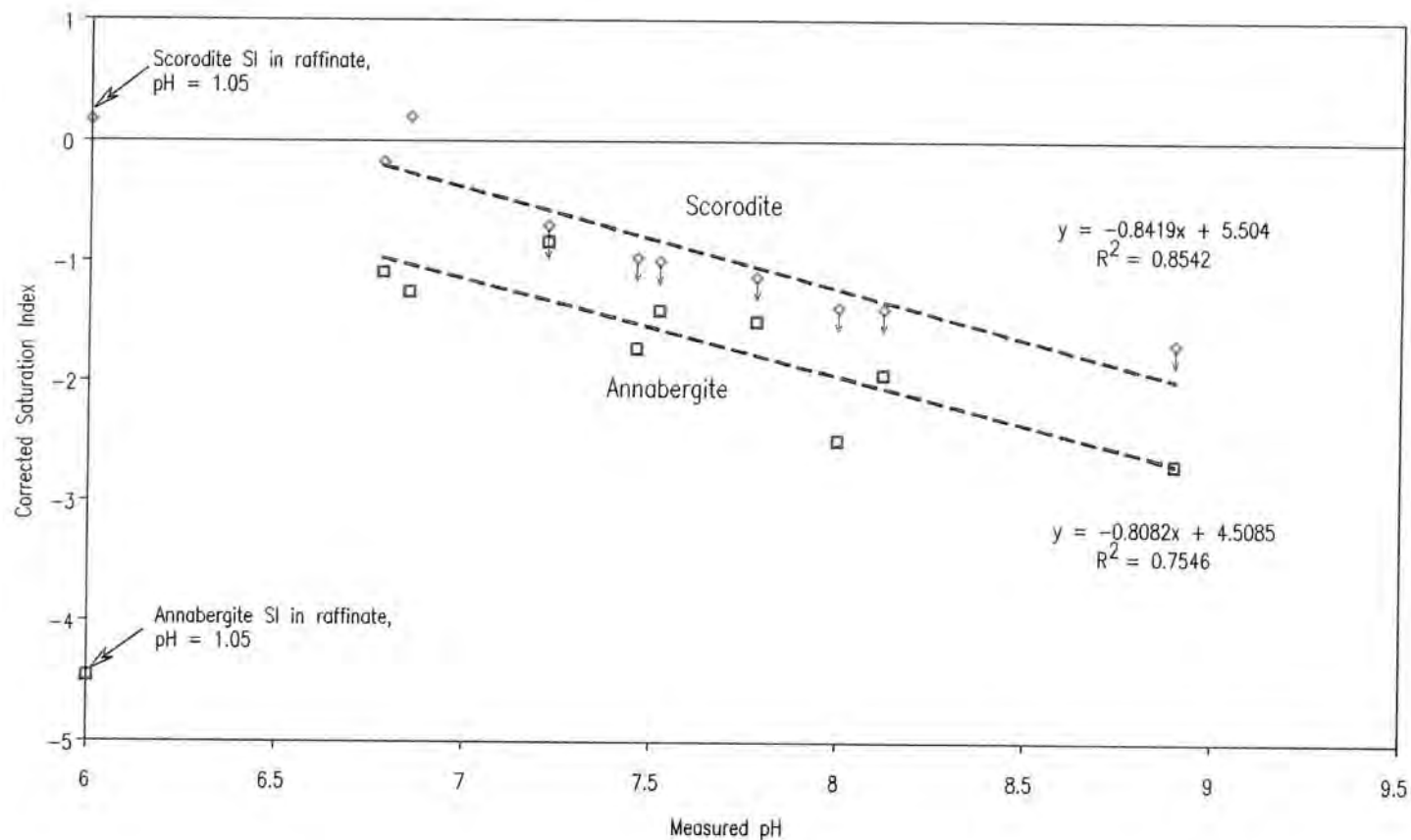
▲ JEB ○ McClean Lake — Average shown in Fig. 28
 □ SUE A+B ◇ Cigar Lake

Arsenic concentrations in some tailings pore waters
 at pH 7.5 (the data points) computed with PHREEQC,
 compared to the regression line describing
 average arsenic concentration at 25°C

APPENDIX 3

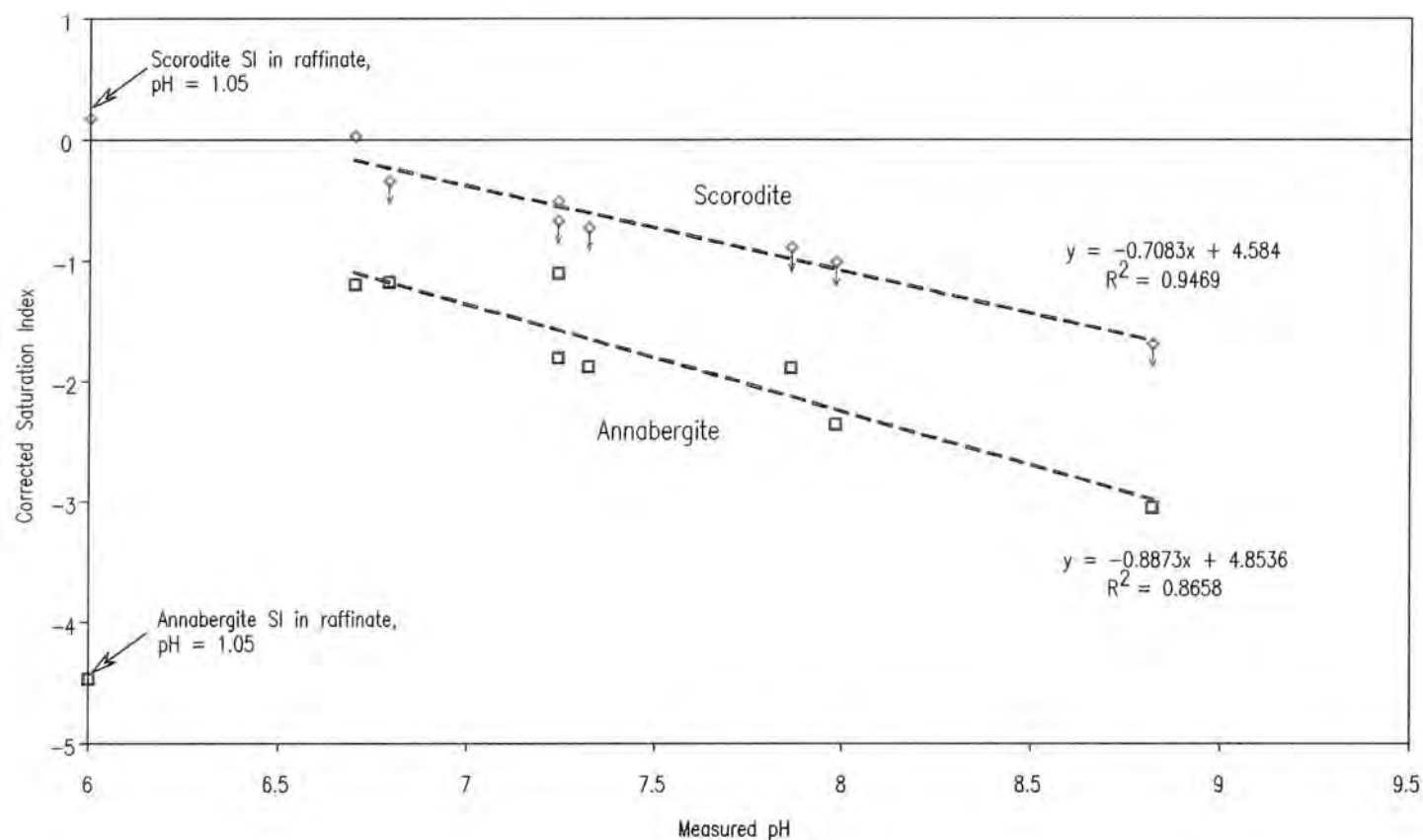
FIGURE

29



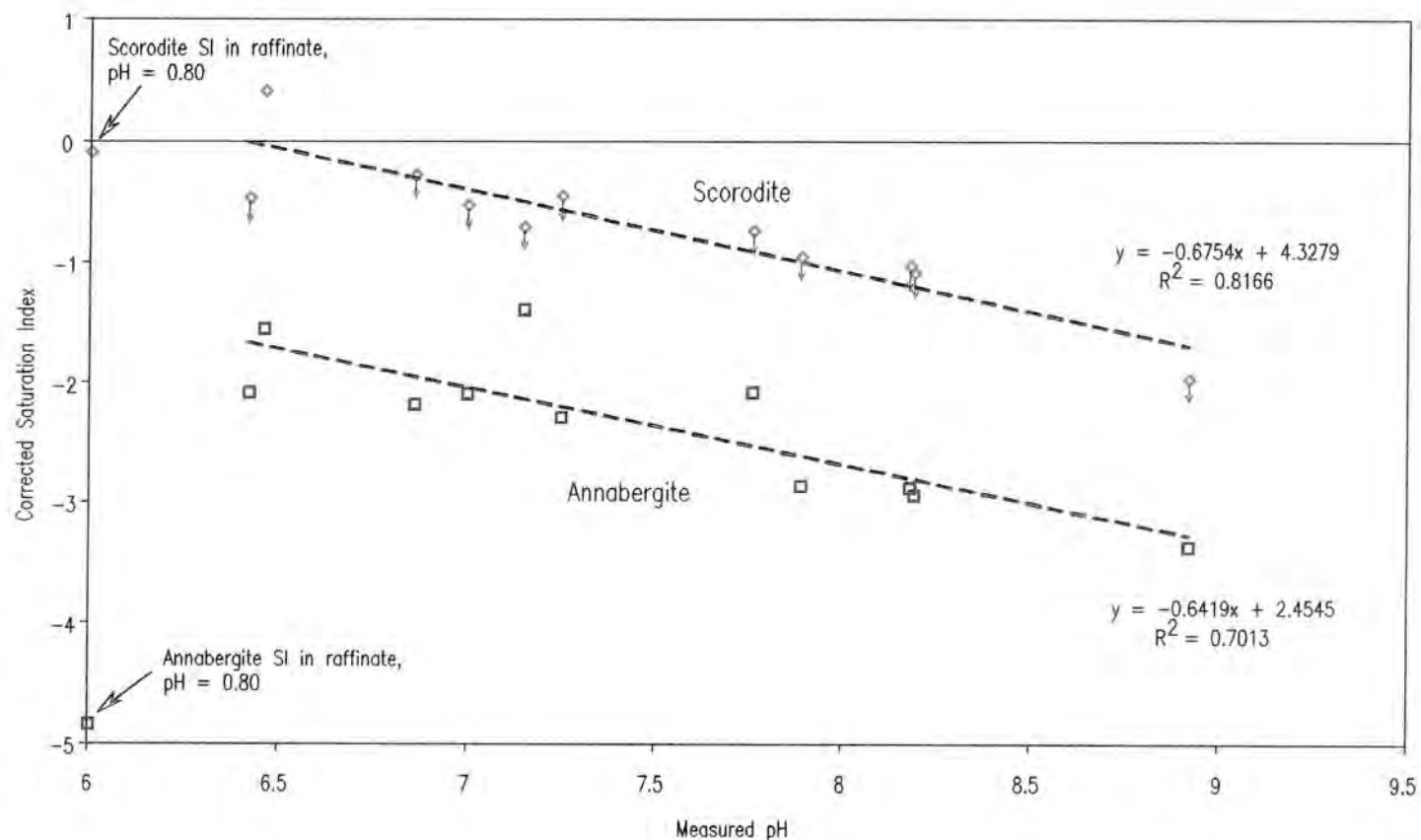
NOTE: AGING TIMES FROM 0 TO 120 HOURS. SI VALUES IN MINTEQA2 DIVIDED BY NUMBER OF SPECIES IN FORMULA EXCLUDING STRUCTURAL H₂O. RAFFINATE VALUES NOT USED IN REGRESSIONS. SCORODITE SI VALUES SHOWN WITH ARROW (↓) ARE UPPER BOUNDS (SEE TEXT).

APPENDIX 3



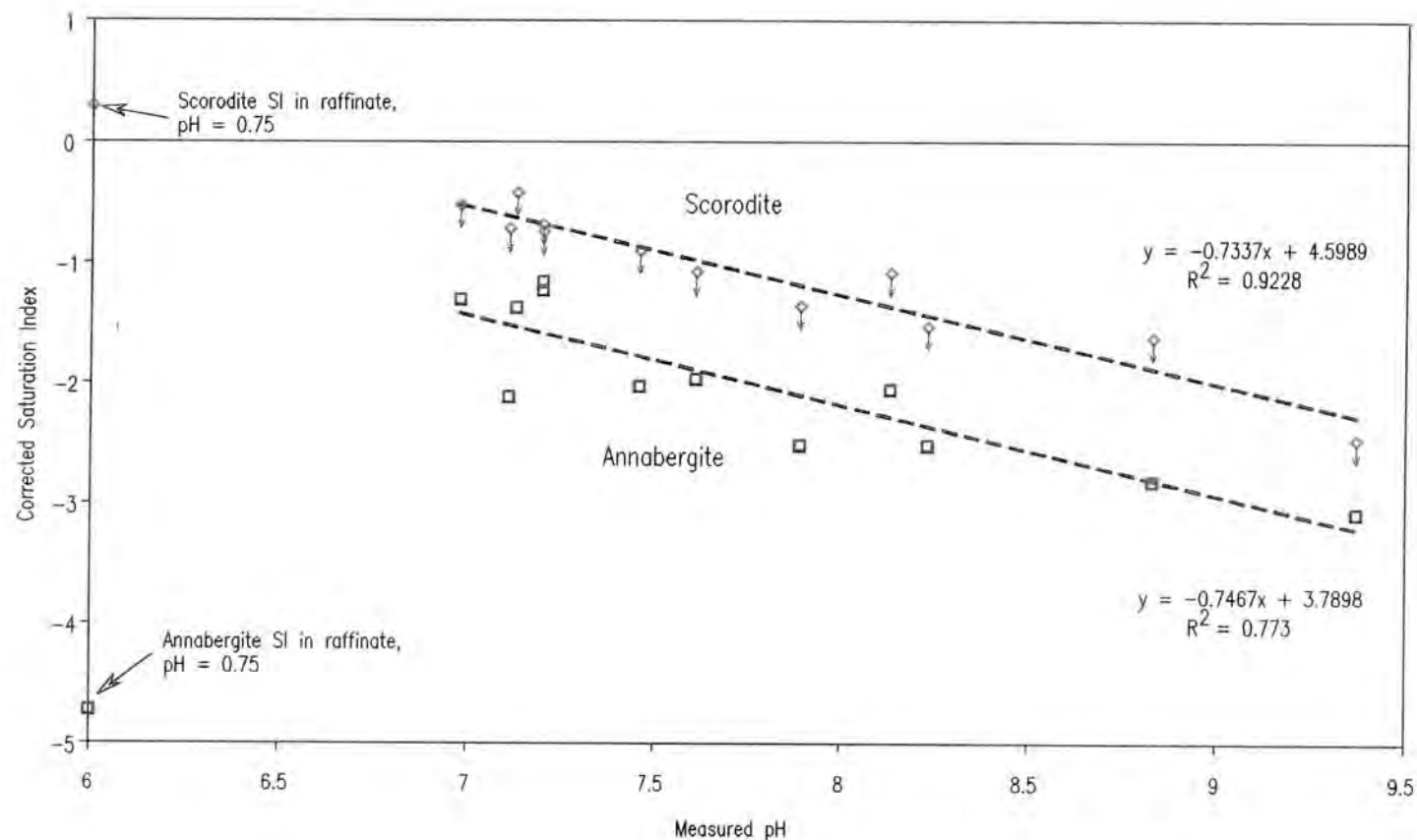
NOTE: AGING TIMES FROM 0 TO 120 HOURS. SI VALUES IN MINTEQA2 DIVIDED BY NUMBER OF MOLES OF SPECIES IN FORMULA EXCLUDING STRUCTURAL H₂O. RAFFINATE VALUES NOT USED IN REGRESSIONS. SCORODITE SI VALUES SHOWN WITH ARROW (↓) ARE UPPER BOUNDS (SEE TEXT).

APPENDIX 3



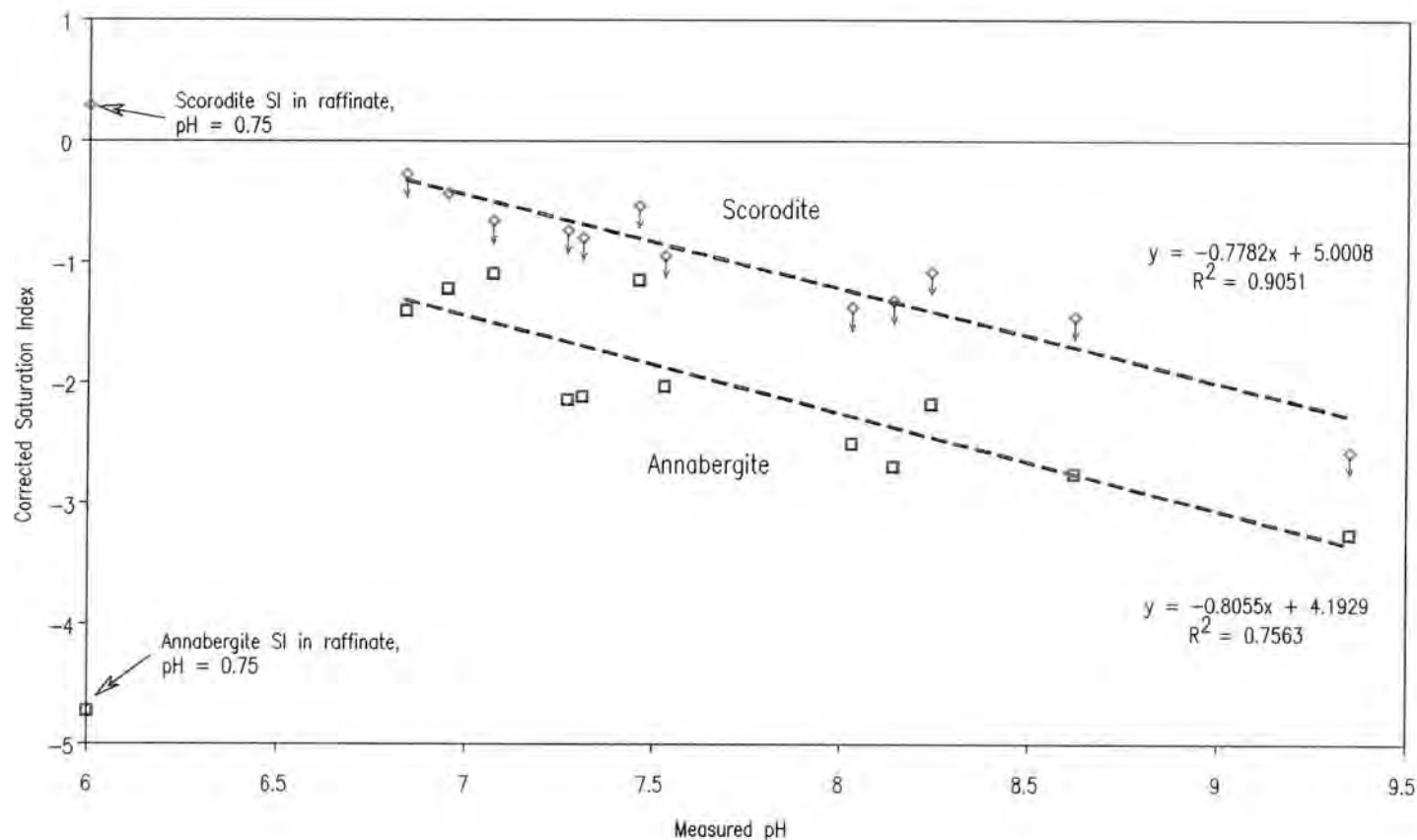
NOTE: AGING TIMES FROM 0 TO 120 HOURS. SI VALUES IN MINTEQA2 DIVIDED BY NUMBER OF MOLES OF SPECIES IN FORMULA EXCLUDING STRUCTURAL H₂O. RAFFINATE VALUES NOT USED IN REGRESSIONS. SCORODITE SI VALUES SHOWN WITH ARROW (↓) ARE UPPER BOUNDS (SEE TEXT).

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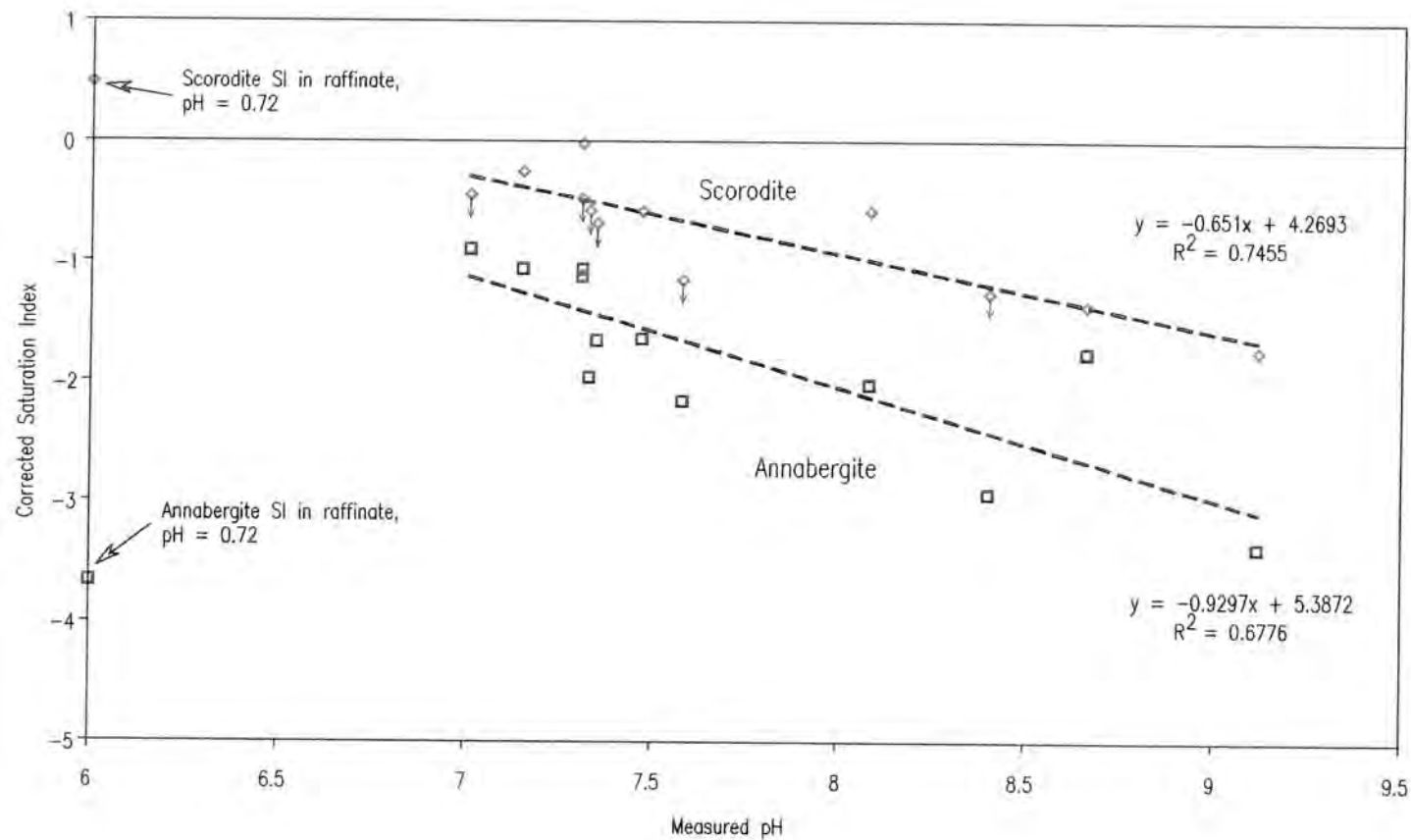
NOTE: AGING TIMES FROM 0 TO 120 HOURS. SI VALUES IN MINTEQA2 DIVIDED BY NUMBER OF MOLES OF SPECIES IN FORMULA EXCLUDING STRUCTURAL H₂O. RAFFINATE VALUES NOT USED IN REGRESSIONS. SCORODITE SI VALUES SHOWN WITH ARROW (↓) ARE UPPER BOUNDS (SEE TEXT).

APPENDIX 3



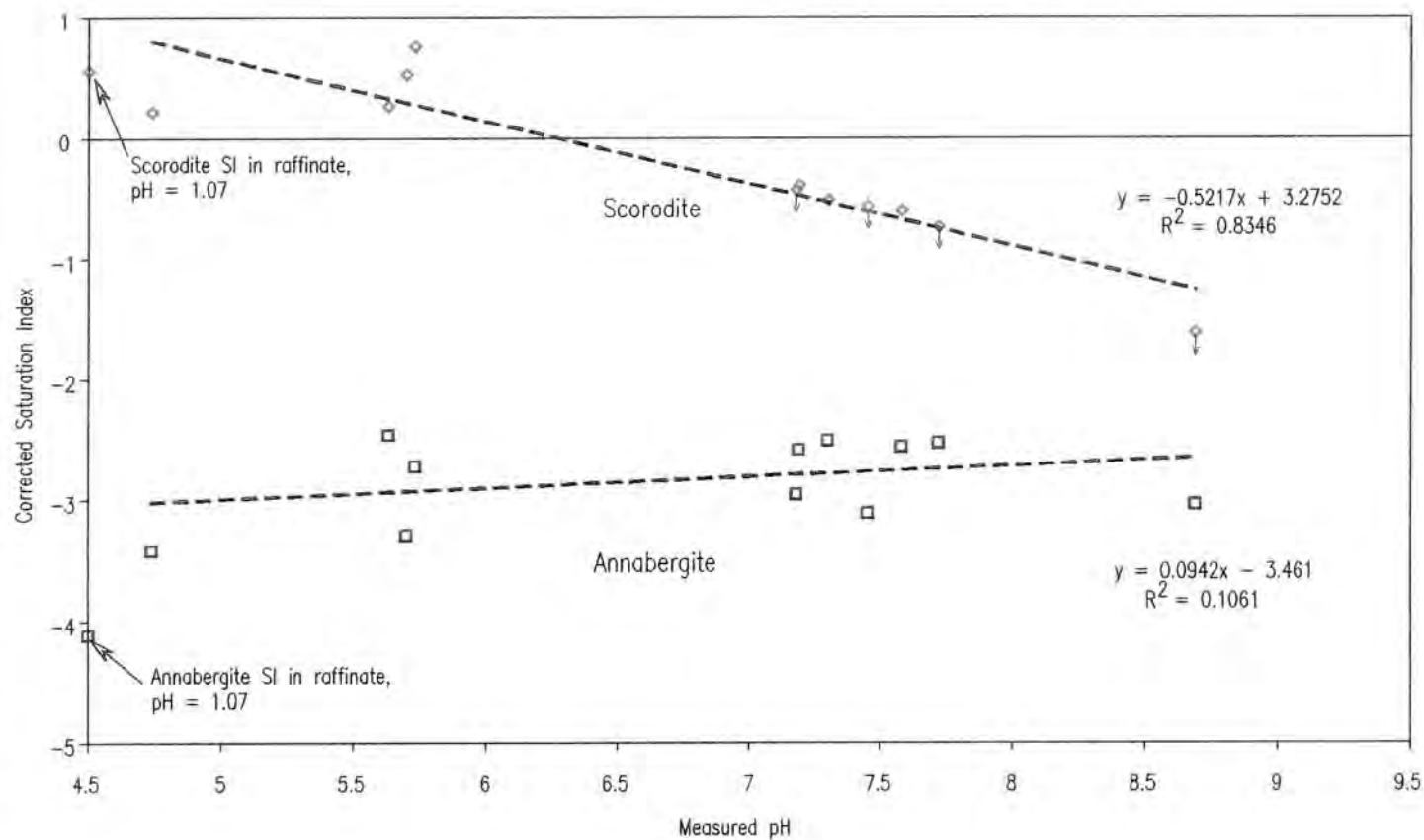
NOTE: AGING TIMES FROM 0 TO 120 HOURS. SI VALUES IN MINTEQA2 DIVIDED BY NUMBER OF MOLES OF SPECIES IN FORMULA EXCLUDING STRUCTURAL H₂O. RAFFINATE VALUES NOT USED IN REGRESSIONS. SCORODITE SI VALUES SHOWN WITH ARROW (↓) ARE UPPER BOUNDS (SEE TEXT).

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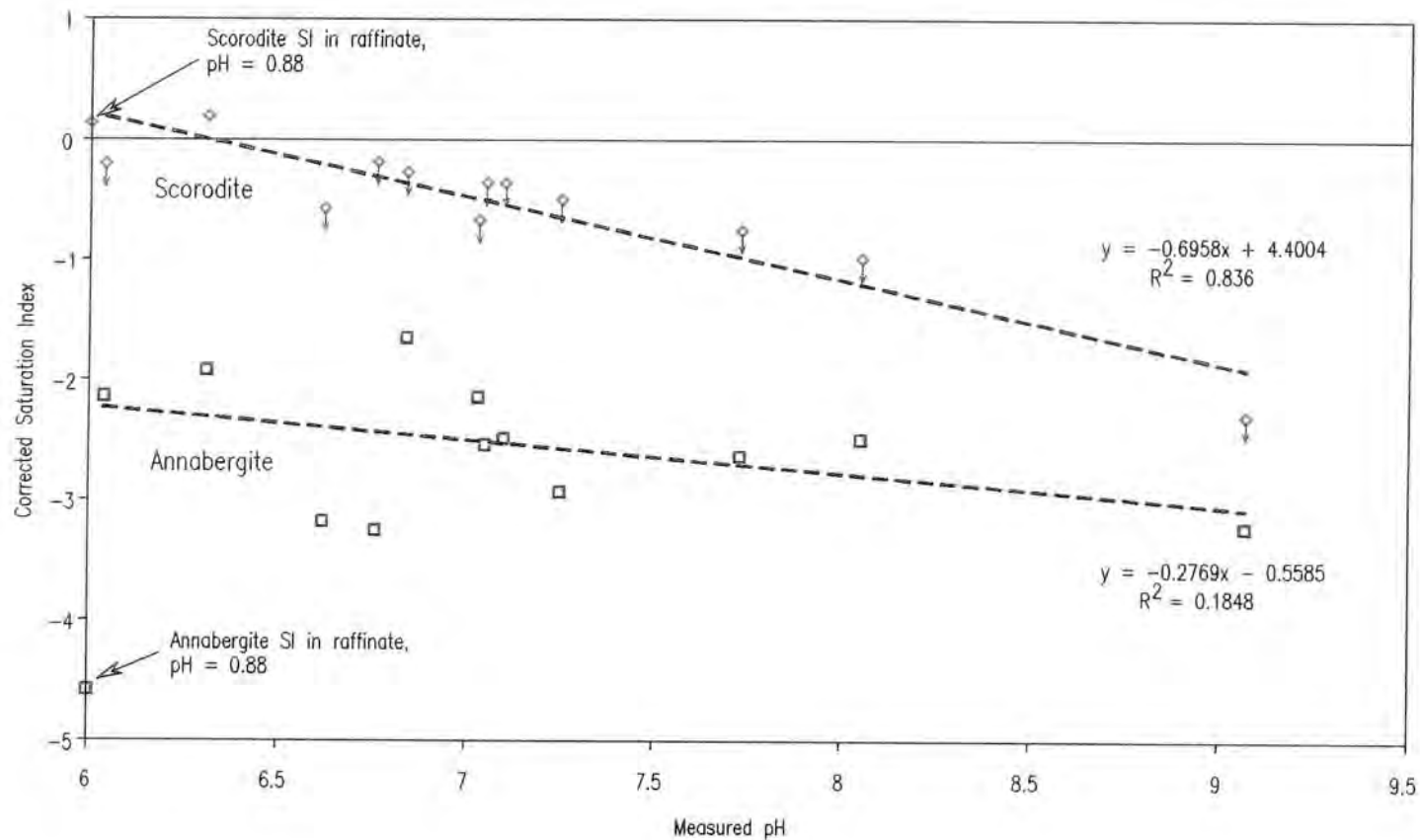
NOTE: AGING TIMES FROM 0 TO 120 HOURS. SI VALUES IN MINTEQA2 DIVIDED BY NUMBER OF MOLES OF SPECIES IN FORMULA EXCLUDING STRUCTURAL H₂O. RAFFINATE VALUES NOT USED IN REGRESSIONS. SCORODITE SI VALUES SHOWN WITH ARROW (↓) ARE UPPER BOUNDS (SEE TEXT).

APPENDIX 3



NOTE: AGING TIMES FROM 0 TO 120 HOURS. SI VALUES IN MINTEQA2 DIVIDED BY NUMBER OF MOLES OF SPECIES IN FORMULA EXCLUDING STRUCTURAL H₂O. RAFFINATE VALUES NOT USED IN REGRESSIONS. SCORODITE SI VALUES SHOWN WITH ARROW (↓) ARE UPPER BOUNDS (SEE TEXT).

APPENDIX 3



NOTE: AGING TIMES FROM 0 TO 120 HOURS. SI VALUES IN MINTEQA2 DIVIDED BY NUMBER OF MOLES OF SPECIES IN FORMULA EXCLUDING STRUCTURAL H₂O. RAFFINATE VALUES NOT USED IN REGRESSIONS. SCORODITE SI VALUES SHOWN WITH ARROW (↓) ARE UPPER BOUNDS (SEE TEXT).

APPENDIX 3

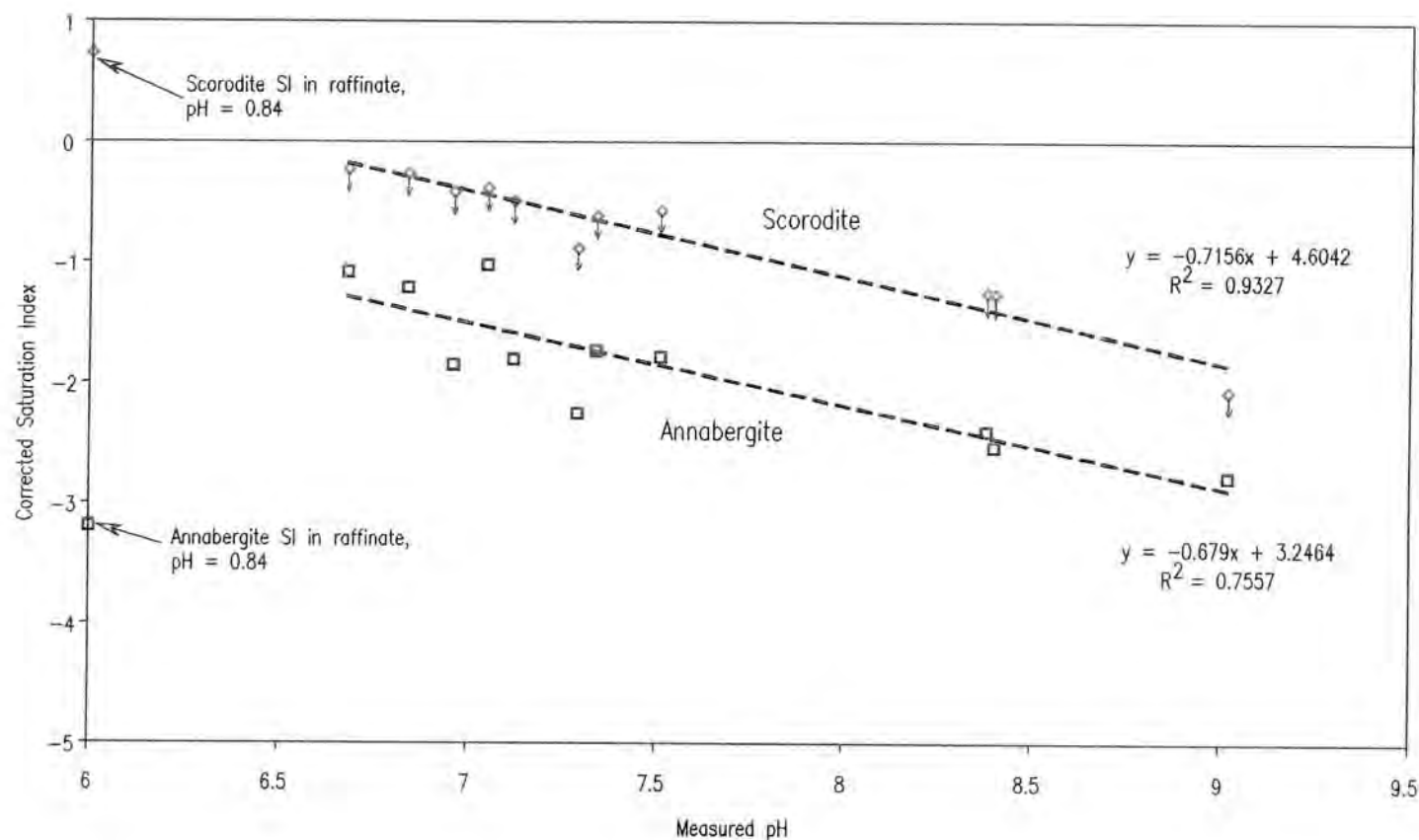
HCI HYDROLOGIC
CONSULTANTS, INC.

JOB NO: HCI-1722	DATE: 4/20/98
BY: AKM	DRAWING: GRAF-SAT
CHKD:	PLOT: S-BLD1

Saturation state of Blend 1 (75% Sue C + 25% Cigar Lake) tailings with molar Fe/As=7.6 at 25°C with respect to scorodite (FeAsO₄·2H₂O) and annabergite (Ni₃(AsO₄)₂·8H₂O) vs. measured pH

FIGURE

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NOTE: AGING TIMES FROM 0 TO 120 HOURS. SI VALUES IN MINTEQA2 DIVIDED BY NUMBER OF MOLES OF SPECIES IN FORMULA EXCLUDING STRUCTURAL H₂O. RAFFINATE VALUES NOT USED IN REGRESSIONS. SCORODITE SI VALUES SHOWN WITH ARROW (↓) ARE UPPER BOUNDS (SEE TEXT).

APPENDIX 3

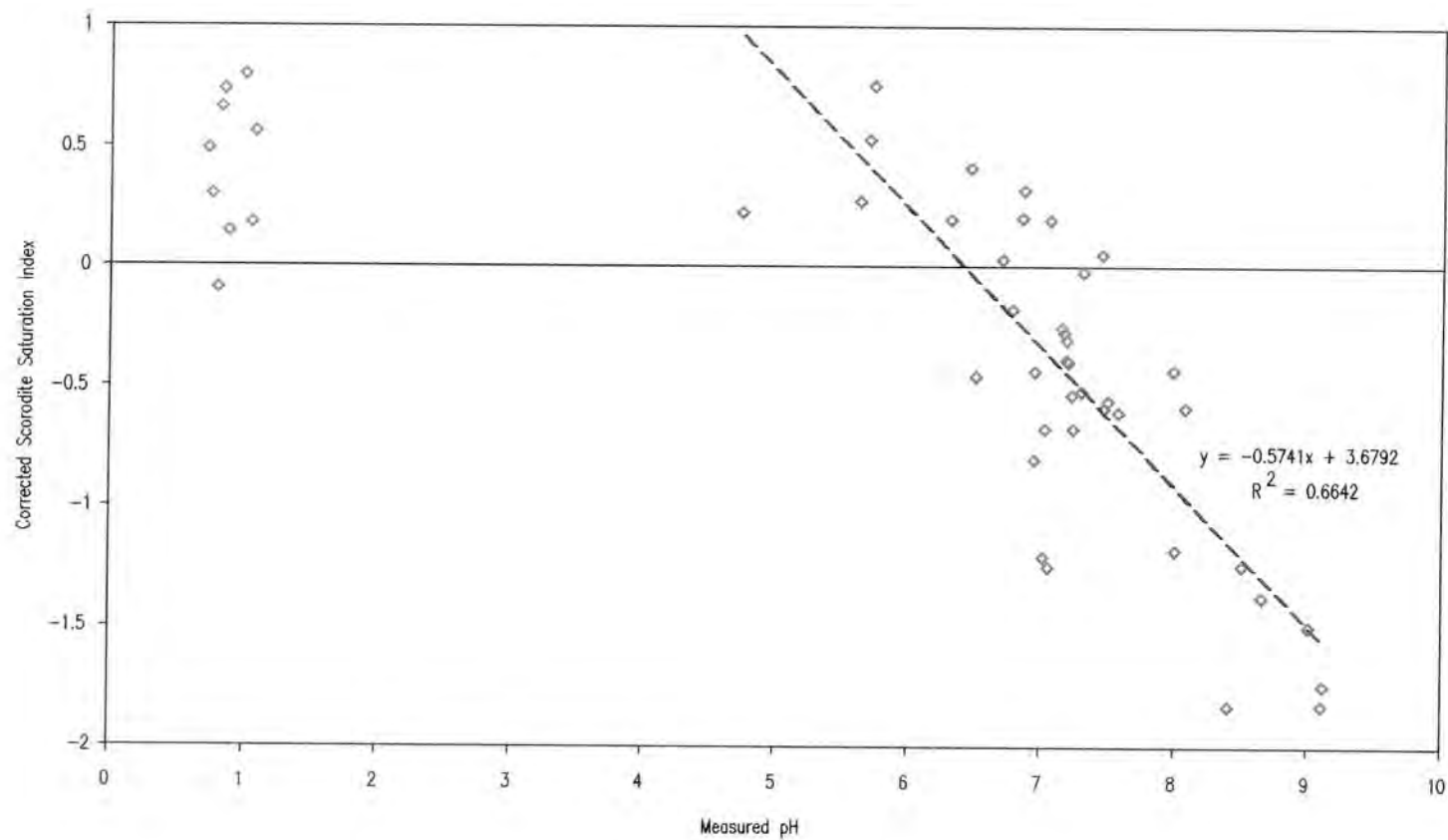
HCI HYDROLOGIC
CONSULTANTS, INC.

JOB NO: HCI-1722	DATE: 4/20/98
BY: AKM	DRAWING: GRAF-SAT
CHKD:	PLOT: S-BLD2

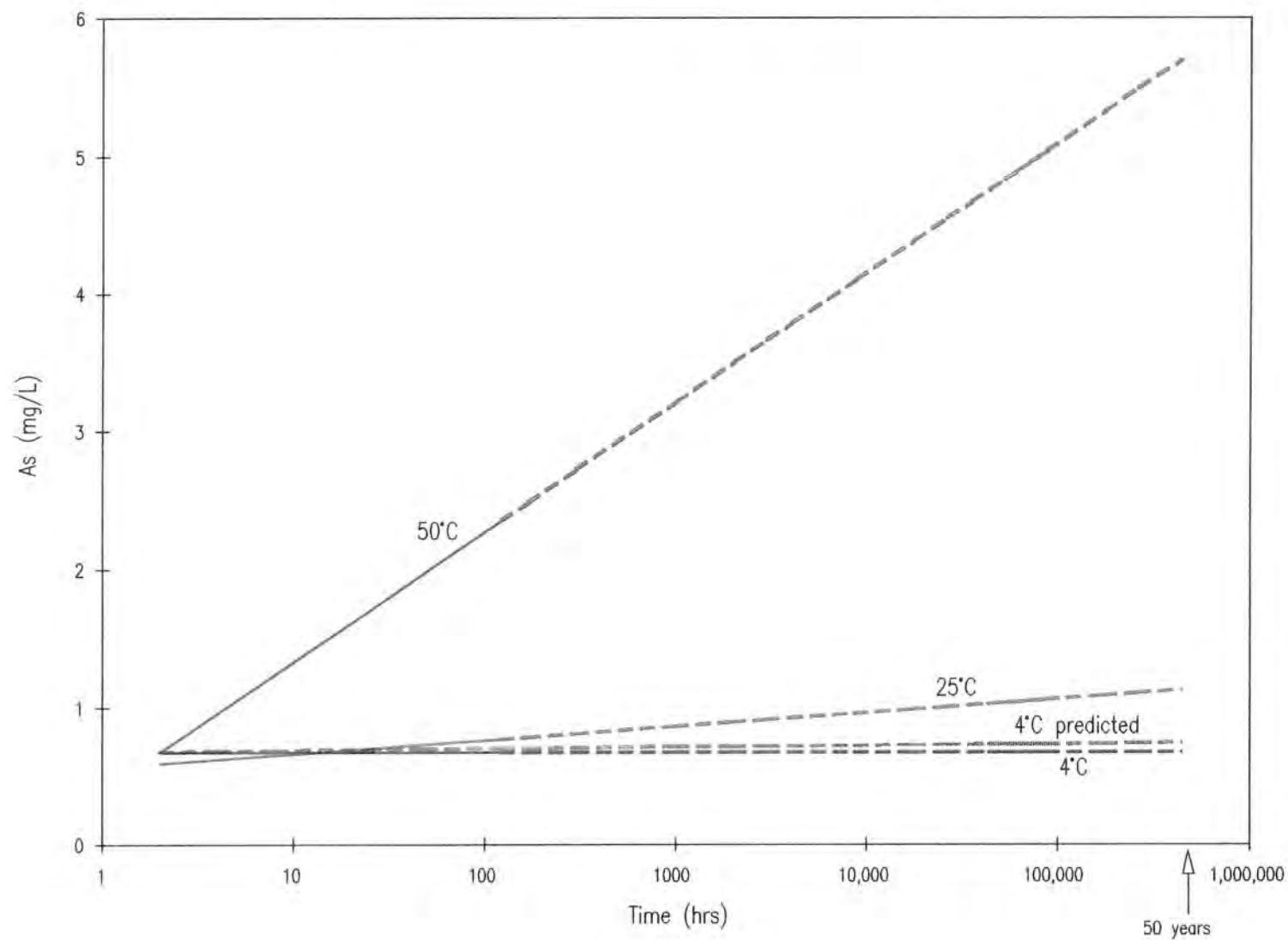
Saturation state of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings with molar Fe/As=3.0 at 25°C with respect to scorodite (FeAsO₄·2H₂O) and annabergite (Ni₃(AsO₄)₂·8H₂O) vs. measured pH

FIGURE

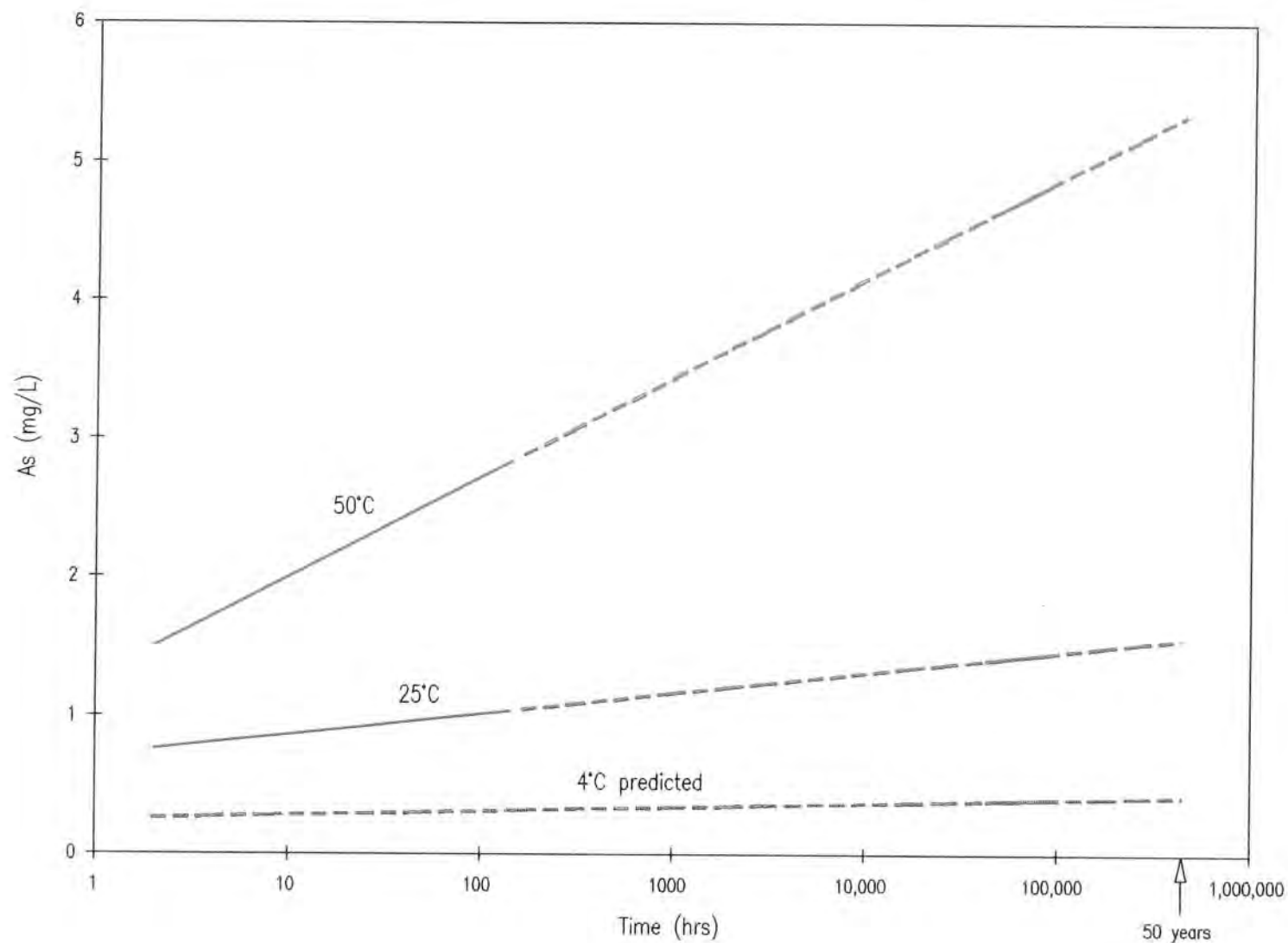
38



APPENDIX 3



APPENDIX 3



APPENDIX 3

Appendix C

Section C - Part A

Subsection C: Chemical Analytical Methods and Results

APPENDIX C

CHEMICAL ANALYTICAL METHODS AND RESULTS

- C1. Experimental Procedures Used in the Large-Scale Tests**
- C2. Methods of Chemical Analysis**
- C3. Chemical Analytical Results**

APPENDIX C – CHEMICAL ANALYTICAL METHODS AND RESULTS

SECTION C.1 EXPERIMENTAL PROCEDURES USED IN THE LARGE SCALE TESTS

1.0 INTRODUCTION

This appendix describes procedures used in the testing of tailings and raffinate samples. The primary purpose of the testing was to determine the optimum pH and Fe/As molar ratio for the various tailings that will be placed in the JEB Tailings Management Facility (TMF) so as to stabilize the concentrations of arsenic to values as low as possible.

The tests were carried out at COGEMA's Service D'etude de Procédés et Analyses (SEPA) facility in Bessines, France. Drs. Donald Langmuir and John Mahoney designed the testing procedures, and Drs. Michel Roche and Isabelle Picquet of SEPA carried out the testing. Analytical procedures used at SEPA are described in Section C.2 of this appendix. Initial testing was performed during October and November 1997. Additional testing was initiated in December and continued through February 1998.

The experiments were performed at nominal pH values of 7.0, 8.0, and 9.0. Therefore, sample sets consisted of groups of three reaction vessels.

The initial iron to arsenic ratio (also called the natural value) for each tailings sample was determined from an analyses of the raffinate from the particular tailings material. The Fe/As ratios used in the tests are given in Table 1.4, 2.1.2 in the text.

Experiments conducted during October and November 1997 were run at 25° and 50°C. Additional testing was also performed on samples from the JEB and SUE C ores at temperatures of 4°C, which is the temperature anticipated in the TMF. This testing at 4°C was initiated in December 1997 and followed the same procedures as described for the 25° and 50°C measurements except that the samples were stored in a refrigerator. The low temperature experiments were run for up to 1008 hours for the JEB materials and 1176 hours for the SUE C tailings.

In addition to the two procedures outlined below, partial extractions using hydroxylamine-HCl were performed to estimate the amounts of amorphous iron and aluminum phases present in the tailings. The extraction procedure is included as part of Section C.2 of this appendix.

2.0 DESCRIPTION OF TEST PROCEDURES FOR TAILINGS AND RAFFINATE

The following test procedures were designed to evaluate the impact of iron (III) additions on dissolved arsenic concentrations in tailings and raffinates that will be disposed of in the JEB Tailings Management Facility (TMF), as a function of the Fe(III)/As ratio and pH of the raffinate. The tests are batch tests, with tailings solids and liquids from the first tests supplying starting material for the second tests. The first set of tests, which involve the addition of lime and iron(III) sulfate to the raffinate solution, were intended to define optimum conditions for removal of dissolved arsenic from the raffinates during processing of the tailings. The first set of tests were performed in contact with atmospheric oxygen (air) and were run for approximately 3 hours, the expected residence time of the JEB tailings during neutralization in the mill.

The second set of tests, which took from five days (128 hours) to 49 days (1176 hours), were designed to help predict dissolved arsenic concentrations in ground waters within the TMF long-term after tailings disposal. The tests were run under oxygen-free (strictly anaerobic) conditions at 4°, 25°, and 50°C. In order to speed up the tests, the 25°C and 50°C reaction vessels were agitated on a shaker table.

The first test procedure was designed to simulate expected processing conditions in the mill. In the mill processing, the current proportion of raffinate to tailings will be 6 m³ of raffinate per tonne of tailings, therefore, the proportions of raffinate to tailings in the tests reflect this 6:1 ratio.

Results from these experiments were used to estimate reaction rates to permit long term predictions of arsenic concentrations within the TMF, consequently, the time between the completion of first procedure and the second procedure was as short as possible.

3.0 EQUIPMENT

In addition to standard laboratory equipment, such as balances, filtration equipment, and specific conductance and pH and Eh meters the following items were required.

For the Procedure 1 experiments, high density polyethylene bottles, approximately 8 to 10 liters capacity were recommended. The vessels were acid washed and rinsed in deionized or distilled water prior to use.

For the Procedure 2 experiments, high density polyethylene bottles of approximately 2 liters capacity were specified. The vessels were acid washed and rinsed in deionized or distilled water prior to use.

Procedure 2 also required two thermostat shaker tables (water baths) capable of maintaining temperatures up to 50°C. One shaker table operated at 25°C and the other operated at 50°C.

4.0 INITIAL SETUP

1. Tailings and raffinates were prepared based upon current tailings processing procedures.
2. The lime slurry (slaked lime also known as $\text{Ca}(\text{OH})_2$) was prepared based upon 15 percent $\text{Ca}(\text{OH})_2$ by weight.
3. The ferric sulfate solution - 12.6 percent was prepared based upon iron by weight.
4. The tailings solids and raffinate were analyzed for the parameters listed in paragraph 5. Concentrations of iron and arsenic in the raffinate were determined before the amounts of iron to be added to provide the specified Fe/As ratio were calculated.
5. For all liquid samples (e.g., solids, raffinate and filtered liquids) the standard list of analytical parameters included pH, conductivity, Eh, total iron and speciated iron, total arsenic, and a separate analysis for speciated arsenic, sulfide, sulfate, alkalinity, nitrate and other standard

parameters including Cl, Ca, Na, Mg, Al, U, K, P, Ni and other trace metals (such as Pb) and radionuclides (such as Ra). Because of limited sample volumes, a shorter list of analyses was also used (see Table C-1).

5.0 PROCEDURE 1 – SHORT TERM TESTS

1. Each reaction vessel contained 1 kilogram of tailings and 6.0 liters of raffinate. The vessels had some additional empty volume to accommodate the added lime slurry and the ferric sulfate solution. Therefore, the final ratio of liquid to solids in the vessels was slightly greater than 6 to 1.
2. The amounts of material added to the vessels were measured gravimetrically. The following masses were recorded; mass of vessel (empty), then mass with tailings, raffinate, iron solution added, lime slurry added.
3. To assist in the evaluation of reaction rates (see Procedure 2), the date and time of each chemical addition were recorded.
4. The Fe/As ratio for the various tests were defined as follows:

- 1 - Natural Fe/As molar ratio were calculated from Fe and As concentrations in each raffinate
=

$$\text{Natural Fe/As molar ratio} = \frac{(Fe_0, \text{mg/l})}{55.85} \times \frac{74.92}{(As_0, \text{mg/l})}$$

(Fe₀, mg/l), (As₀, mg/l) = concentrations in the raffinate.

- 2 - Higher Fe/As molar ratios (e.g., 3:1 or 5:1) were achieved by adding a calculated amount of ferric ions =

Example: the objective is Fe/As = 3:1.

$$\text{Target amount of iron: } (Fe_1, \text{ mg/l}) = \frac{(As_0, \text{ mg/l})}{74.92} \times 3 \times 55.85$$

$$\text{In addition: } (Fe_2, \text{ mg/l}) = (Fe_1, \text{ mg/l}) - (Fe_0, \text{ mg/l}).$$

$$\text{Ferric sulfate addition: } (Fe_2(SO_4)_3 \times H_2O, \text{ mg/l}) = \frac{Fe_2, \text{ mg/l}}{111.7} \times 400$$

Ferric sulfate solution was added so that the proportions of added iron to arsenic (molar ratios) were 0:1 (blank or natural ratio, no additional iron required), 3:1, and 5:1 for example. The iron to arsenic ratio was based upon the arsenic concentration in the raffinate only, not in the tailings. For example, if the raffinate contained 330 mg/L arsenic, then the iron concentration in a 2:1 mixture was 480 mg/L. To prepare the 3:1 mixture an additional 240 mg/L was required. For six liters of raffinate, 1.45 grams of iron were required. The supplied solution of ferric sulfate was 12.6 percent iron (126 grams/L). Therefore, 11.5 ml of ferric sulfate solution was added to increase the ratio from the initial 2:1 ratio to 3:1.

5. The $Ca(OH)_2$ slurry was added to each of the vessels to obtain nominal pH values of 7, 8, and 9, and the pH's after slurry addition were recorded.

6. The $Ca(OH)_2$ was added to each of the vessels to obtain a nominal pH value of 5 during 90 minutes, to simulate the operations in the mill.

7a. For JEB, Sue C., McClean and Sue A+B tailings samples, additional $Ca(OH)_2$ was added to each of the vessels to obtain nominal pH values of 7, 8, or 9. Each pulp was neutralized.

7b. For the blends and Cigar Lake tailings samples¹

After neutralization at pH 5, tailings were filtered. Filtrates were treated apart. Barium chloride (100 g/m³) was added at this stage and filtrates were neutralized at pH 7, 8, or 9 for 90 minutes. After this operation, tailings solids and solutions were mixed again and neutralized at pH 7, 8, or 9 for 90 minutes.

¹ 7b: In JEB mill, tailings neutralizations operations will be different for McClean ores and Midwest and Cigar Lake ores.

8. After completion of slaked lime addition, the filled vessels were continually agitated for two hours. The vessels were decanted for 1 hour to allow the solids to settle. The supernatant liquid was removed without disturbing the solids. The decanted liquid was filtered with a 0.45 micron filter and analyzed for the complete list of parameters.

9. The remaining solids and liquids were filtered. In this step the solids were separated from the liquids to make handling and recompositing easier in Procedure 2. Procedure 2 started immediately after completion of Procedure 1.

6.0 PROCEDURE 2 – AGING TESTS

1. The tailings within the TMF should become anaerobic because of the presence of Fe(II) minerals and traces of arsenide and sulfide minerals in the solids. To assure that the experiments reflect the anticipated conditions in the TMF, oxygen was excluded from the Procedure 2 reaction vessels at all times during the experiments.

2. To maintain anaerobic conditions, the vessels were equipped with an airtight sampling port. During the course of the study, small aliquots of the liquid were removed for chemical analyses. Each bottle top was equipped with two tubes holding stopcocks in order to blow nitrogen gas through one tube (to remove excess oxygen). The second tube was placed in the liquid and was used to recover samples. The samples were frequently analyzed for conductivity and pH to monitor reaction progress.

3. For the second set of tests an approximately 2:1 ratio of tailings to liquid was desired. For each sample from the first test, the wet solids were split into two separate vessels (approximately equal proportions). The mass of solids was recorded. Enough liquid was added so that each vessel contained a total of 1 liter of liquid and approximately 500 grams of tailings.

4. To remove excess oxygen, samples were sparged with nitrogen gas for 20 to 30 minutes. Stopcock grease was used to seal the vessels and to prevent oxygen entry.

5. The vessels were placed on shaker tables to speed up the tests, and keep most of the solids in suspension. Some samples were maintained at 25°C and others at 50°C.

6. Samples were collected in accordance with the attached schedule (Table C-1). To minimize changes to the solid to liquid ratios in the vessels during the experiments, only the minimum volume of sample required for an analyses was removed. To recover samples, a volume of pump was sampled by blowing nitrogen gas into the vessel. Pressure forced liquid out through the second tube in the vessel.

SECTION C2. METHODS OF CHEMICAL ANALYSIS

Analytical methods employed at SEPA are summarized in Table C-2.

The partial extraction method used to remove amorphous iron and aluminum oxides is also included in this section of the appendix.

NH₂OH·HCl METHOD FOR EXTRACTING SORBED METALS AND AMORPHIC Fe AND Mn OXIDES FROM SOILS AND SEDIMENTS²

Everett A. Jenne

SUMMARY OF METHOD

Oven-dry, sieve, and homogenize the tailings sample. Add a portion of the oven-dried sample (0.40 g) to 100 mL of hot (50°C) extraction solution (0.25M NH₂OH·HCl and 0.25M HCl) and shake for 60 min. Filter approximately 25 mL of the suspension through a 0.2-μm membrane filter. Store the filtrate in a polyethylene bottle. Analyze the filtrate for iron and arsenic by inductively coupled plasma (ICP), graphite furnace atomic absorption spectroscopy (GFAAS), or equivalent method.

EQUIPMENT

- Shaking hot water bath
- Analytical balance with 0.1-mg accuracy
- Reagent grade hydroxylamine hydrochloride
- Reagent grade hydrochloric acid
- 250-mL and 30-mL polyethylene bottles
- 1-L wide-mouth polyethylene bottles

²Method is after Jenne, E.A., DiToro, D.M., Allen, H.E., and Zarba, C.S., 1986, An activity-based model for developing sediment criteria for metals - I, A new approach: in Proceedings of Chemicals in the Environment- International Conference, eds. Lester, J.N., Perry, A., and Sterritt, R.M. Selper Ltd., London, p. 560-562.

- 100-mL graduated cylinder
- 30-mL plastic syringes
- 0.2- μ m in-line membrane filters (Gelman polysulfone Acrodisc, product no. 4191 or equivalent)
- 60-mesh (0.25-mm) sieve (solder free) with nylon screen
- Inductively coupled plasma, graphite furnace atomic absorption spectrometry or equivalent equipment

EQUIPMENT PREPARATION

- To clean polyethylene bottles, graduated cylinder, and syringes, soak in 5% HCl for 24 hours and rinse five times with double-deionized water. Air-dry in laminar flow hood.
- To clean in-line filters, force 30 mL of 5% HNO₃ through the filters and rinse with 90 mL of double-deionized water.

ANALYTICAL PROCEDURE

- Prepare an aqueous extraction solution of 0.25M hydroxylamine hydrochloride (NH₂OH·HCl) and 0.25M hydrochloric acid (HCl).
- Place 100 mL of extraction solution in a 250-mL polyethylene bottle.
- Warm solution to 50°C in a hot water bath.
- Add 0.40 of air-dried, sieved sediment to warm solution. (up to 1.0/100 ml of sieved sediment may be used to increase the soluble concentration of metal, if necessary.)

- Return sample bottle to hot water bath (50°C) and shake for 60 min.
- Remove sample bottle from the hot water bath.
- Withdraw 25 mL of solution from sample bottle using a 30-mL plastic syringe and filter through a 0.2 µm in-line filter (Gelman polysulfone Acrodisc, product no. 4192).
- Collect filtrate in a 30-mL polyethylene bottle.
- Cap filtrate bottles tightly.
- Analyze filtrate for total iron, nickel, and arsenic by ICP, AA, or equivalent method.
- Analyze filtrate for sulfate.

QUALITY CONTROL

- All samples should be analyzed in triplicate.
- Prepare procedural blanks by following the procedure, but without adding sieved sediment. One procedural blank for each five samples should be included.

TABLE C-1. SCHEDULE OF SAMPLING AND ANALYSIS REQUIREMENTS

Time (in hours)	pH and Conductance	Fe and As (total)	Complete List of Parameters³
2	Y	--	Y
4	Y	Y	--
8	Y	Y	--
16	Y	--	Y
32	Y	Y	--
64	Y	Y	--
128	Y	--	Y

³ The standard list of analytical parameters includes pH, conductivity, Eh, total iron and speciated iron, total arsenic, and a separate analysis for speciated arsenic, sulfide, sulfate, alkalinity, nitrate and other standard parameters including Cl, Ca, Na, Mg, Al, U, K, P, Ni and other trace metals (such as Pb) and radionuclides (such as Ra)).

TABLE C-2. LIST OF ANALYTICAL METHODS

Element/Measure	Analytical Method	Standard	Relative Uncertainty
Alkalinity	Potentiometry	AFNOR NF EN ISO 9963-1	<5%
Acidity	Potentiometry	OPTIMUM CETAMA 22	<10%
Conductivity		AFNOR NF EN 2788	<5%
pH		AFNOR NFT 90-008	<5%
Eh		AFNOR NFT 90-008	<5%
Al, As, Ca, Fe, K, Mg, Mo, Na, Ni, P, S, Si, V	ICP-AES	Internal Method 2 N and ISO DI S 11885 AFNOR NFT 90-119 AFNOR NFT 90-112	2-5%
	Atomic Absorption Spectroscopy	AFNOR NFT 90-005 and Internal Methods	2 – 5%
U	ICP-AES	OPTIMUM CETAMA 23	2 – 5%
	UV Spectroscopy	OPTIMUM CETAMA 01	2 – 5%
Cl, NO ₃ , SO ₄	Ionic Chromatography	AFNOR NF ISO 10304-1	2 – 5%
S	IR Analysis	Internal Method	<5%

As speciation: - separation by ionic exchanger

- As³⁺ analyzed by ICP-AES
- As⁵⁺ calculated, As⁵⁺ = Total As – As³⁺

Fe speciation: - Fe²⁺ UV Spectrophotometry (relative uncertainty = 10%)

- Fe³⁺ calculated, Fe³⁺ = Total Fe – Fe²⁺

Appendix C-3 - TABLE 1

Procedure 2 : Jeb Tailings Temperature 4°C
Treatment: Fe/As Ratio of 3 and Neutralization at pH 8

		Raffinate	Procedure 1	Procedure 2 2h	Procedure 2 6h	Procedure 2 24h	Procedure 2 48h	Procedure 2 120h	Procedure 2 144h
pH		—	7.5	7	7.1	6.8	7	7.15	7.22
Eh(Ag/AgCl)	mV	411	120	172		152			
Conductivity	mS	88	4.92	5.67	5.54	5	4.73	5.07	5.01
Alkalinity		—	0.28	0.31		0.22			0.26
Al	mg/l	648	0.03	<0.02		<0.02			<0.02
As	mg/l	413.5	1.24	1.27	1.16	1.21	1.38	1.36	1.24
As ⁵⁺	mg/l	264.5	0.28	0.46		0.39			<0.02
As ³⁺	mg/l	149	0.96	0.81		0.82			1.32
Ca	mg/l	518	454	429		425			432
Cl	mg/l	67.4	62.6	57.9		59.3			69.6
Fe	mg/l	596	<0.02	<0.02	<0.02	<0.02	<0.02	<0.03	<0.02
Fe ²⁺	mg/l	458.1	<	<		<	<	<	<
Fe ³⁺	mg/l	137.9	<	<		<	<	<	<
H ⁺	N	0.37	NA	NA		NA			NA
K	mg/l	204	103	94.7		94.9			87.7
Mg	mg/l	374	227	238		248			254
Mo	mg/l	NA	2.19	NA		NA			1.21
Na	mg/l	150	582	590		588			583
Ni	mg/l	206	1.62	1.79		1.92			2.49
NO ₃	mg/l	50.3	8.1	10.2		10.2			9.9
P	mg/l	110	0.18	1.58		0.3			0.84
Ra	Bg/l	70.82	138.32	NA		NA			34.52
Si	mg/l	NA	4.52	NA		NA			5.13
S ²⁻	g/l	NA	NA	NA					NA
SO ₄ ²⁻	g/l	18.9	3.328	3.292		3.4			3.685
Stot	g/l	6.57	1.12	1.1		0.995			1.04
U	mg/l	<0.2	<0.2	<0.2		<0.2			<0.2

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 2
Procedure 2 : Jeb Tailings Temperature 4°C
Treatment: Fe/As ratio of 5 and neutralization at pH 8

	Raffinate	Procedure 1	Procedure 2 2h	Procedure 2 6h	Procedure 2 24h	Procedure 2 48h	Procedure 2 72h	Procedure 2 144h	Procedure 2 336h	Procedure 2 840h	Procedure 2 1008h
pH	—	7.9	7.45	7.52	7.9	7.6	7	7.3	7.7	7.9	7.7
Eh(Ag/AgCl) mV	389	406	514		397			443		419	387
Conductivity mS	50.6	4.94	5.02	5.6	4.84	4.96	6.92	4.9	5.03		5.17
Alkalinity	NA	0.69	0.61		0.59			0.44			
Al mg/l	434	0.07	0.03		0.04			0.02			<0.02
As mg/l	366	0.88	0.6	0.71	0.62	0.89	NA	0.53	0.54	0.78	0.74
As ⁵⁺ mg/l	294	<1	<1		<1			<1			
As ³⁺ mg/l	72	<1	<1		<1			<1			
Ca mg/l	590	496	435		448			441			461
Cl mg/l	38.7	45.9	46.4		46.8			47.2			44.6
Fe mg/l	430	<0.2	<0.02	<0.02	0.08	<0.02	1.15	<0.02	<0.02	0.02	<0.02
Fe ²⁺ mg/l	310	<	<		<			<			<
Fe ³⁺ mg/l	120	<	<		<			<			<
H ⁺ N	0.17										NA
K mg/l	241	110	95.2		92.1			89.6			100
Mg mg/l	341	185	186		195			202			208
Mo mg/l	NA							0.13			0.26
Na mg/l	148	545	528		552			557			560
Ni mg/l	201	0.73	0.71		0.8			0.72		0.97	0.85
NO ₃ mg/l	25.3	7.9	6.6		9.2			9.5			4.9
P mg/l	91	0.14	0.68		1.12			1.9			1.7
Ra Bq/l	56.84	247.02	105.34		98.91			48.91			150.3
Si mg/l	NA	NA	NA		NA			2.86			4.21
S ²⁻ g/l	NA	NA	NA		NA			—			
SO ₄ ²⁻ g/l	15.3	3.34	3.05		3.22			3.28			3.282
Stot g/l	4.95	1.1	1.06		1.07			1.08			
U mg/l	0.54	<0.25	<0.25		<0.25			<0.05			<0.05

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 3
Procedure 1 : Jeb Tailings

Ores		
U	%	3.2
As	%	0.37
Ni	ppm	1530
Mo	ppm	307
V	ppm	1475
Zr	ppm	166
Fe	%	1.84
S-tot	%	0.19

Leaching efficiency, % 98.52
Weight loss, % 11.72

Tailings			
U-tot	ppm	473	
As-tot	ppm	919	
Ni-tot	ppm	414	
Mo-tot	ppm	149	
Fe-HFO	ppm	389	% tot
As-HFO	ppm	145	16%
Ni-HFO	ppm	34.1	8%
Al-HFO	ppm	1383	
SO ₄ -HFO	%	2.8	

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
Iron	kg/t	0	0	0	0.6	0.6	0.6	3.6	3.6	3.6
Slaked lime	kg/t	105	105	115	104	105	111	108	113	120

Appendix C-3 - TABLE 4
Procedure 1 : Jeb Tailings

		Raffinate	Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		—	6.95	7.84	8.9	7.22	7.78	8.9	7.24	7.68	8.82
Eh(Ag/AgCl)	mV	374	299	178	199	255	229	182	238	201	155
Conductivity	mS	35.4	5.24	4.89	4.47	5.1	4.83	4.39	5.11	4.89	4.41
Alkalinity	mM/l	NA	0.13	0.44	1.06	0.14	0.4	1.11	0.13	0.35	0.91
Al	mg/l	503	< 0,02	0.06	0.55	<0,02	0.05	0.39	< 0,02	0.06	0.54
As	mg/l	271	1.04	2.87	3.95	0.86	2.02	3.29	0.3	0.51	0.97
As ⁵⁺	mg/l	218.1	NA	2.41	3.8	NA	1.89	3.16	NA	NA	NA
As ³⁺	mg/l	52.9	NA	0.46	0.15	NA	0.13	0.13	NA	NA	NA
Ca	mg/l	441	462	459	474	455	460	473	444	464	469
Cl	mg/l	35.2	32.8	32.3	30.3	29.5	30.9	31.9	32.6	33	32
Fe	mg/l	517	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02
Fe ²⁺	mg/l	413	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02
Fe ³⁺	mg/l	104	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02
H ⁺	N	0.36	NA	NA	NA	NA	NA	NA	NA	NA	NA
K	mg/l	219	111	101	91.6	112	100	92	113	102	97.6
Mg	mg/l	303	227	182	84.1	226	179	109	229	186	95.1
Na	mg/l	25.8	546	533	531	540	544	533	539	547	543
Ni	mg/l	144	17.2	0.78	0.02	23.2	0.93	0.05	18.3	0.51	0.02
NO ₃	mg/l	53.6	7	7.2	7	6.7	6.8	7.2	7.3	7.4	7.2
P	mg/l	69	0.13	0.29	0.3	0.12	0.27	0.28	0.09	0.16	0.17
Ra	Bg/l	43	50.41	68.09	81.27	166.03	115.98	85.34	151.08	147.73	139.03
S ²⁻	g/l	1.43	ND	ND	ND	ND	ND	ND	ND	ND	ND
SO ₄ ²⁻	g/l	26.9	3.963	3.481	2.832	3.773	3.395	3.082	4.099	3.576	3.151
Stot	g/l	7.55	1.27	1.05	0.989	1.2	1.16	1.01	1.17	1.23	0.975
U	mg/l	0.07	< 005	0.11	0.15	< 0,05	0.14	0.62	< 0,05	0.06	0.11

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 5

Procedure 2 : Jeb Tailings Temperature 25°C Aging time 2h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.78	7.35	8.49	6.78	7.52	8.12	6.79	7.24	7.98
Eh(Ag/AgCl)	mV	241	218	160	216	187	175	221	190	171
Conductivity	mS	5.47	4.85	4.41	5.2	4.83	4.49	5.13	4.91	4.53
Alkalinity		—	—	—	—	—	—	—	—	—
Al	mg/l	< 0,02	< 0,02	0.26	0.05	< 0,02	0.22	< 0,02	0.03	0.19
As	mg/l	1.59	3.33	5.14	1.44	2.28	3.96	0.47	0.61	1.3
As ⁵⁺	mg/l	0.25	2.49	4.8	0.48	1.7	3.63	<	<	0.77
As ³⁺	mg/l	1.34	0.84	0.34	0.96	0.58	0.33	<	<	0.53
Ca	mg/l	446	474	471	439	453	478	435	441	487
Cl	mg/l	37.5	39.6	34.6	35.5	34.6	36.1	35.1	36.4	37.8
Fe	mg/l	< 0,02	< 0,02	< 0,02	0.04	< 0,02	< 0,02	< 0,02	0.03	< 0,02
Fe ²⁺	mg/l	< 0,02	< 0,02	< 0,02	<	< 0,02	< 0,02	< 0,02	<	< 0,02
Fe ³⁺	mg/l	< 0,02	< 0,02	< 0,02	<	< 0,02	< 0,02	< 0,02	<	< 0,02
H ⁺	N	—	—	—	—	—	—	—	—	—
K	mg/l	104	95.4	89.9	103	92.4	87.2	107	91.2	88.8
Mg	mg/l	242	211	76	234	184	103	228	192	90.2
Na	mg/l	560	586	538	537	527	532	534	527	531
Ni	mg/l	18.5	0.78	0.02	27.3	0.84	0.03	19	0.58	0.02
NO ₃	mg/l	8.5	9.1	8	8.3	8.3	8.7	8.3	8.4	10.1
P	mg/l	< 0,02	0.28	0.36	< 0,02	0.21	0.34	< 0,02	0.09	0.27
Ra	Bq/l	NA	NA	NA	NA	NA	NA	NA	NA	NA
S ²⁻	g/l	ND	1.16E-02	3.79E-02	2.86E-03	ND	ND	ND	1.60E-01	5.47E-03
SO ₄ ²⁻	g/l	3.578	3.381	2.655	3.527	3.166	2.958	3.593	3.087	2.875
Stot	g/l	1.12	1.14	0.924	1.18	1.04	0.882	1.15	1.19	0.965
U	mg/l	< 0,05	0.23	0.36	< 0,05	0.26	1.54	< 0,05	0.11	0.3

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 6

Procedure 2 : Jeb Tailings Temperature 25°C Aging Time 4h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.58	7.45	7.91	6.91	7.4	7.91	6.93	7	7.72
'Eh(Ag/AgCl)	mV	—	—	—	—	—	—	—	—	—
Conductivity	mS	5.25	4.76	4.34	4.99	5.01	4.44	5.17	4.93	4.46
Alkalinity	mM/l	—	—	—	—	—	—	—	—	—
Al	mg/l	—	—	—	—	—	—	—	—	—
As	mg/l	1.68	3.48	4.9	1.47	2.4	3.68	0.48	0.65	1.25
As ⁵⁺	mg/l	—	—	—	—	—	—	—	—	—
As ³⁺	mg/l	—	—	—	—	—	—	—	—	—
Ca	mg/l	—	—	—	—	—	—	—	—	—
Cl	mg/l	—	—	—	—	—	—	—	—	—
Fe	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	0.11	< 0,02	< 0,02
Fe ²⁺	mg/l	—	—	—	—	—	—	—	—	—
Fe ³⁺	mg/l	—	—	—	—	—	—	—	—	—
H ⁺	N	—	—	—	—	—	—	—	—	—
K	mg/l	—	—	—	—	—	—	—	—	—
Mg	mg/l	—	—	—	—	—	—	—	—	—
Na	mg/l	—	—	—	—	—	—	—	—	—
Ni	mg/l	—	—	—	—	—	—	—	—	—
NO ₃	mg/l	—	—	—	—	—	—	—	—	—
P	mg/l	—	—	—	—	—	—	—	—	—
Ra	Bg/l	—	—	—	—	—	—	—	—	—
S ²⁻	g/l	—	—	—	—	—	—	—	—	—
SO ₄ ²⁻	g/l	—	—	—	—	—	—	—	—	—
Stot	g/l	—	—	—	—	—	—	—	—	—
U	mg/l	—	—	—	—	—	—	—	—	—

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 7

Procedure 2 : Jeb Tailings Temperature 25°C Aging Time 8h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.68	7.47	7.48	6.79	7.46	7.88	6.93	7.36	7.68
Eh(Ag/AgCl)	mV	—	—	—	—	—	—	—	—	—
Conductivity	mS	4.92	4.65	4.59	4.82	4.59	4.21	4.83	4.65	4.3
Alkalinity	mM/l	—	—	—	—	—	—	—	—	—
Al	mg/l	—	—	—	—	—	—	—	—	—
As	mg/l	1.62	3.33	4.98	6.79	2.15	3.96	0.5	0.65	1.3
As ⁵⁺	mg/l	—	—	—	—	—	—	—	—	—
As ³⁺	mg/l	—	—	—	—	—	—	—	—	—
Ca	mg/l	—	—	—	—	—	—	—	—	—
Cl	mg/l	—	—	—	—	—	—	—	—	—
Fe	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Fe ²⁺	mg/l	—	—	—	—	—	—	—	—	—
Fe ³⁺	mg/l	—	—	—	—	—	—	—	—	—
H ⁺	N	—	—	—	—	—	—	—	—	—
K	mg/l	—	—	—	—	—	—	—	—	—
Mg	mg/l	—	—	—	—	—	—	—	—	—
Na	mg/l	—	—	—	—	—	—	—	—	—
Ni	mg/l	—	—	—	—	—	—	—	—	—
NO ₃	mg/l	—	—	—	—	—	—	—	—	—
P	mg/l	—	—	—	—	—	—	—	—	—
Ra	Bq/l	—	—	—	—	—	—	—	—	—
S ²⁻	g/l	—	—	—	—	—	—	—	—	—
SO ₄ ²⁻	g/l	—	—	—	—	—	—	—	—	—
Stot	g/l	—	—	—	—	—	—	—	—	—
U	mg/l	—	—	—	—	—	—	—	—	—

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 8

Procedure 2 : Jeb Tailings Temperature 25°C Aging Time 24h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.77	7.42	7.79	6.61	7.44	7.72	6.41	7.16	BOTTLE
'Eh(Ag/AgCl)	mV	209	189	176	198	174	154	195	159	BROKEN
Conductivity	mS	5.23	4.9	4.44	5.14	4.79	4.44	5.32	4.88	
Alkalinity	mM/l	—	—	—	—	—	—	—	—	
Al	mg/l	< 0,02	0.15	0.1	< 0,02	0.02	0.13	0.03	< 0,02	
As	mg/l	1.93	3.56	5.83	1.63	2.5	4.31	0.56	0.63	
As ⁵⁺	mg/l	—	—	—	—	—	—	—	—	
As ³⁺	mg/l	—	—	—	—	—	—	—	—	
Ca	mg/l	463	482	511	468	482	495	485	475	
Cl	mg/l	—	—	—	—	—	—	—	—	
Fe	mg/l	< 0,02	0.05	< 0,02	< 0,02	< 0,02	0.05	< 0,02	< 0,02	
Fe ²⁺	mg/l	—	—	—	—	—	—	—	—	
Fe ³⁺	mg/l	—	—	—	—	—	—	—	—	
H ⁺	N	—	—	—	—	—	—	—	—	
K	mg/l	109	95.6	90.1	107	93.2	87.7	117	101	
Mg	mg/l	242	202	81.2	250	192	108	257	204	
Na	mg/l	558	553	563	563	539	544	592	548	
Ni	mg/l	19.5	0.71	0.03	30.6	0.81	0.04	21.8	0.6	
NO ₃	mg/l	—	—	—	—	—	—	—	—	
P	mg/l	0.04	0.28	0.36	< 0,02	< 0,22	0.34	< 0,02	0.07	
Ra	Bg/l	—	—	—	—	—	—	—	—	
S ²⁻	g/l	—	—	—	—	—	—	—	—	
SO ₄ ²⁻	g/l	—	—	—	—	—	—	—	—	
Stot	g/l	—	—	—	—	—	—	—	—	
U	mg/l	< 0,05	0.23	0.38	< 0,05	0.21	1.1	< 0,05	0.06	

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 9

Procedure 2 : Jeb Tailings Temperature 25°C Aging Time 48h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.8	7.41	7.44	6.63	7.52	7.66	6.61	7.27	BOTTLE
'Eh(Ag/AgCl) mV		—	—	—	—	—	—	—	—	BROKEN
Conductivity mS		5.07	4.79	4.42	5.05	4.7	4.37	4.99	4.93	
Alkalinity		—	—	—	—	—	—	—	—	
Al mg/l		—	—	—	—	—	—	—	—	
As mg/l		2.17	3.59	5.98	1.8	2.59	4.41	0.67	0.72	
As ⁵⁺ mg/l		—	—	—	—	—	—	—	—	
As ³⁺ mg/l		—	—	—	—	—	—	—	—	
Ca mg/l		—	—	—	—	—	—	—	—	
Cl mg/l		—	—	—	—	—	—	—	—	
Fe mg/l		< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	
Fe ²⁺ mg/l		—	—	—	—	—	—	—	—	
Fe ³⁺ mg/l		—	—	—	—	—	—	—	—	
H ⁺ N		—	—	—	—	—	—	—	—	
K mg/l		—	—	—	—	—	—	—	—	
Mg mg/l		—	—	—	—	—	—	—	—	
Na mg/l		—	—	—	—	—	—	—	—	
Ni mg/l		—	—	—	—	—	—	—	—	
NO ₃ mg/l		—	—	—	—	—	—	—	—	
P mg/l		—	—	—	—	—	—	—	—	
Ra Bg/l		—	—	—	—	—	—	—	—	
S ²⁻ g/l		—	—	—	—	—	—	—	—	
SO ₄ ²⁻ g/l		—	—	—	—	—	—	—	—	
Stot g/l		—	—	—	—	—	—	—	—	
U mg/l		—	—	—	—	—	—	—	—	

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 10

Procedure 2 : Jeb Tailings Temperature 25°C Aging Time 72h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.82	7.44	8.23	7.09	7.49	7.65	6.72	7.24	BOTTLE
'Eh(Ag/AgCl) mV		—	—	—	—	—	—	—	—	BROKEN
Conductivity mS		5.89	5.29	4.77	5.7	5.3	4.86	5.84	5.38	
Alkalinity		—	—	—	—	—	—	—	—	
Al mg/l		—	—	—	—	—	—	—	—	
As mg/l		2.12	3.54	5.71	1.72	2.45	4.34	0.6	0.68	
As ⁵⁺ mg/l		—	—	—	—	—	—	—	—	
As ³⁺ mg/l		—	—	—	—	—	—	—	—	
Ca mg/l		—	—	—	—	—	—	—	—	
Cl mg/l		—	—	—	—	—	—	—	—	
Fe mg/l		< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	0.02	< 0,02	
Fe ²⁺ mg/l		—	—	—	—	—	—	—	—	
Fe ³⁺ mg/l		—	—	—	—	—	—	—	—	
H ⁺ N		—	—	—	—	—	—	—	—	
K mg/l		—	—	—	—	—	—	—	—	
Mg mg/l		—	—	—	—	—	—	—	—	
Na mg/l		—	—	—	—	—	—	—	—	
Ni mg/l		—	—	—	—	—	—	—	—	
NO ₃ mg/l		—	—	—	—	—	—	—	—	
P mg/l		—	—	—	—	—	—	—	—	
Ra Bg/l		—	—	—	—	—	—	—	—	
S ²⁻ g/l		—	—	—	—	—	—	—	—	
SO ₄ ²⁻ g/l		—	—	—	—	—	—	—	—	
Stot g/l		—	—	—	—	—	—	—	—	
U mg/l		—	—	—	—	—	—	—	—	

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 11

Procedure 2 : Jeb Tailings Temperature 25°C Aging Time 120h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.93	7.56	7.66	6.85	7.46	8	6.7	7.32	BOTTLE
Eh(Ag/AgCl)	mV	358	294	225	259	225	213	243	235	BROKEN
Conductivity	mS	5.62	5.27	4.76	5.25	4.85	4.6	5.61	5.36	
Alkalinity	mM/l	0.12	0.59	0.56	0.18	0.67	0.76	0.16	0.43	
Al	mg/l	< 0,02	< 0,02	0.1	< 0,02	< 0,02	0.08	< 0,02	< 0,02	
As	mg/l	2.39	3.81	5.64	1.98	2.66	4.68	0.75	0.79	
As ⁵⁺	mg/l	0.53	2.62	5.14	0.38	1.75	4.19	<	<	
As ³⁺	mg/l	1.86	1.19	0.5	1.6	0.91	0.49	<	<	
Ca	mg/l	460	478	495	456	483	485	462	471	
Cl	mg/l	37.3	35.2	36.8	36.1	34.5	34.5	35.1	34.2	
Fe	mg/l	< 0,02	< 0,02	< 0,02	0.15	< 0,02	< 0,02	0.1	< 0,02	
Fe ²⁺	mg/l	< 0,02	< 0,02	< 0,02	<	< 0,02	< 0,02	<	< 0,02	
Fe ³⁺	mg/l	< 0,02	< 0,02	< 0,02	<	< 0,02	< 0,02	<	< 0,02	
H ⁺	N	—	—	—	—	—	—	—	—	
K	mg/l	100	88.9	83.6	99.8	89.4	83.9	105	95.6	
Mg	mg/l	253	208	85.4	257	207	109	252	221	
Na	mg/l	548	541	541	546	553	526	551	546	
Ni	mg/l	19.4	0.59	0.02	29.7	0.59	0.02	20.1	0.52	
NO ₃	mg/l	1.6	8.8	9.6	3.1	8.7	9.5	2.7	1.2	
P	mg/l	1.53	1.38	1.48	1.42	1.8	1.33	0.84	0.69	
Ra	Bg/l	7.04	12.11	59.35	50.66	50.89	40.88	26.79	66.9	
S ²⁻	g/l	ND	ND	ND	ND	ND	ND	ND	ND	
SO ₄ ²⁻	g/l	3.807	3.519	2.907	3.964	3.45	2.939	3.79	3.487	
Stot	g/l	1.24	1.15	0.956	1.28	1.11	0.973	1.25	1.16	
U	mg/l	< 0,05	0.22	0.15	< 0,05	0.25	1.23	< 0,05	0.08	

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 12

Procedure 2 : Jeb Tailings Temperature 50°C Aging Time 2h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		7.04	7.39	8.05	6.96	6.93	7.77	6.8	7.39	7.96
'Eh(Ag/AgCl)	mV	209	202	166	211	181	153	189	159	160
Conductivity	mS	5.25	4.47	4.46	5.26	4.92	4.62	5.17	4.97	4.51
Alkalinity		NA	NA	NA	NA	NA	NA	NA	NA	NA
Al	mg/l	< 0,02	0.04	0.18	0.04	0.06	0.07	< 0,02	0.04	0.14
As	mg/l	3.6	3.96	5.71	2.91	3	4.5	0.99	1.03	1.64
As ⁵⁺	mg/l	1.14	3.08	4.68	0.73	1.92	3.91	<	<	1.13
As ³⁺	mg/l	2.46	0.88	1.03	2.18	1.08	0.59	<	<	0.51
Ca	mg/l	474	410	489	462	476	506	463	482	485
Cl	mg/l	38.3	32.7	36.7	40.3	37.8	38.1	37	37.6	37.1
Fe	mg/l	< 0,02	< 0,02	< 0,02	0.11	< 0,02	< 0,02	0.04	0.03	< 0,02
Fe ²⁺	mg/l	< 0,02	< 0,02	< 0,02	<	< 0,02	< 0,02	<	<	< 0,02
Fe ³⁺	mg/l	< 0,02	< 0,02	< 0,02	<	< 0,02	< 0,02	<	<	< 0,02
H ⁺	N	—	—	—	—	—	—	—	—	—
K	mg/l	125	93.6	98.9	121	107	106	115	109	101
Mg	mg/l	231	150	64.9	231	175	95.5	233	188	80.8
Na	mg/l	548	457	502	535	522	549	544	535	528
Ni	mg/l	16.8	0.66	0.04	25.6	1.37	0.29	18.5	0.63	0.03
NO ₃	mg/l	9.5	8.4	14.9	11.1	9.5	10	9.3	47	14.9
P	mg/l	1.24	0.68	0.67	0.47	4.81	2.49	1.7	0.29	0.38
Ra	Bg/l	NA	NA	NA	NA	NA	NA	NA	NA	NA
S ²⁻	g/l	ND	2.29E-02	5.69E-02	5.35E-02	ND	1.08E-02	9.28E-02	ND	3.18E-02
SO ₄ ²⁻	g/l	3.624	2.724	2.604	3.585	3.277	2.883	3.587	3.249	2.829
Stot	g/l	1.17	0.932	0.926	1.25	1.07	0.973	1.29	1.06	0.976
U	mg/l	< 0,05	0.08	0.29	< 0,05	< 0,05	0.72	< 0,05	0.09	0.27

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 13

Procedure 2 : Jeb Tailings Temperature 50°C Aging Time 4h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		7.1	7.52	7.85	6.88	7.55	7.77	6.95	7.34	7.61
Eh(Ag/AgCl)	mV	—	—	—	—	—	—	—	—	—
Conductivity	mS	5.11	4.99	4.23	5.04	4.51	4.29	4.98	4.57	4.44
Alkalinity	mM/l	—	—	—	—	—	—	—	—	—
Al	mg/l	—	—	—	—	—	—	—	—	—
As	mg/l	3.33	4.52	5.68	2.91	2.97	4.4	1.1	0.96	1.81
As ⁵⁺	mg/l	—	—	—	—	—	—	—	—	—
As ³⁺	mg/l	—	—	—	—	—	—	—	—	—
Ca	mg/l	—	—	—	—	—	—	—	—	—
Cl	mg/l	—	—	—	—	—	—	—	—	—
Fe	mg/l	0.05	< 0,02	< 0,02	0.03	< 0,02	< 0,02	0.06	< 0,02	0.03
Fe ²⁺	mg/l	—	—	—	—	—	—	—	—	—
Fe ³⁺	mg/l	—	—	—	—	—	—	—	—	—
H ⁺	N	—	—	—	—	—	—	—	—	—
K	mg/l	—	—	—	—	—	—	—	—	—
Mg	mg/l	—	—	—	—	—	—	—	—	—
Na	mg/l	—	—	—	—	—	—	—	—	—
Ni	mg/l	—	—	—	—	—	—	—	—	—
NO ₃	mg/l	—	—	—	—	—	—	—	—	—
P	mg/l	—	—	—	—	—	—	—	—	—
Ra	Bg/l	—	—	—	—	—	—	—	—	—
S ²⁻	g/l	—	—	—	—	—	—	—	—	—
SO ₄ ²⁻	g/l	—	—	—	—	—	—	—	—	—
Stot	g/l	—	—	—	—	—	—	—	—	—
U	mg/l	—	—	—	—	—	—	—	—	—

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 14

Procedure 2 : Jeb Tailings Temperature 50°C Aging Time 8h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.9	7.65	7.98	6.71	7.67	7.9	7.47	7.87	7.62
'Eh(Ag/AgCl)	mV	—	—	—	—	—	—	—	—	—
Conductivity	mS	4.97	4.55	3.95	4.79	4.62	4.11	4.43	4.07	4.09
Alkalinity	mM/l	—	—	—	—	—	—	—	—	—
Al	mg/l	—	—	—	—	—	—	—	—	—
As	mg/l	3.28	4.56	5.81	2.6	2.97	4.37	0.97	1.77	1.79
As ⁵⁺	mg/l	—	—	—	—	—	—	—	—	—
As ³⁺	mg/l	—	—	—	—	—	—	—	—	—
Ca	mg/l	—	—	—	—	—	—	—	—	—
Cl	mg/l	—	—	—	—	—	—	—	—	—
Fe	mg/l	0.03	< 0,02	< 0,02	0.07	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Fe ²⁺	mg/l	—	—	—	—	—	—	—	—	—
Fe ³⁺	mg/l	—	—	—	—	—	—	—	—	—
H ⁺	N	—	—	—	—	—	—	—	—	—
K	mg/l	—	—	—	—	—	—	—	—	—
Mg	mg/l	—	—	—	—	—	—	—	—	—
Na	mg/l	—	—	—	—	—	—	—	—	—
Ni	mg/l	—	—	—	—	—	—	—	—	—
NO ₃	mg/l	—	—	—	—	—	—	—	—	—
P	mg/l	—	—	—	—	—	—	—	—	—
Ra	Bg/l	—	—	—	—	—	—	—	—	—
S ²⁻	g/l	—	—	—	—	—	—	—	—	—
SO ₄ ²⁻	g/l	—	—	—	—	—	—	—	—	—
Stot	g/l	—	—	—	—	—	—	—	—	—
U	mg/l	—	—	—	—	—	—	—	—	—

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 15

Procedure 2 : Jeb Tailings Temperature 50°C Aging Time 24h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.46	7.57	7.51	6.35	BOTTLE	7.68	6.65	7.34	7.52
'Eh(Ag/AgCl)	mV	193	145	136	165	BROKEN	121	177	137	126
Conductivity	mS	5.04	4.54	4.57	5.07		4.41	5.04	4.76	4.47
Alkalinity	mM/l	—	—	—	—		—	—	—	—
Al	mg/l	0.03	0.13	0.1	0.07		0.15	0.07	0.04	0.11
As	mg/l	4.38	5.77	9.18	3.68		6.14	1.13	1.37	2.79
As ⁵⁺	mg/l	—	—	—	—		—	—	—	—
As ³⁺	mg/l	—	—	—	—		—	—	—	—
Ca	mg/l	477	457	533	483		507	462	468	519
Cl	mg/l	—	—	—	—		—	—	—	—
Fe	mg/l	0.05	0.05	< 0,02	0.13		< 0,02	0.18	< 0,02	< 0,02
Fe ²⁺	mg/l	—	—	—	—		—	—	—	—
Fe ³⁺	mg/l	—	—	—	—		—	—	—	—
H ⁺	N	—	—	—	—		—	—	—	—
K	mg/l	116	86.3	95.1	109		92.2	107	99.9	96.6
Mg	mg/l	237	182	78.8	255		95.6	246	196	92.7
Na	mg/l	559	507	558	556		541	548	531	564
Ni	mg/l	15.1	0.54	0.04	23.8		0.04	19.4	0.54	0.04
NO ₃	mg/l	—	—	—	—		—	—	—	—
P	mg/l	0.06	0.33	0.53	0.02		0.45	< 0,02	0.1	0.28
Ra	Bg/l	—	—	—	—		—	—	—	—
S ²⁻	g/l	—	—	—	—		—	—	—	—
SO ₄ ²⁻	g/l	—	—	—	—		—	—	—	—
Stot	g/l	—	—	—	—		—	—	—	—
U	mg/l	< 0,05	0.17	0.3	< 0,05		0.94	< 0,05	0.06	0.48

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 16

Procedure 2 : Jeb Tailings Temperature 50°C Aging Time 48h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.37	7.5	7.66	6.22	BOTTLE BROKEN	7.7	6.27	7.42	7.62
Eh(Ag/AgCl)	mV	—	—	—	—	—	—	—	—	—
Conductivity	mS	5.07	5.52	5.06	6.29	—	5.03	6	5.65	5.1
Alkalinity	mM/l	—	—	—	—	—	—	—	—	—
Al	mg/l	—	—	—	—	—	—	—	—	—
As	mg/l	5.12	6.54	10.3	4.49	—	6.96	1.82	1.74	3.39
As ⁵⁺	mg/l	—	—	—	—	—	—	—	—	—
As ³⁺	mg/l	—	—	—	—	—	—	—	—	—
Ca	mg/l	—	—	—	—	—	—	—	—	—
Cl	mg/l	—	—	—	—	—	—	—	—	—
Fe	mg/l	< 0,02	< 0,02	< 0,02	0.12	—	< 0,02	0.04	< 0,02	< 0,02
Fe ²⁺	mg/l	—	—	—	—	—	—	—	—	—
Fe ³⁺	mg/l	—	—	—	—	—	—	—	—	—
H ⁺	N	—	—	—	—	—	—	—	—	—
K	mg/l	—	—	—	—	—	—	—	—	—
Mg	mg/l	—	—	—	—	—	—	—	—	—
Na	mg/l	—	—	—	—	—	—	—	—	—
Ni	mg/l	—	—	—	—	—	—	—	—	—
NO ₃	mg/l	—	—	—	—	—	—	—	—	—
P	mg/l	—	—	—	—	—	—	—	—	—
Ra	Bg/l	—	—	—	—	—	—	—	—	—
S ²⁻	g/l	—	—	—	—	—	—	—	—	—
SO ₄ ²⁻	g/l	—	—	—	—	—	—	—	—	—
Stot	g/l	—	—	—	—	—	—	—	—	—
U	mg/l	—	—	—	—	—	—	—	—	—

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 17

Procedure 2 : Jeb Tailings Temperature 50°C Aging Time 72h

	Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH	6.52	7.5	7.54	6.08	BOTTLE	7.68	6.35	7.48	7.57
'Eh(Ag/AgCl) mV	—	—	—	—	BROKEN	—	—	—	—
Conductivity mS	5.79	5.27	4.84	5.86		5.1	5.72	5.42	4.97
Alkalinity	—	—	—	—		—	—	—	—
Al mg/l	—	—	—	—		—	—	—	—
As mg/l	6.08	7.66	11.6	4.95		7.98	2.21	1.96	3.91
As ⁵⁺ mg/l	—	—	—	—		—	—	—	—
As ³⁺ mg/l	—	—	—	—		—	—	—	—
Ca mg/l	—	—	—	—		—	—	—	—
Cl mg/l	—	—	—	—		—	—	—	—
Fe mg/l	< 0,02	< 0,02	< 0,02	0.39		< 0,02	< 0,02	< 0,02	< 0,02
Fe ²⁺ mg/l	—	—	—	—		—	—	—	—
Fe ³⁺ mg/l	—	—	—	—		—	—	—	—
H ⁺ N	—	—	—	—		—	—	—	—
K mg/l	—	—	—	—		—	—	—	—
Mg mg/l	—	—	—	—		—	—	—	—
Na mg/l	—	—	—	—		—	—	—	—
Ni mg/l	—	—	—	—		—	—	—	—
NO ₃ mg/l	—	—	—	—		—	—	—	—
P mg/l	—	—	—	—		—	—	—	—
Ra Bg/l	—	—	—	—		—	—	—	—
S ²⁻ g/l	—	—	—	—		—	—	—	—
SO ₄ ²⁻ g/l	—	—	—	—		—	—	—	—
Stot g/l	—	—	—	—		—	—	—	—
U mg/l	—	—	—	—		—	—	—	—

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 18

Procedure 2 : Jeb Tailings Temperature 50°C Aging Time 120h

		Solution Fe/As 2,6 pH 7	Solution Fe/As 2,6 pH 8	Solution Fe/As 2,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.58	7.4	7.9	6.63	BOTTLE	7.84	6.64	7.44	7.88
Eh(Ag/AgCl)	mV	243	206	181	223		176	315	264	226
Conductivity	mS	5.63	5.23	4.83	5.77		4.95	5.69	5.42	4.91
Si	mg/l									7.07
Alkalinity	mM/l	0.1	0.6	0.8	0.13		1.09	0.11	0.47	0.72
Al	mg/l	< 0,02	< 0,02	0.06	0.03		0.05	0.03	< 0,02	0.04
As	mg/l	7.22	8.09	10.9	5.86		8.34	2.82	2.34	4.29
As ⁵⁺	mg/l	2.38	5.6	10.31	2.31		7.54	0.98	1.56	4.29
As ³⁺	mg/l	4.84	2.49	0.59	3.55		0.8	1.84	0.78	< 0,02
Ca	mg/l	482	490	516	485		512	467	492	504
Cl	mg/l	30.3	35.5	35.5	34.5		35.8	35.4	35.8	36
Fe	mg/l	0.22	< 0,02	< 0,02	0.73		< 0,02	0.61	< 0,02	< 0,02
Fe ²⁺	mg/l	<	<	<	<		<	<	<	<
Fe ³⁺	mg/l	<	<	<	<		<	<	<	<
H ⁺	N	—	—	—	—		—	—	—	—
K	mg/l	110	93.3	92.4	108		90.2	110	97.8	90.9
Mg	mg/l	268	205	90.7	266		108	269	224	106
Na	mg/l	559	539	545	562		539	550	554	538
Ni	mg/l	11.5	0.37	0.03	18.1		0.04	18.1	0.42	0.04
NO ₃	mg/l	9.3	11	10	9		9.1	9.4	0.9	1.9
P	mg/l	2.33	1.26	0.82	0.48		0.68	0.41	0.57	0.57
Ra	Bq/l	12.89	17.87	101.57	89.19		91.06	35.91	69.42	132.36
S ²⁻	g/l	ND	ND	ND	ND		ND	ND	ND	ND
SO ₄ ²⁻	g/l	3.95	3.474	3.02	4.131		2.952	3.961	3.568	3.004
Stot	g/l	1.36	1.15	1.01	1.31		1.04	1.36	1.21	1.04
U	mg/l	< 0,05	< 0,05	0.15	< 0,05		0.92	< 0,05	< 0,05	0.35

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 19
Procedure 1 : McClean Tailings

Ores		
U	%	2.33
As	%	0.28
Ni	ppm	1085
Mo	ppm	1055
V	ppm	1545
Zr	ppm	588
Fe	%	4.55
S-tot	%	0.19

Tailings		
U-tot	ppm	137
As-tot	ppm	600
Ni-tot	ppm	229
Mo-tot	ppm	237
Fe-HFO	ppm	539
As-HFO	ppm	110.67
Ni-HFO	ppm	9.03
Al-HFO	ppm	765
SO ₄ -HFO	%	1.38
		% tot
		18%
		4%

Leaching efficiency, 99.41
Weight loss, % 10.59

	Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
Iron kg/t	0	0	0	0.6	0.6	0.6			
Slaked lime kg/t	118	122	120	116	119	125			

Appendix C-3 - TABLE 20
Procedure 1 : McClean Tailings

		Raffinate	Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		0.75	7.13	8.13	9.37	7.46	8.24	9.35			
Eh(Ag/AgCl)	mV	421	460	199	144	194	183	151			
Conductivity	mS	118	4.99	4.73	4.52	5	4.82	4.63			
Alkalinity	mM/l	—	0.28	0.44	1.5	0.26	0.43	1.3			
Al	mg/l	393	0.03	0.14	0.87	0.02	0.15	0.78			
As	mg/l	275	0.7	1.16	2.52	0.6	0.87	1.5			
As5+	mg/l	222.5	0.27	0.77	2.52	0.18	0.54	1.28			
As3+	mg/l	52.5	0.43	0.39	< 0,2	0.42	0.33	0.22			
Ca	mg/l	126	466	474	497	479	492	491			
Cl	mg/l	30.1	32.3	32	31.5	32.9	33.3	32.5			
Fe	mg/l	948	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
Fe2+	mg/l	419	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
Fe3+	mg/l	531	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
H+	N	—	—	—	—	—	—	—			
K	mg/l	174	109	103	91.3	111	103	96.4			
Mg	mg/l	81.7	90.4	66.5	30.1	94.2	67.9	29.9			
Na	mg/l	31.7	593	598	603	607	621	612			
Ni	mg/l	164	7.14	0.23	0.03	14.8	0.2	0.02			
NO3	mg/l	35.9	8	7.9	8.1	12	10.7	8.3			
P	mg/l	23	0.14	0.25	0.3	0.13	0.18	0.29			
Ra	Bg/l	1.18	38.77	67.27	90.95	117.6	84.52	59.79			
S2-	g/l	ND	ND	0.072176	0.093938	0.007416	0.085501	0.079268			
SO42-	g/l	26.1	2.944	2.78	2.55	3.004	2.8	2.558			
Stot	g/l	7.73	0.977	1	0.945	1.01	1.02	0.933			
U	mg/l	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	0.07	< 0,05			

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 21

Procedure 2 : McClean Tailings Temperature 25°C Aging Time 2h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		7.2	7.46	8.83	7.07	7.27	8.62			
Eh(Ag/AgCl)	mV	211	203	167	219	201	162			
Conductivity	mS	5.12	5.02	4.67	5.24	5.05	4.81			
Alkalinity	nM/l	0.41	0.51	0.94	0.39	0.48	1.03			
Al	mg/l	0.03	0.05	0.39	< 0,02	0.07	0.33			
As	mg/l	0.95	1.67	3.72	0.83	1.13	2.33			
As5+	mg/l	<	1.14	3.47	<	0.73	2.04			
As3+	mg/l	<	0.53	0.25	<	0.4	0.29			
Ca	mg/l	479	500	510	486	488	504			
Cl	mg/l	35.7	35.3	35	34	34.7	32.6			
Fe	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
Fe2+	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
Fe3+	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
H+	N	—	—	—	—	—	—			
K	mg/l	106	98.2	86.4	102	94.8	90.8			
Mg	mg/l	94.3	72.6	25.7	96.2	70.5	28.7			
Na	mg/l	611	612	606	602	621	600			
Ni	mg/l	6.59	0.19	0.02	10.5	0.18	0.03			
NO3	mg/l	10.8	10.9	9.6	9.5	11.3	8.9			
P	mg/l	0.29	0.47	0.66	1.87	1.95	0.49			
Ra	Bq/l	—	—	—	—	—	—			
S2-	g/l	0.138417	1.33E-01	1.31E-01	1.50E-01	0.135834	0.118258			
SO42-	g/l	3.001	2.837	2.532	3.056	2.799	2.582			
Stot	g/l	1.14	1.08	0.976	1.17	1.07	0.98			
U	mg/l	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05			

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 22

Procedure 2 : McClean Tailings Temperature 25°C Aging time 4h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		7.11	7.43	8.3	7.14	7.42	8.34			
Eh(Ag/AgCl) mV										
Conductivity mS		5.1	4.96	4.67	5.26	5.01	4.74			
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	0.97	1.91	4.68	0.85	1.18	2.32			
As5+	mg/l									
As3+	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	0.27	0.05	0.15	0.07	0.16	0.13			
Fe2+	mg/l									
Fe3+	mg/l									
H+	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO3	mg/l									
P	mg/l									
Ra	Bq/l									
S2-	g/l									
SO42-	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 23

Procedure 2 : McClean Tailings Temperature 25°C Aging Time 8h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		7.01	7.4	7.48	6.98	7.43	7.52			
'Eh(Ag/AgCl)	mV									
Conductivity	mS	5.15	4.98	4.84	5.11	5.08	4.89			
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	0.95	1.46	3.56	0.5	0.77	1.73			
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 24

Procedure 2 : McClean Tailings Temperature 25°C Aging Time 24h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		6.98	7.11	7.89	6.84	7.31	8.14			
Eh(Ag/AgCl)	mV	190	236	151	466	135	125			
Conductivity	mS	5.49	5.34	4.97	5.58	5.31	5.04			
Alkalinity	mM/l	0.23	0.6	1.03	0.34	0.51	1.11			
Al	mg/l	0.07	0.7	0.37	0.05	0.07	0.38			
As	mg/l	1.14	1.86	4.34	1.04	1.33	2.58			
As5+	mg/l	0.68	1.23	4.09	0.28	0.83	2.31			
As3+	mg/l	0.46	0.63	0.25	0.76	0.5	0.27			
Ca	mg/l	473	486	488	477	471	475			
Cl	mg/l	33.3	33.5	33.6	32.7	33	32.8			
Fe	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
Fe2+	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
Fe3+	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
H+	N	—	—	—	—	—	—			
K	mg/l	101	94	86.3	104	95.2	85.5			
Mg	mg/l	99.7	74.9	25.8	103	73.1	28.3			
Na	mg/l	604	588	563	599	584	579			
Ni	mg/l	5.88	0.18	0.02	10.2	0.18	0.02			
NO3	mg/l	8.9	8.8	7.4	9	8.1	9			
P	mg/l	0.2	0.42	0.53	0.41	0.4	0.45			
Ra	Bq/l	—	—	—	—	—	—			
S2-	g/l	0.007095	0.012822	ND	0.053398	0.061503	0.032946			
SO42-	g/l	2.975	2.829	2.503	3.046	2.794	2.532			
Stot	g/l	1	0.957	0.807	1.07	0.994	0.878			
U	mg/l	< 0,05	< 0,05	0.06	< 0,05	< 0,05	0.08			

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 25

Procedure 2 : McClean Tailings Temperature 25°C Aging Time 48h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		6.48	7.42	7.52	6.73	7.57	7.77			
Eh(Ag/AgCl)	mV									
Conductivity	mS	5.59	5.63	5.08	5.65	5.46	5.18			
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	1.23	2.41	4.88	1.24	0.87	2.98			
As5+	mg/l									
As3+	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	0.03	< 0,02	< 0,02	0.04	< 0,02	< 0,02			
Fe2+	mg/l									
Fe3+	mg/l									
H+	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO3	mg/l									
P	mg/l									
Ra	Bq/l									
S2-	g/l									
SO42-	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 26

Procedure 2 : McClean Tailings Temperature 25°C Aging time 72h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		6.67	7.39	7.68	6.69	7.42	7.61			
'Eh(Ag/AgCl)	mV									
Conductivity	mS	5.63	5.44	5.07	5.74	5.45	5.18			
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	1.04	1.76	3.7	0.86	1.38	3.03			
As5+	mg/l									
As3+	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	< 0,02	< 0,02	< 0,02	0.03	< 0,02	< 0,02			
Fe2+	mg/l									
Fe3+	mg/l									
H+	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO3	mg/l									
P	mg/l									
Ra	Bq/l									
S2-	g/l									
SO42-	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 27

Procedure 2 : McClean Tailings Temperature 25°C Aging Time 144h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		7.2	7.61	8.23	6.95	7.53	8.03			
Eh(Ag/AgCl)	mV	168	156	135	188	167	147			
Conductivity	mS	5.45	5.34	5.03	5.49	5.35	5.06			
Alkalinity	mM/l	0.25	0.67	0.88	0.17	0.64	0.74			
Al	mg/l	< 0,02	< 0,02	0.13	< 0,02	< 0,02	0.05			
As	mg/l	1.33	2.53	5.78	1.04	1.7	3.75			
As5+	mg/l	0.54	1.92	5.41	0.46	1.21	3.42			
As3+	mg/l	0.79	0.61	0.37	0.58	0.49	0.33			
Ca	mg/l	469	494	511	472	482	491			
Cl	mg/l	34.2	34.9	35	34.4	34.8	34.5			
Fe	mg/l	< 0,02	< 0,02	< 0,02	0.03	< 0,02	< 0,02			
Fe2+	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
Fe3+	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
H+	N									
K	mg/l	96.5	88	78	94.7	89.5	80.1			
Mg	mg/l	99.1	77.4	23.7	99.2	77.9	27.9			
Na	mg/l	605	607	590	590	609	600			
Ni	mg/l	6.62	0.19	0.02	10.9	0.2	0.02			
NO3	mg/l	2.1	2.2	2.9	2.2	2.2	4.7			
P	mg/l	1.16	1.11	0.62	1.73	1.13	1.23			
Ra	Bq/l	11.58	14.15	47.07	8.46	4.78	38.82			
S2-	g/l	0.077762	0.087157	0.082607	0.069406	0.084808	0.109919			
SO42-	g/l	2.973	2.825	2.545	3.028	2.862	2.595			
Stot	g/l	1.07	1.03	0.932	1.08	1.04	0.976			
U	mg/l	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05			

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 28

Procedure 2 : McClean Tailings Temperature 50°C Aging Time 2h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		7.11	7.39	8.11	7.17	7.55	8.64			
Eh(Ag/AgCl)	mV	448	164	109	172	161	119			
Conductivity	mS	5.19	5.02	4.65	5.15	4.96	4.78			
Alkalinity	mM/l	0.57	0.92	1.3	0.44	0.78	1.3			
Al	mg/l	0.06	0.07	0.7	0.02	0.13	0.6			
As	mg/l	2.21	2.84	4.94	2.26	2.01	3.46			
As5+	mg/l	0.51	1.52	4.46	0.41	1.06	2.95			
As3+	mg/l	1.7	1.32	0.48	1.85	0.95	0.51			
Ca	mg/l	479	491	507	491	488	499			
Cl	mg/l	32.3	32.1	32.7	33	32.5	33.6			
Fe	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
Fe2+	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
Fe3+	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
H+	N	—	—	—	—	—	—			
K	mg/l	90.8	107	102	116	110	102			
Mg	mg/l	28.7	64.6	21	93.4	63.6	24.2			
Na	mg/l	600	583	578	601	594	593			
Ni	mg/l	0.03	0.22	0.03	10.5	0.21	0.03			
NO3	mg/l	8.9	9.1	9	9.2	9	9.4			
P	mg/l	0.49	0.48	0.55	0.46	0.58	0.54			
Ra	Bq/l	—	—	—	—	—	—			
S2-	g/l	0.118258	1.31E-01	1.24E-01	4.53E-02	0.142509	8.52E-02			
SO42-	g/l	2.582	2.785	2.491	3.25	2.779	2.621			
Stot	g/l	0.98	1.06	0.955	1.13	1.07	0.96			
U	mg/l	< 0,05	< 0,05	< 0,05	< 0,05	0.05	< 0,05			

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 29

Procedure 2 : McClean Tailings Temperature 50°C Aging time 4h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		7.34	7.6	8.11	7.12	7.55	8.26			
'Eh(Ag/AgCl)	mV									
Conductivity	mS	5.17	5.13	4.77	5.76	5.13	4.81			
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	1.71	1.75	3.82	1.13	1.21	2.65			
As5+	mg/l									
As3+	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
Fe2+	mg/l									
Fe3+	mg/l									
H+	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO3	mg/l									
P	mg/l									
Ra	Bq/l									
S2-	g/l									
SO42-	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 30

Procedure 2 : McClean Tailings Temperature 50°C Aging Time 8h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		7.09	7.47	7.72	6.85	6.85	7.65			
'Eh(Ag/AgCl)	mV									
Conductivity	mS	5.42	5.16	4.89	5.28	5.07	4.99			
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	1.99	2.3	5.06	1.43	2.18	4.24			
As5+	mg/l									
As3+	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	< 0,02	< 0,02	< 0,02	0.03	< 0,02	< 0,02			
Fe2+	mg/l									
Fe3+	mg/l									
H+	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO3	mg/l									
P	mg/l									
Ra	Bq/l									
S2-	g/l									
SO42-	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 31

Procedure 2 : McClean Tailings Temperature 50°C Aging Time 24h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		6.87	7.27	8.15	6.9	7.18	7.4			
Eh(Ag/AgCl)	mV	167	159	133	186	172	159			
Conductivity	mS	6.17	5.8	5	5.95	5.29	5.29			
Alkalinity	mM/l	0.32	0.68	1.15	0.3	0.79	1.33			
Al	mg/l	0.08	0.08	0.25	0.06	0.09	0.19			
As	mg/l	3.93	4.78	8.32	3.85	3.21	6.07			
As5+	mg/l	0.95	2.74	7.76	0.71	1.75	5			
As3+	mg/l	2.98	2.04	0.56	3.14	1.46	1.07			
Ca	mg/l	456	467	485	456	471	494			
Cl	mg/l	39.4	38.2	33.4	37.2	33.5	38.5			
Fe	mg/l	0.07	< 0,02	< 0,02	0.2	< 0,02	< 0,02			
Fe2+	mg/l	<	< 0,02	< 0,02	<	< 0,02	< 0,02			
Fe3+	mg/l	<	< 0,02	< 0,02	<	< 0,02	< 0,02			
H+	N	—	—	—	—	—	—			
K	mg/l	132	119	96.6	126	101	98.9			
Mg	mg/l	118	84.2	24.3	124	74.5	28.9			
Na	mg/l	702	682	571	665	569	615			
Ni	mg/l	6.34	0.25	0.04	12.6	0.21	0.04			
NO3	mg/l	10.1	10.2	9.2	9.9	8.9	10.9			
P	mg/l	0.25	0.41	0.57	0.23	0.38	0.64			
Ra	Bq/l	—	—	—	—	—	—			
S2-	g/l	0.027933	0.006043	0.022288	0.001951	0.008836	0.046896			
SO42-	g/l	3.362	3.098	2.51	3.32	2.796	2.652			
Stot	g/l	1.15	1.04	0.86	1.11	0.942	0.932			
U	mg/l	< 0,05	< 0,05	< 0,05	0.06	0.06	0.06			

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 32

Procedure 2 : McClean Tailings Temperature 50°C Aging Time 48h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		7.01	7.56	7.76	7	7.51	7.66			
'Eh(Ag/AgCl)	mV									
Conductivity	mS	5.37	5.49	5.11	5.58	5.73	5.2			
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	3.78	4.07	8.68	2.65	3.38	6.6			
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	0.12	< 0,02	< 0,02	0.13	< 0,02	< 0,02			
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 33

Procedure 2 : McClean Tailings Temperature 50°C Aging Time 72h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		6.57	7.41	7.74	6.71	7.41	7.79			
Eh(Ag/AgCl)	mV									
Conductivity	mS	5.88	5.27	5.18	6.01	5.74	5.7			
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	3.85	5.41	8.87	4.89	4.25	6.65			
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	0.1	< 0,02	< 0,02	0.38	< 0,02	< 0,02			
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 34

Procedure 2 : McClean Tailings Temperature 50°C Aging Time 144h

		Solution Fe/As 4,6 pH 7	Solution Fe/As 4,6 pH 8	Solution Fe/As 4,6 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9			
pH		6.88	7.54	7.78	6.85	7.5	7.94			
'Eh(Ag/AgCl)	mV	190	159	142	181	158	138			
Conductivity	mS	5.6	5.31	5.3	5.77	5.38	5.11			
Si	mg/l						6.23			
Alkalinity	mM/l	0.2	0.85	1.05	0.13	0.64	1.07			
Al	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	0.02			
As	mg/l	5.75	6.65	9.38	5.3	4.77	7.11			
As ⁵⁺	mg/l	2.11	4.45	8.87	1.38	3.21	6.68			
As ³⁺	mg/l	3.64	2.2	0.51	3.92	1.56	0.43			
Ca	mg/l	511	520	535	489	508	527			
Cl	mg/l	35	33.7	38.3	34.5	36.1	35.2			
Fe	mg/l	0.15	< 0,02	< 0,02	0.33	< 0,02	< 0,02			
Fe ²⁺	mg/l	<	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
Fe ³⁺	mg/l	<	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02			
H ⁺	N									
K	mg/l	103	88.9	84.9	95.1	86.1	84.9			
Mg	mg/l	108	81.9	33.3	108	84.9	36.6			
Na	mg/l	602	584	621	597	597	597			
Ni	mg/l	7.17	0.26	0.05	13.5	0.26	0.05			
NO ₃	mg/l	9.8	9.5	10.2	9.6	9.8	10			
P	mg/l	2.26	2.24	0.97	1.16	1.19	1.32			
Ra	Bq/l	13.65	15.92	69.73	13.49	13.97	82.24			
S ²⁻	g/l	1.17E-01	1.35E-01	1.35E-01	1.07E-01	1.05E-01	1.56E-01			
SO ₄ ²⁻	g/l	3.125	2.831	2.741	3.094	2.892	2.62			
Stot	g/l	1.16	1.08	1.05	1.14	1.07	1.03			
U	mg/l	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05			

_ : Not analysed

ND : Not detected

Appendix C - TABLE 35
Procedure 1 : SUE A+B Tailings

Ores		
U	%	0.8022
As	%	2.28
Ni	%	1.3
Mo	ppm	256
V	ppm	1225
Zr	ppm	446
Fe	%	3.38
S-tot	%	0.23

Tailings			
U-tot	ppm	181	
As-tot	ppm	7905	
Ni-tot	ppm	682	
Mo-tot	ppm	110	
Fe-HFO	ppm	2575	%tot
As-HFO	ppm	3275	41%
Ni-HFO	ppm	94.8	14%
Al-HFO	ppm	357	
SO ₄ -HFO	%	1.12	

Leaching efficiency, 97.74
Weight loss, % 13.00

	Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
Iron kg/t	0	0	0	24.0	24.0	24.0	42.0	42.0	42.0
Slaked lime kg/t	123	132	142	161	170	192	197	199	221

Appendix C - TABLE 36
Procedure 1 : SUE A+B Tailings

		Raffinate	Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		—	7.23	8.01	9.01	7.31	8.08	9.12	7.5	7.99	9.11
Eh(Ag/AgCl) mV		289	231	203	156	203	185	148	191	178	141
Conductivity mS		113	7.37	6.5	5.33	7.25	6.41	5.29	7.14	6.38	5.3
Alkalinity mM/l		—	0.23	0.71	1.43	0.19	0.3	1.07	0.21	0.25	0.99
Al mg/l		1690	0.19	0.19	0.18	0.2	0.19	0.18	0.22	0.2	0.18
As mg/l		2430	19.9	22.2	21.4	1.04	0.58	0.82	0.37	0.34	0.52
As5+ mg/l		1937	3.4	13.9	18.4	0.21	0.27	0.82	< 0,2	< 0,2	< 0,2
As3+ mg/l		493	16.5	8.31	3	0.83	0.31	< 0,2	0.36	< 0,2	< 0,2
Ca mg/l		304	430	446	468	447	485	465	436	450	463
Cl mg/l		35.6	30.6	30.1	29.8	29.3	29.7	29.6	30	30	30.4
Fe mg/l		1080	0.16	0.17	0.16	0.18	0.16	0.17	0.18	0.17	0.16
Fe2+ mg/l		821	<	<	<	<	<	<	<	<	<
Fe3+ mg/l		259	<	<	<	<	<	<	<	<	<
H+ N		0.52	—	—	—	—	—	—	—	—	—
K mg/l		357	194	174	169	192	185	171	187	186	189
Mg mg/l		716	411	268	60.4	395	242	23.9	390	215	21.1
Na mg/l		46.8	583	554	545	574	546	519	545	538	489
Ni mg/l		2740	111	2.07	0.03	40.7	0.6	< 0,01	33.6	0.42	< 0,01
NO3 mg/l		39.8	11.3	11.4	11.4	11.2	11.5	11.7	10.9	10.8	10.9
P mg/l		27.2	0.36	0.45	0.44	0.39	0.37	0.33	0.4	0.42	0.32
Ra Bq/l		28.74	43.15	28.84	31.45	48.95	41.57	17.49	56.06	46.82	40.31
S2- g/l		ND	0.132352	0.116077	0.147169	ND	0.161776	0.106836	ND	ND	ND
SO42- g/l		37.1	4.757	3.817	2.795	4.688	3.74	2.796	4.993	3.967	2.991
Stot g/l		11.7	1.72	1.39	1.08	1.64	1.41	1.04	1.62	1.38	1.04
U mg/l		0.2	0.1	< 0,05	0.06	0.07	< 0,05	< 0,05	< 0,05	0.07	0.05

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 37

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 2h

		Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.77	7.63	8.5	7.31	7.33	8.4	7.1	7.39	8.37
Eh(Ag/AgCl) mV		445.7	142.3	117.4	157.1	157.2	133.1	181.7	174.8	184
Conductivity mS		7.59	6.43	5.28	6.81	5.55	5.02	7.48	6.15	4.58
Alkalinity	mM/l	0.18	0.91	1.17	0.25	0.3	0.57	0.19	0.27	0.54
Al	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
As	mg/l	26.4	29.5	26	1.49	0.82	1.2	0.51	0.39	0.67
As5+	mg/l	5.8	19.5	23.2	0.18	0.37	1	0.21	0.14	0.42
As3+	mg/l	20.6	10	2.77	1.31	0.45	0.2	0.3	0.25	0.25
Ca	mg/l	440	441	478	467	482	471	464	464	464
Cl	mg/l	31.7	30.8	31.8	33	32.6	32.3	33.5	33.7	32.5
Fe	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Fe2+	mg/l	<	<	<	<	<	<	<	<	<
Fe3+	mg/l	<	<	<	<	<	<	<	<	<
H+	N	—	—	—	—	—	—	—	—	—
K	mg/l	168	146	146	176	158	146	166	158	155
Mg	mg/l	419	264	61.5	405	259	27.1	411	228	28.5
Na	mg/l	531	499	503	540	534	483	518	500	452
Ni	mg/l	123	2.49	< 0,01	33	0.61	< 0,01	26.8	0.39	< 0,01
NO3	mg/l	13.2	14.1	13.4	14.4	13.9	13.4	14.3	15.6	17.4
P	mg/l	1.16	0.81	0.29	0.67	0.32	0.3	1.02	0.37	0.22
Ra	Bg/l	—	—	—	—	—	—	—	—	—
S2-	g/l	0.089941	8.24E-02	6.38E-02	ND	ND	0.083511	ND	9.54E-02	7.92E-02
SO42-	g/l	4.944	3.768	2.985	4.714	3.979	2.776	4.719	3.819	2.729
Stot	g/l	1.74	1.34	1.06	1.63	1.39	1.01	1.62	1.37	0.99
U	mg/l	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 38

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 4h

	Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH	6.87	7.72	7.94	6.9	7.26	8.39	6.82	7.11	7.81
'Eh(Ag/AgCl) mV									
Conductivity mS	7.33	6.41	5.5	6.94	6.28	5.24	7.07	6.41	5.1
Alkalinity mM/l									
Al mg/l									
As mg/l	29.1	32.8	26.7	1.44	0.82	1.26	0.4	0.36	0.78
As5+ mg/l									
As3+ mg/l									
Ca mg/l									
Cl mg/l									
Fe mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Fe2+ mg/l									
Fe3+ mg/l									
H+ N									
K mg/l									
Mg mg/l									
Na mg/l									
Ni mg/l									
NO3 mg/l									
P mg/l									
Ra Bg/l									
S2- g/l									
SO42- g/l									
Stot g/l									
U mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 39

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 8h

	Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH	6.89	7.71	8.04	7.01	7.34	8.56	6.79	7.09	7.59
Eh(Ag/AgCl) mV									
Conductivity mS	7.6	6.28	5.36	6.81	6.28	5.1	6.81	6.54	5.24
Alkalinity mM/l									
Al mg/l									
As mg/l	27.2	31.1	26.4	1.43	0.8	1.31	0.37	0.36	0.9
As5+ mg/l									
As3+ mg/l									
Ca mg/l									
Cl mg/l									
Fe mg/l	< 0,02	< 0,02	< 0,02	0.02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Fe2+ mg/l									
Fe3+ mg/l									
H+ N									
K mg/l									
Mg mg/l									
Na mg/l									
Ni mg/l									
NO3 mg/l									
P mg/l									
Ra Bq/l									
S2- g/l									
SO42- g/l									
Stot g/l									
U mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 40

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 24h

		Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.95	7.06	8.41	7.15	7.47	8.66	7.17	7.45	8.51
'Eh(Ag/AgCl) mV		283.6	250.3	213.8	248.8	230.5	199.6	241.1	221.2	196.3
Conductivity mS		6.91	5.95	5.15	6.68	5.93	4.81	6.59	5.55	4.83
Alkalinity mM/l		0.29	1.11	1.02	0.27	0.38	0.67	0.27	0.42	0.54
Al mg/l		0.04	0.03	0.03	0.03	0.04	0.03	0.04	0.03	0.03
As mg/l		29.2	32.7	27.2	1.78	0.89	1.55	0.58	0.49	1.07
As5+ mg/l		3.9	22.8	24.4	0.23	0.45	1.55	0.26	0.49	1.07
As3+ mg/l		25.3	9.95	2.81	1.55	0.44	< 0,2	0.32	< 0,2	< 0,2
Ca mg/l		434	447	476	442	449	457	444	454	466
Cl mg/l		32.7	31.3	32.4	32.9	32.4	31.2	34.3	35.5	32.5
Fe mg/l		0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03
Fe2+ mg/l		<	<	<	<	<	<	<	<	<
Fe3+ mg/l		<	<	<	<	<	<	<	<	<
H+ N		—	—	—	—	—	—	—	—	—
K mg/l		167	141	156	168	154	141	167	159	164
Mg mg/l		430	296	64.1	412	272	29.2	412	246	35.6
Na mg/l		546	536	537	563	542	506	540	528	497
Ni mg/l		138	3.81	1.05	40.1	1.78	1.01	32.3	1.66	1.01
NO3 mg/l		13.7	13.7	13.9	13.7	13.9	13.7	14.2	14.4	14
P mg/l		0.69	0.59	0.35	0.57	0.36	0.21	0.64	0.57	0.23
Ra Bg/l		—	—	—	—	—	—	—	—	—
S2- g/l		0.014873	ND	0.07042	ND	ND	0.052843	ND	ND	0.078171
SO42- g/l		5.109	3.945	2.995	4.819	3.961	2.778	4.711	3.814	2.792
Stot g/l		1.72	1.38	1.07	1.6	1.35	0.98	1.59	1.32	1.01
U mg/l		< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 41

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 48h

	Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH	6.62	7.61	8.36	7.15	7.25	8.5	6.9	7.34	7.57
'Eh(Ag/AgCl) mV									
Conductivity mS	7.21	6.29	5.28	7.34	7.11	4.95	7.54	6.11	5.29
Alkalinity									
Al mg/l									
As mg/l	34.4	37	30.2	1.89	0.9	1.97	0.52	0.49	1.26
As5+ mg/l									
As3+ mg/l									
Ca mg/l									
Cl mg/l									
Fe mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Fe2+ mg/l									
Fe3+ mg/l									
H+ N									
K mg/l									
Mg mg/l									
Na mg/l									
Ni mg/l									
NO3 mg/l									
P mg/l									
Ra Bg/l									
S2- g/l									
SO42- g/l									
Stot g/l									
U mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 42

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 72h

	Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH	6.89	7.88	7.86	7.17	7.41	7.46	6.81	7.37	7.48
Eh(Ag/AgCl) mV									
Conductivity mS	6.84	6.71	5.47	6.84	6.3	5.47	7.19	6.16	5.2
Alkalinity									
Al mg/l									
As mg/l	35	37.2	30.5	2.23	1.02	2.23	0.54	0.56	1.32
As5+ mg/l									
As3+ mg/l									
Ca mg/l									
Cl mg/l									
Fe mg/l	< 0,02	< 0,02	< 0,02	0.03	< 0,02	< 0,02	0.02	< 0,02	< 0,02
Fe2+ mg/l									
Fe3+ mg/l									
H+ N									
K mg/l									
Mg mg/l									
Na mg/l									
Ni mg/l									
NO3 mg/l									
P mg/l									
Ra Bq/l									
S2- g/l									
SO42- g/l									
Stot g/l									
U mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 43

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 144h

	Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH	6.58	7.55	7.77	7.01	7.35	7.58	6.84	7.31	7.33
Eh(Ag/AgCl) mV	258.5	264.5	216.5	248.8	238.8	212.3	209.8	256.4	232.2
Conductivity mS	6.46	4.89	4.37	5.33	4.71	4.36	5.26	4.73	4.2
Alkalinity mM/l	0.34	1.35	1.49	NA	NA	0.56	0.21	0.42	0.49
Al mg/l	0.06	< 0,02	0.03	0.03	0.03	0.03	0.04	< 0,02	< 0,02
As mg/l	37.2	29.4	30.6	1.03	1.11	3.1	0.52	0.61	1.71
As5+ mg/l	5.9	18.8	27.8	0.44	0.61	2.74	0.15	0.35	1.55
As3+ mg/l	31.3	10.6	2.78	0.59	0.5	0.36	0.37	0.26	0.16
Ca mg/l	460	409	448	411	385	454	393	392	434
Cl mg/l	35.2	28.5	29.1	31	28.3	29.2	29.7	28.7	28
Fe mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Fe2+ mg/l	<	<	<	<	<	<	<	<	<
Fe3+ mg/l	<	<	<	<	<	<	<	<	<
H+ N	—	—	—	—	—	—	—	—	—
K mg/l	179	111	126	131	128	124	135	126	136
Mg mg/l	462	268	68.2	372	249	43.1	369	233	50.1
Na mg/l	726	592	618	604	571	631	595	566	571
Ni mg/l	171	2.97	0.09	44.8	0.92	0.06	40	0.77	0.06
NO3 mg/l	4	4.2	3.5	5.1	5	5.6	5.2	5.1	8.2
P mg/l	0.69	3.15	1.39	3.95	3.42	0.81	2.61	2.09	2.09
Ra Bg/l	NA	NA	NA	NA	NA	15.38	NA	NA	NA
S2- g/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
SO42- g/l	5.677	3.612	2.78	4.363	3.489	2.816	4.241	3.464	2.647
Stot g/l	1.66	1.12	0.9	1.32	1.05	0.883	1.3	1.11	0.85
U mg/l	< 0,05	< 0,05	0.12	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	0.1

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 44

Procedure 2 : SUE A+B Tailings Temperature 50°C Aging Time 2h

	Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH	7.07	7.7	8.45	7.33	7.63	8.63	7.33	7.55	8.39
Eh(Ag/AgCl) mV	214.7	186.1	164.7	199.8	190.2	162.5	198.6	196.9	159.3
Conductivity mS	7.07	6.22	5.43	6.94	6.28	5.23	6.87	6.22	5.36
Alkalinity	0.44	1.31	1.41	0.38	0.56	0.95	0.37	0.51	0.95
Al mg/l	< 0,02	< 0,02	< 0,02	0.04	< 0,02	< 0,02	< 0,02	< 0,02	0.13
As mg/l	51.8	43.9	30	4.07	1.87	2.39	1.15	0.89	1.5
As5+ mg/l	10.3	23.6	24.2	0.46	0.64	1.17	0.12	0.36	1.21
As3+ mg/l	41.5	20.3	5.82	3.61	1.23	1.22	1.03	0.53	0.29
Ca mg/l	470	468	485	465	463	498	458	474	493
Cl mg/l	32	30.9	31.3	32	31.4	30.2	33.6	33	31.3
Fe mg/l	< 0,02	< 0,02	< 0,02	0.03	< 0,02	< 0,02	< 0,02	< 0,02	0.11
Fe2+ mg/l	<	<	<	<	<	<	<	<	<
Fe3+ mg/l	<	<	<	<	<	<	<	<	<
H+ N	—	—	—	—	—	—	—	—	—
K mg/l	179	158	154	179	163	160	170	167	178
Mg mg/l	427	258	50.7	392	235	24.7	397	214	31.4
Na mg/l	529	496	503	520	498	475	501	501	461
Ni mg/l	134	2.66	< 0,01	38.4	0.85	< 0,01	35.3	0.62	< 0,01
NO3 mg/l	13.1	13.1	13.3	14.3	13.9	13.6	15.4	15.6	15.3
P mg/l	2.09	1.26	0.54	1.75	1.03	0.2	0.84	0.48	0.25
Ra Bq/l	—	—	—	—	—	—	—	—	—
S2- g/l	ND	8.84E-02	1.22E-01	ND	0.082381	8.05E-02	ND	0.074742	6.94E-02
SO42- g/l	5.115	3.96	2.959	4.696	3.888	2.845	4.724	3.821	2.998
Stot g/l	1.78	1.41	1.11	1.61	1.38	1.03	1.62	1.35	1.07
U mg/l	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05

NA, _ : Not analysed

ND : Not detected

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Procedure 2 : SUE A+B Tailings Temperature 50°C Aging Time 4h

	Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH	6.78	7.77	8.12	7.06	7.48	8.31	7.13	7.48	7.28
'Eh(Ag/AgCl) mV									
Conductivity mS	7.6	6.41	5.5	7.2	6.28	5.36	6.94	6.15	5.76
Alkalinity									
Al mg/l									
As mg/l	51.1	43.8	33.4	3.49	1.46	2.8	1.05	0.76	1.61
As5+ mg/l									
As3+ mg/l									
Ca mg/l									
Cl mg/l									
Fe mg/l	< 0,02	< 0,02	< 0,02	0.11	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Fe2+ mg/l									
Fe3+ mg/l									
H+ N									
K mg/l									
Mg mg/l									
Na mg/l									
Ni mg/l									
NO3 mg/l									
P mg/l									
Ra Bq/l									
S2- g/l									
SO42- g/l									
Stot g/l									
U mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 46

Procedure 2 : SUE A+B Tailings Temperature 50°C Aging Time 8h

	Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH	6.68	7.75	8.06	7.03	7.57	7.94	7.15	7.56	7.41
'Eh(Ag/AgCl) mV									
Conductivity mS	7.46	6.41	5.63	7.2	6.28	5.24	6.94	6.28	5.76
Alkalinity									
Al mg/l									
As mg/l	49.9	42.8	34.1	3.48	1.63	2.99	1.08	0.87	1.58
As5+ mg/l									
As3+ mg/l									
Ca mg/l									
Cl mg/l									
Fe mg/l	0.02	< 0,02	< 0,02	0.09	< 0,02	< 0,02	0.05	< 0,02	< 0,02
Fe2+ mg/l									
Fe3+ mg/l									
H+ N									
K mg/l									
Mg mg/l									
Na mg/l									
Ni mg/l									
NO3 mg/l									
P mg/l									
Ra Bq/l									
S2- g/l									
SO42- g/l									
Stot g/l									
U mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 47

Procedure 2 : SUE A+B Tailings Temperature 50°C Aging Time 24h

	Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH	6.84	7.54	8.25	7.15	7.57	8.1	7.17	7.61	7.96
'Eh(Ag/AgCl) mV	242.6	215	182.7	220.8	206.9	185.9	220.5	207.8	190.7
Conductivity mS	7.16	6.02	5.13	6.6	6.04	5.06	6.85	5.77	5.1
Alkalinity	0.36	1.22	1.44	0.43	0.76	0.89	0.55	0.75	0.82
Al mg/l	0.05	0.03	0.03	0.1	0.03	0.03	0.11	0.03	0.03
As mg/l	64.1	46.6	39.6	5.71	2.74	5.33	2.19	1.53	2.81
As5+ mg/l	11.7	22.2	33.1	0.72	1.04	4.45	0.31	<	2.28
As3+ mg/l	52.4	24.4	6.5	4.99	1.7	0.88	1.88	1.58	0.53
Ca mg/l	468	463	477	457	457	480	471	455	478
Cl mg/l	34.4	32	32.4	32.2	32.2	31.1	33.7	31.6	31.8
Fe mg/l	0.04	0.03	0.03	0.09	0.03	0.03	0.1	0.03	0.03
Fe2+ mg/l	<	<	<	<	<	<	<	<	<
Fe3+ mg/l	<	<	<	<	<	<	<	<	<
H+ N	—	—	—	—	—	—	—	—	—
K mg/l	178	154	154	167	178	155	169	157	171
Mg mg/l	463	290	55.5	426	281	42.7	431	251	52.4
Na mg/l	567	530	531	545	548	530	560	523	513
Ni mg/l	158	3.44	1.09	52.1	2.15	1.07	59	2.14	1.1
NO3 mg/l	13.1	12.8	13.2	13	13.6	13.2	14.4	13.6	14.4
P mg/l	1.26	0.84	0.51	0.95	0.77	0.37	1.07	0.69	0.48
Ra Bg/l	—	—	—	—	—	—	—	—	—
S2- g/l	ND	0.069365	0.056452	ND	ND	0.063473	ND	ND	ND
SO42- g/l	5.282	3.927	2.917	4.826	3.99	2.866	4.899	3.772	3.093
Stot g/l	1.76	1.38	1.03	1.64	1.38	1.02	1.66	1.31	1.08
U mg/l	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 48

Procedure 2 : SUE A+B Tailings Temperature 50°C Aging Time 48h

		Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.3	7.46	8.12	6.79	7.54	7.91	6.86	7.5	7.81
Eh(Ag/AgCl) mV										
Conductivity mS		7.39	6.64	5.26	7.1	6.12	5.26	7.36	6.23	5.06
Alkalinity										
Al mg/l										
As mg/l		65.4	47.4	45	5.36	2.7	6.08	1.98	1.61	3.09
As5+ mg/l										
As3+ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		< 0,02	< 0,02	< 0,02	0.06	< 0,02	< 0,02	0.14	< 0,02	< 0,02
Fe2+ mg/l										
Fe3+ mg/l										
H+ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO3 mg/l										
P mg/l										
Ra Bg/l										
S2- g/l										
SO42- g/l										
Stot g/l										
U mg/l										

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 49

Procedure 2 : SUE A+B Tailings Temperature 50°C Aging Time 72h

		Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.81	7.51	7.87	7.24	7.65	7.77	7.02	7.6	7.73
Eh(Ag/AgCl) mV										
Conductivity mS		7.53	6.57	5.75	7.8	6.84	5.34	6.02	6.84	5.75
Alkalinity										
Al mg/l										
As mg/l		64	47.7	50.2	5.85	2.41	6.16	1.87	1.58	3.22
As5+ mg/l										
As3+ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		< 0,02	0.06	< 0,02	0.42	< 0,02	0.05	< 0,02	0.03	0.04
Fe2+ mg/l										
Fe3+ mg/l										
H+ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO3 mg/l										
P mg/l										
Ra Bq/l										
S2- g/l										
SO42- g/l										
Stot g/l										
U mg/l										

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 50

Procedure 2 : SUE A+B Tailings Temperature 50°C Aging Time 144h

	Solution Fe/As 0,6 pH 7	Solution Fe/As 0,6 pH 8	Solution Fe/As 0,6 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH	6.83	7.1	7.54	6.85		7.31	6.78	7.06	7.33
Eh(Ag/AgCl) mV	245	222.5	191	211.3	204.3	194.1	226	215.1	198.8
Conductivity mS	6.4	5.44	4.95	5.77		4.78	5.28	5.31	4.25
Si mg/l									7.07
Alkalinity	NA	0.87	NA	0.37	NA	1.05	0.37	0.42	0.72
Al mg/l	0.06	< 0,02	< 0,02	0.05	< 0,02	< 0,02	0.06	< 0,02	< 0,02
As mg/l	68.3	44.5	48.6	5.67	3.1	7.45	2.29	1.63	3.63
As5+ mg/l	12.8	25.9	45.9	0.67	1.79	6.83	0.67	1.15	3.43
As3+ mg/l	55.5	18.6	2.69	5	1.31	0.62	1.62	0.48	0.2
Ca mg/l	468	456	462	420	427	477	416	417	422
Cl mg/l	31.8	30.6	35.7	34.4	30.2	31.3	38.7	28.1	26.8
Fe mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Fe2+ mg/l	<	<	<	<	<	<	<	<	<
Fe3+ mg/l	<	<	<	<	<	<	<	<	<
H+ N	—	—	—	—	—	—	—	—	—
K mg/l	147	135	128	148	127	129	188	149	127
Mg mg/l	455	294	83.2	477	300	74.2	557	334	76.5
Na mg/l	699	659	720	703	611	652	779	587	539
Ni mg/l	167	2.49	0.16	84.7	1.92	0.29	131	2.38	0.11
NO3 mg/l	11.6	12	13.4	13.3	12.3	12.4	16	12.3	12
P mg/l	1.46	0.96	0.83	1.16	0.86	0.52	1.05	0.92	0.74
Ra Bg/l	7.73	9.95	NA	NA	14.54	16.43	NA	7.06	NA
S2- g/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
SO42- g/l	5.39	4.019	3.062	5.336	3.793	2.884	5.72	3.825	2.496
Stot g/l	1.67	1.23	1	1.6	1.21	0.98	1.82	1.25	0.868
U mg/l	0.08	< 0,05	< 0,05	< 0,05	< 0,05	0.1	0.1	< 0,05	< 0,05

NA, _ : Not analysed

ND : Not detected

Appendix C3 - TABLE 51
Procedure 2 : SUE A+B Tailings

Ores		
U	%	0.8022
As	%	2.28
Ni	%	1.30
Mo	ppm	258
V	ppm	1225
Zr	ppm	446
Fe	%	3.38
S-tot	%	0.23

		Solution Fe/As 1 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2 pH 8	Solution Fe/As 2.5 pH 8
Iron	kg/t	3.5	9.2	14.9	20.6
Slaked lim	kg/t	108	120	134	142

Appendix C3 - TABLE 52
Procedure 1 : SUE A+B Tailings

		Raffinate	Solution Fe/As 1 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2 pH 8	Solution Fe/As 2.5 pH 8					
pH		-	7.7	7.8	7.6	7.6					
Eh(Ag/AgCl)	mV	394	126	127	144	142					
Conductivity	mS	106	5.16	4.99	5	4.91					
Alkalinity	mM/l	-	0.55	0.38	0.34	0.28					
Al	mg/l	1610	<0.02	0.03	0.02	0.03					
As	mg/l	3310	14	4.59	3	1.87					
As5+	mg/l	1770	6.08	1.32	0.88	0.6					
As3+	mg/l	1540	7.92	3.27	2.14	1.24					
Ca	mg/l	351	448	452	449	457					
Cl	mg/l	73.8	30.1	30.5	32.4	29.3					
Fe	mg/l	1710	<0.02	<0.02	<0.02	<0.02					
Fe2+	mg/l	1303	<	<	<	<					
Fe3+	mg/l	410	<	<	<	<					
H+	N	0.34	-	-	-	-					
K	mg/l	264	141	140	144	148					
Mg	mg/l	679	269	269	247	238					
Mo	mg/l	-	2.44	1.87	2.15	1.73					
Na	mg/l	48.1	570	591	588	606					
Ni	mg/l	2610	4.78	2.68	2	1.94					
NO3	mg/l	42.3	10.4	9.4	9.6	9.6					
P	mg/l	138	0.23	0.18	0.15	0.12					
Ra	Bq/l	33.85	17.54	16.92	18.78	25.86					
Si	mg/l	-	8.05	3.89	2.28	1.76					
S ²⁻	g/l	-	-	-	-						
SO ₄ ²⁻	g/l	34.6	3.537	3.561	3.454	3.292					
Stot	g/l	13.3	1.19	1.19	1.15	1.16					
U	mg/l	0.41	<0.2	<0.2	<0.2	<0.2					

NA, _ : Not analysed

ND : Not detected

Appendix C3 - TABLE 53

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 2h

		Solution Fe/As 1 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2 pH 8	Solution Fe/As 2.5 pH 8					
pH		7	7.2	7	7					
Eh(Ag/AgCl)	mV	161	149	153	155					
Conductivity	mS	6.1	6.1	6.1	5.96					
Alkalinity	mM/l	0.9	0.59	0.51	0.48					
Al	mg/l	<0.02	<0.02	<0.02	<0.02					
As	mg/l	30.8	9.22	5.75	3.04					
As5+	mg/l	12.6	1.66	1.72	0.87					
As3+	mg/l	18.2	7.56	4.03	2.17					
Ca	mg/l	474	471	471	465					
Cl	mg/l	32.6	32.9	33.5	33.9					
Fe	mg/l	<0.2	<0.2	<0.2	<0.2					
Fe2+	mg/l	<	<	<	<					
Fe3+	mg/l	<	<	<	<					
H+	N	-	-	-	-					
K	mg/l	126	132	138	139					
Mg	mg/l	306	302	271	259					
Mo	mg/l	-	-	-	-					
Na	mg/l	584	585	600	597					
Ni	mg/l	12.3	5.75	2.94	2.17					
NO3	mg/l	12	11.2	11.3	11.7					
P	mg/l	1.07	1.9	1.32	0.15					
Ra	Bq/l	23.29	18.87	22.72	24.7					
Si	mg/l	-	-	-	-					
S ²⁻	g/l	-	-	-	-					
SO ₄ ²⁻	g/l	3.655	3.659	3.685	3.661					
Stot	g/l	1.29	1.28	1.28	1.26					
U	mg/l	<0.2	<0.2	<0.2	<0.2					

NA, _ : Not analysed

ND : Not detected

Appendix C3 - TABLE 54

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 6h

		Solution Fe/As 1 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2 pH 8	Solution Fe/As 2.5 pH 8					
pH		7.3	7.2	7.3	7.2					
Eh(Ag/AgCl)	mV									
Conductivity	mS	6.36	6.18	5.97	5.97					
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	33.2	10.4	5.49	3.37					
As5+	mg/l									
As3+	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	<0.02	<0.02	<0.02	<0.02					
Fe2+	mg/l									
Fe3+	mg/l									
H+	N									
K	mg/l									
Mg	mg/l									
Mo	mg/l									
Na	mg/l									
Ni	mg/l									
NO3	mg/l									
P	mg/l									
Ra	Bq/l									
Si	mg/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C3 - TABLE 55

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 24h

		Solution Fe/As 1 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2 pH 8	Solution Fe/As 2.5 pH 8					
pH		7.4	7.3	7.1	7.2					
Eh(Ag/AgCl)	mV	161	163	169	170					
Conductivity	mS	5.2	5.01	4.94	4.88					
Alkalinity	mM/l	1	0.7	0.58	0.47					
Al	mg/l	<0.02	<0.02	<0.02	<0.02					
As	mg/l	37.8	12.7	6.18	3.77					
As5+	mg/l	15.3	2.1	0.65	0.7					
As3+	mg/l	22.5	10.6	5.53	3.07					
Ca	mg/l	478	479	479	477					
Cl	mg/l	32.6	33.3	33.8	37					
Fe	mg/l	<0.02	<0.02	<0.02	<0.02					
Fe2+	mg/l	<	<	<	<					
Fe3+	mg/l	<	<	<	<					
H+	N	-	-	-	-					
K	mg/l	125	136	138	147					
Mg	mg/l	318	313	288	280					
Mo	mg/l	-	-	-	-					
Na	mg/l	591	600	593	622					
Ni	mg/l	15.7	7.01	3.31	2.66					
NO3	mg/l	11.4	10.9	10.9	13.9					
P	mg/l	0.45	0.35	0.29	0.17					
Ra	Bq/l	24.35	24.54	3.75	14					
Si	mg/l	-	-	-	-					
S ²⁻	g/l	-	-	-	-					
SO ₄ ²⁻	g/l	3.898	3.951	3.914	3.815					
Stot	g/l	1.12	1.11	1.08	1.06					
U	mg/l	<0.02	<0.02	0.22	<0.02					

NA, _ : Not analysed

ND : Not detected

Appendix C3 - TABLE 56

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 48h

		Solution Fe/As 1 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2 pH 8	Solution Fe/As 2.5 pH 8					
pH		7.4	7.4	7.4	7.3					
Eh(Ag/AgCl)	mV									
Conductivity	mS	5.07	5.05	5.02	4.95					
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	35.4	12.4	6.33	3.6					
As5+	mg/l									
As3+	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	<0.02	<0.02	<0.02	<0.02					
Fe2+	mg/l									
Fe3+	mg/l									
H+	N									
K	mg/l									
Mg	mg/l									
Mo	mg/l									
Na	mg/l									
Ni	mg/l									
NO3	mg/l									
P	mg/l									
Ra	Bq/l									
Si	mg/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C3 - TABLE 57

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 120h

		Solution Fe/As 1.0 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2.0 pH 8	Solution Fe/As 2.5 pH 8					
pH		7.4	7.5	7.5	7.4					
Eh(Ag/AgCl)	mV									
Conductivity	mS	5.52	5.43	5.41	5.54					
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	35.8	12.6	6.37	3.82					
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	<0.02	<0.02	<0.02	<0.02					
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Mo	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
Si	mg/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C3 - TABLE 58

Procedure 2 : SUE A+B Tailings Temperature 25°C Aging Time 144h

		Solution Fe/As 1.0 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2.0 pH 8	Solution Fe/As 2.5 pH 8					
pH		7.4	7.2	7.4	7.3					
Eh(Ag/AgCl)	mV	196.6	193.8	186.8	185.2					
Conductivity	mS	5.35	5.41	5.3	5.34					
Alkalinity	mM/l	0.9	0.79	0.82	0.59					
Al	mg/l	<0.02	<0.02	<0.02	<0.02					
As	mg/l	37.2	12.9	6.6	4.09					
As ⁵⁺	mg/l	12.7	2.2	0.96	0.89					
As ³⁺	mg/l	24.5	10.7	5.62	3.2					
Ca	mg/l	474	468	469	464					
Cl	mg/l	32.6	33.2	33.3	34.6					
Fe	mg/l	<0.02	<0.02	<0.02	<0.02					
Fe ²⁺	mg/l	<	<	<	<					
Fe ³⁺	mg/l	<	<	<	<					
H ⁺	N	—	—	—	—					
K	mg/l	112	121	128	128					
Mg	mg/l	326	327	298	291					
Mo	mg/l	4.03	2.25	1.96	1.36					
Na	mg/l	575	591	605	602					
Ni	mg/l	19	9.29	3.97	2.87					
NO ₃	mg/l	5.2	1.5	2.8	1.5					
P	mg/l	0.6	0.7	0.37	0.38					
Ra	Bq/l	20.34	10.88	10.77	7.42					
Si	mg/l	16.5	12.4	8.18	7.42					
S ²⁻	g/l	—	—	—	—					
SO ₄ ²⁻	g/l	4.202	4.222	4.084	4.046					
Stot	g/l									
U	mg/l	<0.2	<0.2	<0.2	<0.2					

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 59

Procedure 2 : SUE C Tailings Fe/As Natureal Ratio and Neutralization at pH 8 Temperature 4°C

	Raffinate	Procedure 1	Procedure 1 2h	Procedure 1 6h	Procedure 1 24h	Procedure 1 48h	Procedure 1 72h	Procedure 1 144h	Procedure 1 336h	Procedure 1 840h	Procedure 1 1176h
pH		7.8	7.1	6.9	6.72	6.67	7.05	6.27	6.5	6.92	7.95
Eh(Ag/AgCl) mV	621	422	435		347			457	434	462	389
Conductivity mS	139	5.25	4.85	4.92	4.15	5.16	4.83	5.14			5.11
Alkalinity mM/l		0.25	0.12		<0.05			0.22			
Al mg/l	708	<0.02	<0.02		<0.02			0.02			<0.02
As mg/l	141	0.07	0.07	0.08	0.07	0.04	0.11	0.1	0.2	0.97	0.13
As ⁵⁺ mg/l	112	<0.1	<0.1		<0.1			<.1			
As ³⁺ mg/l	29	<0.1	<0.1		<0.1			<.1			
Ca mg/l	629	474	500		379			449			453
Cl mg/l	31.1	35.4	36.8		29.2			37.4			34.3
Fe mg/l	811	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.08	0.19	<0.02	<0.02
Fe ²⁺ mg/l	633	<	<		<			<			<
Fe ³⁺ mg/l	178	<	<		<			<			<
H ⁺ N	0.49	—	—		—			—			—
K mg/l	209	92	99.3		59.3			95.3			80.9
Mg mg/l	455	178	231		166			237			257
Mo mg/l		0.64	—		—			0.49			0.61
Na mg/l	39.8	592	575		454			564			574
Ni mg/l	145	0.02	<0.01		<0.01			0.08	0.08	2.94	0.07
NO ₃ mg/l	37.1	8.4	10		8.8			10.2			11.1
P mg/l	18.2	0.1	0.76		1.16			0.9			0.29
Ra Bg/l	27.31	196.07	119.48		62.61			60.2			285.02
S g/l	—	1.4	—		—			2.07			2.14
S ²⁻ g/l	—	—	—		—			—			—
SO ₄ ²⁻ g/l	35	3.265	3.87		2.546			3.369			3.45
Stot g/l	10.9	11	1.03		0.887			1.08			
U mg/l	<0.05	<0.2	<0.2		<0.2			<0.2			0.09

_: Not analysed

ND : Not detected

Appendix C3 - TABLE 60
Procedure 1 : SUE C Tailings

Ores		
U	%	5.2
As	%	0.2
Ni	ppm	1510
Mo	ppm	865
V	ppm	1950
Zr	ppm	332
Fe	%	1.58
S-tot	%	0.13

Leaching efficiency, 99.3
 Weight loss, % 13.00

Tailings		
U-tot	ppm	342
As-tot	ppm	1030
Ni-tot	ppm	359
Mo-tot	ppm	295
Fe-HFO	ppm	80.8
As-HFO	ppm	191
Ni-HFO	ppm	43.3
Al-HFO	ppm	948
SO ₄ -HFO	%	1.36
		% tot
		19%
		12%

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
Iron	kg/t	0	0	0						
Slaked lime	kg/t	143	146	152						

Appendix C-3 - TABLE 61
Procedure 1 : SUE C Tailings

		Raffinate	Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		—	7.15	7.76	8.92						
Eh(Ag/AgCl)	mV	413	170	152	125						
Conductivity	mS	139	6.33	6	5.07						
Alkalinity	mM/l	—	0.18	0.3	0.96						
Al	mg/l	708	0.03	0.09	0.57						
As	mg/l	141	0.12	0.26	0.56						
As ⁵⁺	mg/l	112	0.12	0.26	0.56						
As ³⁺	mg/l	29	< 0,2	< 0,2	< 0,2						
Ca	mg/l	629	447	445	477						
Cl	mg/l	31.1	33.3	32.9	33.2						
Fe	mg/l	811	< 0,02	< 0,02	< 0,02						
Fe ²⁺	mg/l	633	< 0,02	< 0,02	< 0,02						
Fe ³⁺	mg/l	178	< 0,02	< 0,02	< 0,02						
H ⁺	N	0.49	—	—	—						
K	mg/l	209	103	79.9	72.2						
Mg	mg/l	455	317	266	83.9						
Na	mg/l	39.8	546	555	544						
Ni	mg/l	145	12	0.38	< 0,01						
NO ₃	mg/l	37.1	8.9	8.8	8.8						
P	mg/l	18.2	0.12	0.07	0.17						
Ra	Bg/l	27.31	139.98	116.06	72.71						
S ²⁻	g/l	ND	5.81E-02	1.72E-02	2.69E-02						
SO ₄ ²⁻	g/l	35	3.871	3.574	2.736						
Stot	g/l	10.9	1.35	1.21	0.94						
U	mg/l	< 0,05	< 0,1	0.34	0.16						

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 62

Procedure 2 : SUE C Tailings Temperature 25°C Aging Time 2h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.42	7	8.19						
'Eh(Ag/AgCl)	mV	453	162	145						
Conductivity	mS	6.53	6.14	5.1						
Alkalinity	nM/l	0.31	0.42	0.51						
Al	mg/l	0.04	0.03	0.11						
As	mg/l	0.3	0.34	0.71						
As ⁵⁺	mg/l	< 0,2	0.34	0.71						
As ³⁺	mg/l	0.29	< 0,02	< 0,02						
Ca	mg/l	452	468	471						
Cl	mg/l	35.8	35.9	35.4						
Fe	mg/l	< 0,02	< 0,02	< 0,02						
Fe ²⁺	mg/l	< 0,02	< 0,02	< 0,02						
Fe ³⁺	mg/l	< 0,02	< 0,02	< 0,02						
H ⁺	N	—	—	—						
K	mg/l	88.4	79.7	70						
Mg	mg/l	336	284	85						
Na	mg/l	569	552	537						
Ni	mg/l	18.8	0.58	0.01						
NO ₃	mg/l	10.6	10.6	10.9						
P	mg/l	3.04	1.98	2.38						
Ra	Bq/l	—	—	—						
S ²⁻	g/l	8.96E-03	3.98E-02	5.49E-02						
SO ₄ ²⁻	g/l	4.108	3.716	2.742						
Stot	g/l	1.38	1.28	0.97						
U	mg/l	0.06	0.23	0.35						

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 63

Procedure 2 : SUE C Tailings Temperature 25°C Aging Time 4h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.99	7.33	8.35						
'Eh(Ag/AgCl) mV										
Conductivity mS		6.07	6.12	5.1						
Alkalinity mM/l										
Al mg/l										
As mg/l		0.34	0.37	0.77						
As ⁵⁺ mg/l										
As ³⁺ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		< 0,02	< 0,02	< 0,02						
Fe ²⁺ mg/l										
Fe ³⁺ mg/l										
H ⁺ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO ₃ mg/l										
P mg/l										
Ra Bg/l										
S ²⁻ g/l										
SO ₄ ²⁻ g/l										
Stot g/l										
U mg/l										

_ : Not analysed

ND : Not detected

Appendix C-6 - TABLE 64

Procedure 2 : SUE C Tailings Temperature 25°C Aging Time 8h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.85	7.19	7.57						
Eh(Ag/AgCl)	mV									
Conductivity	mS	7.08	6.17	5.16						
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	0.4	0.35	0.78						
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	< 0,02	< 0,02	< 0,02						
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 65

Procedure 2 : SUE C Tailings Temperature 25°C Aging Time 24h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.58	6.86	7.89						
'Eh(Ag/AgCl)	mV	464	190	171						
Conductivity	mS	6.68	6.12	5.17						
Alkalinity	mM/l	0.21	0.29	0.42						
Al	mg/l	0.03	0.03	0.13						
As	mg/l	0.3	0.27	0.67						
As ⁵⁺	mg/l	< 0,2	0.27	0.67						
As ³⁺	mg/l	0.3	< 0,2	< 0,2						
Ca	mg/l	439	452	476						
Cl	mg/l	37.8	36.5	36.8						
Fe	mg/l	0.02	< 0,02	< 0,02						
Fe ²⁺	mg/l	<	< 0,02	< 0,02						
Fe ³⁺	mg/l	<	< 0,02	< 0,02						
H ⁺	N	—	—	—						
K	mg/l	87.3	82.8	72.4						
Mg	mg/l	346	295	91.6						
Na	mg/l	592	583	555						
Ni	mg/l	22	0.6	< 0,01						
NO ₃	mg/l	11.3	11.1	11.4						
P	mg/l	1.19	0.97	0.77						
Ra	Bq/l	—	—	—						
S ²⁻	g/l	3.69E-02	6.42E-03	5.88E-02						
SO ₄ ²⁻	g/l	4.264	3.786	2.82						
Stot	g/l	1.46	1.27	1						
U	mg/l	< 0,05	0.26	0.78						

_ : Not analysed

ND : Not detected

Appendix C - TABLE 66

Procedure 2 : SUE C Tailings Temperature 25°C Aging Time 48h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.63	7.06	8.07						
Eh(Ag/AgCl) mV										
Conductivity mS		6.39	6.33	5.15						
Alkalinity mM/l										
Al mg/l										
As mg/l		0.22	0.26	0.61						
As ⁵⁺ mg/l										
As ³⁺ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		< 0,02	< 0,02	< 0,02						
Fe ²⁺ mg/l										
Fe ³⁺ mg/l										
H ⁺ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO ₃ mg/l										
P mg/l										
Ra Bq/l										
S ²⁻ g/l										
SO ₄ ²⁻ g/l										
Stot g/l										
U mg/l										

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 67

Procedure 2 : SUE C Tailings Temperature 25°C Aging Time 72h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.55	7.33	8.35						
'Eh(Ag/AgCl) mV										
Conductivity mS		6.32	5.97	4.97						
Alkalinity mM/l										
Al mg/l										
As mg/l		0.23	0.25	0.67						
As ⁵⁺ mg/l										
As ³⁺ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		0.07	< 0,02	< 0,02						
Fe ²⁺ mg/l										
Fe ³⁺ mg/l										
H ⁺ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO ₃ mg/l										
P mg/l										
Ra Bq/l										
S ²⁻ g/l										
SO ₄ ²⁻ g/l										
Stot g/l										
U mg/l										

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 68

Procedure 2 : SUE C Tailings Temperature 25°C Aging Time 144h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.46	7.25	8.18						
'Eh(Ag/AgCl) mV		446	149	131						
Conductivity mS		6.57	6.08	4.92						
Alkalinity mM/l		0.16	0.49	0.61						
Al mg/l		0.21	< 0,02	< 0,02						
As mg/l		0.35	0.3	0.69						
As ⁵⁺ mg/l		<	0.09	0.48						
As ³⁺ mg/l		<	0.21	0.21						
Ca mg/l		478	481	490						
Cl mg/l		36.2	35.3	34.4						
Fe mg/l		0.19	< 0,02	< 0,02						
Fe ²⁺ mg/l		<	< 0,02	< 0,02						
Fe ³⁺ mg/l		<	< 0,02	< 0,02						
H ⁺ N		—	—	—						
K mg/l		105	91.6	77.9						
Mg mg/l		383	328	104						
Na mg/l		581	565	523						
Ni mg/l		22.8	0.58	0.02						
NO ₃ mg/l		5.9	2.3	2.4						
P mg/l		1.27	1.39	0.48						
Ra Bg/l		37.64	30.7	27.46						
S ²⁻ g/l		ND	ND	ND						
SO ₄ ²⁻ g/l		4.269	3.796	2.746						
Stot g/l		1.41	1.27	0.932						
U mg/l		< 0,05	0.58	1.48						

—: Not analysed

ND : Not detected

Appendix C-3 - TABLE 69

Procedure 2 : SUE C Tailings Temperature 50°C Aging Time 2h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.18	7.17	8.11						
Eh(Ag/AgCl)	mV	187	165	132						
Conductivity	mS	6.55	6.32	5.35						
Alkalinity	mM/l	0.33	0.58	0.78						
Al	mg/l	0.04	0.03	0.13						
As	mg/l	0.57	0.5	0.82						
As ⁵⁺	mg/l	< 0,02	0.25	0.82						
As ³⁺	mg/l	0.51	0.25	< 0,02						
Ca	mg/l	476	478	500						
Cl	mg/l	35.5	36.4	37.6						
Fe	mg/l	0.05	< 0,02	< 0,02						
Fe ²⁺	mg/l	<	< 0,02	< 0,02						
Fe ³⁺	mg/l	<	< 0,02	< 0,02						
H ⁺	N	—	—	—						
K	mg/l	103	93.3	83.8						
Mg	mg/l	326	272	80.1						
Na	mg/l	569	568	571						
Ni	mg/l	18.4	0.65	0.02						
NO ₃	mg/l	10.8	10.9	11.1						
P	mg/l	3.98	3.05	2.51						
Ra	Bq/l	—	—	—						
S ²⁻	g/l	3.89E-02	ND	4.68E-02						
SO ₄ ²⁻	g/l	4.168	3.809	2.886						
Stot	g/l	1.43	1.27	1.01						
U	mg/l	< 0,05	0.08	0.58						

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 70

Procedure 2 : SUE C Tailings Temperature 50°C Aging Time 4h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		7	7.47	7.97						
'Eh(Ag/AgCl) mV										
Conductivity mS		6.98	6.32	5.64						
Alkalinity mM/l										
Al mg/l										
As mg/l		0.65	0.5	1.07						
As ⁵⁺ mg/l										
As ³⁺ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		0.1	< 0,02	< 0,02						
Fe ²⁺ mg/l										
Fe ³⁺ mg/l										
H ⁺ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO ₃ mg/l										
P mg/l										
Ra Bq/l										
S ²⁻ g/l										
SO ₄ ²⁻ g/l										
Stot g/l										
U mg/l										

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 71

Procedure 2 : SUE C Tailings Temperature 50°C Aging Time 8h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.83	7.29	7.54						
'Eh(Ag/AgCl) mV										
Conductivity mS		6.74	6.46	5.99						
Alkalinity mM/l										
Al mg/l										
As mg/l		0.6	0.48	1.14						
As ⁵⁺ mg/l										
As ³⁺ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		0.19	< 0,02	< 0,02						
Fe ²⁺ mg/l										
Fe ³⁺ mg/l										
H ⁺ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO ₃ mg/l										
P mg/l										
Ra Bg/l										
S ²⁻ g/l										
SO ₄ ²⁻ g/l										
Stot g/l										
U mg/l										

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 72

Procedure 2 : SUE C Tailings Temperature 50°C Aging Time 24h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.89	7.34	7.79						
Eh(Ag/AgCl)	mV	192	174	158						
Conductivity	mS	6.86	6.28	5.47						
Alkalinity	mM/l	0.23	0.52	0.69						
Al	mg/l	0.03	< 0,02	0.1						
As	mg/l	0.65	0.5	1.04						
As ⁵⁺	mg/l	< 0,2	0.23	1.04						
As ³⁺	mg/l	0.6	0.27	< 0,2						
Ca	mg/l	484	475	497						
Cl	mg/l	37.1	37.2	38						
Fe	mg/l	0.5	< 0,02	< 0,02						
Fe ²⁺	mg/l	<	< 0,02	< 0,02						
Fe ³⁺	mg/l	<	< 0,02	< 0,02						
H ⁺	N	—	—	—						
K	mg/l	104	84.7	90						
Mg	mg/l	353	296	94.8						
Na	mg/l	603	578	586						
Ni	mg/l	17.6	0.42	0.02						
NO ₃	mg/l	11.4	10.8	11.7						
P	mg/l	1.35	1.22	1.38						
Ra	Bq/l	—	—	—						
S ²⁻	g/l	ND	3.04E-02	4.94E-02						
SO ₄ ²⁻	g/l	4.461	3.864	2.968						
Stot	g/l	1.48	1.32	1.04						
U	mg/l	< 0,05	0.09	1.7						

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 73

Procedure 2 : SUE C Tailings Temperature 50°C Aging Time 48h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.64	7.29	7.72						
Eh(Ag/AgCl)	mV									
Conductivity	mS	6.79	6.3	5.8						
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	0.51	0.46	1.17						
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	0.83	< 0,02	< 0,02						
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 74

Procedure 2 : SUE C Tailings Temperature 50°C Aging Time 72h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.13	7.2	8.03						
Eh(Ag/AgCl)	mV									
Conductivity	mS	6.94	6.71	5.6						
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	0.45	0.46	1.24						
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	0.32	< 0,02	< 0,02						
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 75

Procedure 2 : SUE C Tailings Temperature 50°C Aging Time 144h

		Solution Fe/As 7,7 pH 7	Solution Fe/As 7,7 pH 8	Solution Fe/As 7,7 pH 9						
pH		6.57	7.23	7.82						
'Eh(Ag/AgCl)	mV	145	137	126						
Conductivity	mS	6.55	6.5	5.84						
Si	mg/l			6.4						
Alkalinity	mM/l	0.09	0.4	0.72						
Al	mg/l	0.32	< 0,02	0.03						
As	mg/l	0.88	0.69	1.56						
As ⁵⁺	mg/l	0.09	0.28	1.56						
As ³⁺	mg/l	0.79	0.41	< 0,2						
Ca	mg/l	496	524	523						
Cl	mg/l	36.4	38.3	43.7						
Fe	mg/l	0.31	< 0,02	< 0,02						
Fe ²⁺	mg/l	<	< 0,02	< 0,02						
Fe ³⁺	mg/l	<	< 0,02	< 0,02						
H ⁺	N	—	—	—						
K	mg/l	120	111	113						
Mg	mg/l	391	371	153						
Na	mg/l	599	610	663						
Ni	mg/l	12.4	0.33	0.03						
NO ₃	mg/l	10.2	11.1	12.3						
P	mg/l	1.42	1.27	0.78						
Ra	Bg/l	75.26	31.87	50						
S ²⁻	g/l	ND	ND	1.73E-02						
SO ₄ ²⁻	g/l	4.469	4.291	3.334						
Stot	g/l	1.48	1.43	1.13						
U	mg/l	< 0,05	< 0,05	1.06						

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 76
Procedure 1 : Cigar Tailings

Ores		
U	%	21.02
As	%	1.59
Ni	%	1.03
Mo	ppm	3193
V	ppm	1029
Zr	ppm	814
Fe	%	3.78
S-tot	%	2.25

Tailings			TOTAL
U-tot	ppm	1263	
As-tot	%	1.7	
Ni-tot	%	1.2	
Mo-tot	ppm	971	
Fe-HFO	ppm	1287	2%
As-HFO	ppm	275	
Ni-HFO	ppm	67.5	
Al-HFO	ppm	1550	
SO ₄ -HFO	%	5.04	1%

Leaching efficiency, 99.40

Weight loss, % 50.60

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
Iron	kg/t	0	0	0						
Slaked lime	kg/t	195	202	224						

Appendix C-3 - TABLE 77
Procedure 1 : Cigar Lake Tailings

		Raffinate	Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		—	5.63	7.58	8.69						
Eh(Ag/AgCl)	mV	386	100	93	79						
Conductivity	mS	125	7.9	6.95	4.49						
Alkalinity	mM/l	—	< 0,05	0.34	0.97						
Al	mg/l	4280	0.05	0.26	1.16						
As	mg/l	580	0.29	0.69	1.48						
As ⁵⁺	mg/l	454	0.16	0.14	0.61						
As ³⁺	mg/l	126	0.13	0.55	0.87						
Ca	mg/l	724	423	421	461						
Cl	mg/l	81	40.3	42	40.5						
Fe	mg/l	3260	32.5	0.03	< 0,02						
Fe ²⁺	mg/l	2670	32.5	<	<						
Fe ³⁺	mg/l	590	< 0,1	<	<						
H ⁺	N	0.4	—	—	—						
K	mg/l	388	219	194	163						
Mg	mg/l	2330	1370	1060	222						
Na	mg/l	129	466	452	439						
Ni	mg/l	453	9.22	0.18	0.03						
NO ₃	mg/l	40.5	10.4	10.6	10.7						
P	mg/l	156	0.03	0.06	0.15						
Ra	Bq/l	82.71	826.44	663.97	320.73						
S ²⁻	g/l	ND	ND	ND	ND						
SO ₄ ²⁻	g/l	67.2	8.891	7.21	3.18						
Stot	g/l	19.9	2.66	2.12	0.952						
U	mg/l	1.64	< 0,2	< 0,2	< 0,2						

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 78

Procedure 2 : Cigar Lake Tailings Temperature 25°C Aging Time 2h

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		5.7	7.19	7.72						
'Eh(Ag/AgCl) mV		163	147	142						
Conductivity mS		7.78	7.33	4.82						
Alkalinity mM/l		< 0,05	0.39	0.47						
Al mg/l		0.04	0.04	0.13						
As mg/l		0.19	0.45	1.25						
As ⁵⁺ mg/l		0.09	0.13	0.35						
As ³⁺ mg/l		0.1	0.32	0.9						
Ca mg/l		419	435	456						
Cl mg/l		40.2	40.1	36.9						
Fe mg/l		30.1	0.03	< 0,02						
Fe ²⁺ mg/l		20.5	<	<						
Fe ³⁺ mg/l		9.6	<	<						
H ⁺ N		—	—	—						
K mg/l		188	166	152						
Mg mg/l		1400	1250	361						
Na mg/l		465	466	446						
Ni mg/l		6.39	0.27	0.08						
NO ₃ mg/l		12.9	14.7	13.6						
P mg/l		0.58	0.94	0.36						
Ra Bq/l		—	—							
S ²⁻ g/l										
SO ₄ ²⁻ g/l		9.102	8.257	3.761						
Stot g/l		5.3	4.81	2.4						
U mg/l		< 0,2	< 0,2	< 0,2						

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 79

Procedure 2 : Cigar Lake Tailings Temperature 25°C Aging Time 8h

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		5.98	7.21	7.4						
Eh(Ag/AgCl)	mV									
Conductivity	mS	7.91	7.33	5.01						
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	0.51	0.67	1.63						
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	43.5	< 0,1	< 0,1						
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 80

Procedure 2 : Cigar Lake Tailings Temperature 25°C Aging Time 24h

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		4.74	7.3	7.18						
'Eh(Ag/AgCl) mV		223	176	164						
Conductivity mS		7.68	7.33	4.86						
Alkalinity mM/l		< 0,05	0.71	0.6						
Al mg/l		0.06	0.02	0.09						
As mg/l		0.17	0.45	1.13						
As ⁵⁺ mg/l		0.06	0.15	0.24						
As ³⁺ mg/l		< 1	0.3	0.89						
Ca mg/l		442	454	458						
Cl mg/l		47.8	38	40.5						
Fe mg/l		34.8	0.02	< 0,02						
Fe ²⁺ mg/l		34.8	<	<						
Fe ³⁺ mg/l		< 0,1	<	<						
H ⁺ N		—	—	—						
K mg/l		194	173	158						
Mg mg/l		1500	1360	411						
Na mg/l		493	482	449						
Ni mg/l		6.91	0.34	0.03						
NO ₃ mg/l		14.3	14.9	15.8						
P mg/l		0.49	0.82	0.38						
Ra Bq/l		—	—	—						
S ²⁻ g/l										
SO ₄ ²⁻ g/l		NA	NA	NA						
Stot g/l		2.96	2.75	1.38						
U mg/l		< 0,2	< 0,2	< 0,2						

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 81

Procedure 2 : Cigar Lake Tailings Temperature 25°C Aging Time 48h

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		5.01	7.21	7.57						
Eh(Ag/AgCl) mV										
Conductivity mS		8.59	8.19	5.46						
Alkalinity										
Al mg/l										
As mg/l		0.5	0.59	1.46						
As ⁵⁺ mg/l										
As ³⁺ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		49.1	< 0,1	< 0,1						
Fe ²⁺ mg/l										
Fe ³⁺ mg/l										
H ⁺ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO ₃ mg/l										
P mg/l										
Ra Bq/l										
S ²⁻ g/l										
SO ₄ ²⁻ g/l										
Stot g/l										
U mg/l										

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 82

Procedure 2 : Cigar Lake Tailings Temperature 25°C Aging Time 72h

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		5.11	7.3	7.65						
Eh(Ag/AgCl) mV										
Conductivity mS		7.9	7.71	5.09						
Alkalinity										
Al mg/l										
As mg/l		0.29	0.44	1.32						
As ⁵⁺ mg/l										
As ³⁺ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		49.8	< 0,02	< 0,02						
Fe ²⁺ mg/l										
Fe ³⁺ mg/l										
H ⁺ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO ₃ mg/l										
P mg/l										
Ra Bg/l										
S ²⁻ g/l										
SO ₄ ²⁻ g/l										
Stot g/l										
U mg/l										

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 83

Procedure 2 : Cigar Lake Tailings Temperature 25°C Aging Time 120h

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		5.73	7.31	7.45						
'Eh(Ag/AgCl) mV		111.9	99	98.1						
Conductivity mS		8.41	7.94	5.43						
Si mg/l		9.91	4.54	2.14						
Alkalinity mM/l		< 0,05	0.37	0.57						
Al mg/l		0.08	0.03	0.06						
As mg/l		0.28	0.36	1.27						
As ⁵⁺ mg/l		<	< 0,2	< 0,2						
As ³⁺ mg/l		<	0.36	1.12						
Ca mg/l		439	444	471						
Cl mg/l		40.6	34.3	34.5						
Fe mg/l		58.3	0.05	< 0,02						
Fe ²⁺ mg/l		56.1	<	<						
Fe ³⁺ mg/l		2.2	<	<						
H ⁺ N		—	—	—						
K mg/l		181	151	134						
Mg mg/l		1600	1470	512						
Na mg/l		495	478	464						
Ni mg/l		9.57	0.36	0.02						
NO ₃ mg/l		11.4	3.7	1.8						
P mg/l		0.31	1.13	2.35						
Ra Bq/l		265.27	169.23	107.89						
S ²⁻ g/l										
SO ₄ ²⁻ g/l		10.383	9.204	4.493						
Stot g/l		2.56	2.24	1.13						
U mg/l		< 0,25	< 0,25	< 0,25						

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 84

Procedure 2 : Cigar Lake Tailings Temperature 50°C Aging Time 2h

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		5.52	7.38	7.47						
'Eh(Ag/AgCl) mV		153	129	130						
Conductivity mS		8.11	7.54	5.15						
Alkalinity		< 0,05	0.59	0.65						
Al mg/l		0.04	0.05	0.06						
As mg/l		0.56	0.53	1.13						
As ⁵⁺ mg/l		0.08	0.15	0.37						
As ³⁺ mg/l		0.48	0.38	0.76						
Ca mg/l		485	477	511						
Cl mg/l		41.5	40.2	39.2						
Fe mg/l		51.8	0.15	< 0,02						
Fe ²⁺ mg/l		41.7	<	<						
Fe ³⁺ mg/l		10.1	<	<						
H ⁺ N		—	—	—						
K mg/l		222	197	188						
Mg mg/l		1480	1290	374						
Na mg/l		507	492	486						
Ni mg/l		7.49	0.39	0.06						
NO ₃ mg/l		12.8	13.9	14.6						
P mg/l		0.45	0.91	3.54						
Ra Bq/l		—	—	—						
S ²⁻ g/l		—	—	—						
SO ₄ ²⁻ g/l		10.04	8.666	4.123						
Stot g/l		5.68	5.12	2.59						
U mg/l		< 0,2	< 0,2	< 0,2						

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 85

Procedure 2 : Cigar Lake Tailings Temperature 50°C Aging Time 8h

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		5.79	7.32	7.49						
'Eh(Ag/AgCl) mV										
Conductivity mS		7.59	7.12	5.26						
Alkalinity										
Al mg/l										
As mg/l		0.81	0.7	1.68						
As ⁵⁺ mg/l										
As ³⁺ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		75.8	7.32	< 0,1						
Fe ²⁺ mg/l										
Fe ³⁺ mg/l										
H ⁺ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO ₃ mg/l										
P mg/l										
Ra Bg/l										
S ²⁻ g/l										
SO ₄ ²⁻ g/l										
Stot g/l										
U mg/l										

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 86

Procedure 2 : Cigar Lake Tailings Temperature 50°C Aging Time 24h

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		4.63	7.38	7.64						
'Eh(Ag/AgCl) mV		230	152	147						
Conductivity mS		8.58	7.52	4.95						
Alkalinity mM/l		< 0,05	0.79	1.11						
Al mg/l		0.11	0.03	0.11						
As mg/l		0.35	0.47	1.28						
As ⁵⁺ mg/l		0.04	0.15	0.41						
As ³⁺ mg/l		0.31	0.32	0.87						
Ca mg/l		483	489	481						
Cl mg/l		47.7	38.1	40.6						
Fe mg/l		104	0.15	< 0,02						
Fe ²⁺ mg/l		104	<	<						
Fe ³⁺ mg/l		< 0,1	<	<						
H ⁺ N		—	—	—						
K mg/l		220	183	165						
Mg mg/l		1600	1410	463						
Na mg/l		522	492	460						
Ni mg/l		13.5	0.58	0.06						
NO ₃ mg/l		14.3	14.8	15.6						
P mg/l		0.57	1.24	0.6						
Ra Bq/l		—	—	—						
S ²⁻ g/l		—	—	—						
SO ₄ ²⁻ g/l		NA	NA	NA						
Stot g/l		3.29	2.84	1.47						
U mg/l		< 0,2	< 0,2	< 0,2						

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 87

Procedure 2 : Cigar Lake Tailings Temperature 50°C Aging Time 48h

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		4.82	7.63	7.41						
Eh(Ag/AgCl) mV										
Conductivity mS		8.69	7.94	5.57						
Alkalinity										
Al mg/l										
As mg/l		0.9	0.59	1.55						
As ⁵⁺ mg/l										
As ³⁺ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		143	0.22	< 0,1						
Fe ²⁺ mg/l										
Fe ³⁺ mg/l										
H ⁺ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO ₃ mg/l										
P mg/l										
Ra Bq/l										
S ²⁻ g/l										
SO ₄ ²⁻ g/l										
Stot g/l										
U mg/l										

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 88

Procedure 2 : Cigar Lake Tailings Temperature 50°C Aging Time 72h

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		5.09	7.75	7.84						
Eh(Ag/AgCl)	mV									
Conductivity	mS	8.08	7.77	5.44						
Alkalinity										
Al	mg/l									
As	mg/l	0.47	0.41	1.47						
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	152	< 0,02	< 0,02						
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 89

Procedure 2 : Cigar Lake Tailings Temperature 50°C Aging Time 120h

		Solution Fe/As 7,5 pH 7	Solution Fe/As 7,5 pH 8	Solution Fe/As 7,5 pH 9						
pH		4.78	7.19	7.58						
Eh(Ag/AgCl)	mV	179.8	123	112.8						
Conductivity	mS	8.62	8.13	5.66						
Si	mg/l	12.6	6.91	2.91						
Alkalinity	mM/l	< 0,05	0.57	0.91						
Al	mg/l	0.16	0.04	0.04						
As	mg/l	0.16	0.34	1.58						
As ⁵⁺	mg/l	<	< 0,2	0.29						
As ³⁺	mg/l	<	0.32	1.29						
Ca	mg/l	442	438	460						
Cl	mg/l	35.5	33.5	34.1						
Fe	mg/l	153	0.03	< 0,02						
Fe ²⁺	mg/l	142	<	<						
Fe ³⁺	mg/l	11	<	<						
H ⁺	N	—	—	—						
K	mg/l	159	124	98						
Mg	mg/l	1720	1640	684						
Na	mg/l	495	487	450						
Ni	mg/l	16.3	0.47	0.02						
NO ₃	mg/l	11.5	10.7	8.2						
P	mg/l	0.67	2.49	1.59						
Ra	Bq/l	173.49	140.76	127.06						
S ²⁻	g/l	—	—	—						
SO ₄ ²⁻	g/l	10.97	10.114	5.168						
Stot	g/l	2.69	2.49	1.33						
U	mg/l	< 0,25	< 0,25	0.31						

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 90

Procedure 1 : Blend 1 Tailings (75% Sue C + 25% Cigar Lake)

Ores		CIGAR	SUE C
U	%	21.02	5.20
As	%	1.59	0.20
Ni	ppm	10300	1510.00
Mo	ppm	3193	865
V	ppm	1029	1950
Zr	ppm	814	332
Fe	%	3.78	1.58
S-tot	%		0.13

Leaching efficiency, 99.4 99.3

Weight loss, % 50.6 13

Tailings		
U-tot	ppm	572
As-tot	ppm	5023
Ni-tot	ppm	3269
Mo-tot	ppm	464
Fe-HFO	ppm	382
As-HFO	ppm	212
Ni-HFO	ppm	49
Al-HFO	ppm	1099
SO ₄ -HFO	%	2.28

		Solution Fe/As 7,6 pH 7	Solution Fe/As 7,6 pH 8	Solution Fe/As 7,6 pH 9						
Iron	kg/t	0	0	0						
Slaked lime	kg/t	152	157	169						

Appendix C-3 - TABLE 91
Procedure 1 : Blend 1 Tailings (75% Sue C + 25% Cigar Lake)

		Raffinate (calculat.)	Solution Fe/As 7,6 pH 7	Solution Fe/As 7,6 pH 8	Solution Fe/As 7,6 pH 9						
pH		—	7.03	8.05	9.07						
Eh(Ag/AgCl)	mV	—	160	145	110						
Conductivity	mS	—	5.93	5.39	4.28						
Alkalinity	mM/l	—	0.15	0.36	1.18						
Al	mg/l	1744	0.04	0.32	1.63						
As	mg/l	268	0.26	0.34	0.64						
As ⁵⁺	mg/l	—	< 0,03	0.17	0.48						
As ³⁺	mg/l	—	0.25	0.17	0.16						
Ca	mg/l	657	438	447	479						
Cl	mg/l	46	54.2	54.6	53.6						
Fe	mg/l	1521	0.03	< 0,02	< 0,02						
Fe ²⁺	mg/l	—	<	<	<						
Fe ³⁺	mg/l	—	<	<	<						
H ⁺	N	0.46	—	—	—						
K	mg/l	261	131	117	104						
Mg	mg/l	999	558	432	109						
Na	mg/l	66	559	539	527						
Ni	mg/l	234	5.47	0.14	0.03						
NO ₃	mg/l	38	9.1	9.2	9.1						
P	mg/l	58	0.02	0.04	0.16						
Ra	Bq/l	43	85.56	155.05	97.61						
S ²⁻	g/l	—	ND	ND	ND						
SO ₄ ²⁻	g/l	—	4.943	4.344	2.817						
Stot	g/l	13.5	1.58	1.23	0.912						
U	mg/l	<1	< 0,2	< 0,2	0.25						

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 92
Procedure 1 : Blend 1 Tailings (75% Sue C + 25% Cigar Lake)
Temperature 25°C Aging Time 2h

		Solution Fe/As 7,6 pH 7	Solution Fe/As 7,6 pH 8	Solution Fe/As 7,6 pH 9						
pH		6.04	7.1	7.73						
'Eh(Ag/AgCl)	mV	180	172	158						
Conductivity	mS	5.98	5.26	4.29						
Alkalinity	mM/l	0.15	0.21	0.41						
Al	mg/l	0.03	0.04	0.23						
As	mg/l	0.35	0.36	0.69						
As ⁵⁺	mg/l	0.2	0.15	0.35						
As ³⁺	mg/l	0.15	0.21	0.34						
Ca	mg/l	437	419	463						
Cl	mg/l	57.4	54	55						
Fe	mg/l	< 0,02	< 0,02	< 0,02						
Fe ²⁺	mg/l	<	<	<						
Fe ³⁺	mg/l	<	<	<						
H ⁺	N	—	—	—						
K	mg/l	131	103	95.6						
Mg	mg/l	574	455	131						
Na	mg/l	548	510	524						
Ni	mg/l	5.68	0.22	0.04						
NO ₃	mg/l	11	10.9	10.6						
P	mg/l	0.42	0.35	0.23						
Ra	Bq/l	—	—	—						
S ²⁻	g/l	ND	ND	ND						
SO ₄ ²⁻	g/l	5.167	4.184	2.792						
Stot	g/l	3.21	2.5	1.83						
U	mg/l	< 0,2	< 0,2	0.43						

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 93
Procedure 1 : Blend 1 Tailings (75% Sue C + 25% Cigar Lake)
Temperature 25°C Aging Time 8h

		Solution Fe/As 7,6 pH 7	Solution Fe/As 7,6 pH 8	Solution Fe/As 7,6 pH 9						
pH		6.46	7.02	7.91						
Eh(Ag/AgCl)	mV									
Conductivity	mS	5.67	5.22	4.08						
Alkalinity										
Al	mg/l									
As	mg/l	0.38	0.49	0.89						
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	< 0,1	< 0,1	< 0,1						
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 94
Procedure 1 : Blend 1 Tailings (75% Sue C + 25% Cigar Lake)
Temperature 25°C Aging Time 24h

		Solution Fe/As 7,6 pH 7	Solution Fe/As 7,6 pH 8	Solution Fe/As 7,6 pH 9						
pH		6.84	7.05	7.25						
Eh(Ag/AgCl)	mV	171	162	156						
Conductivity	mS	5.99	5.71	4.43						
Alkalinity	mM/l	0.25	0.34	0.5						
Al	mg/l	< 0,02	0.03	0.16						
As	mg/l	0.23	0.32	0.65						
As ⁵⁺	mg/l	< 0,03	0.12	0.29						
As ³⁺	mg/l	< 1	0.2	0.36						
Ca	mg/l	447	461	485						
Cl	mg/l	60.2	63	60.6						
Fe	mg/l	< 0,02	< 0,02	< 0,02						
Fe ²⁺	mg/l	<	<	<						
Fe ³⁺	mg/l	<	<	<						
H ⁺	N	—	—	—						
K	mg/l	136	120	105						
Mg	mg/l	595	522	148						
Na	mg/l	563	570	542						
Ni	mg/l	6.78	0.26	0.02						
NO ₃	mg/l	10.7	11.8	11.2						
P	mg/l	0.25	0.22	0.21						
Ra	Bq/l	—	—	—						
S ²⁻	g/l	—	—	—						
SO ₄ ²⁻	g/l	—	—	—						
Stot	g/l	1.67	1.59	1.09						
U	mg/l	< 0,2	0.24	0.58						

—: Not analysed

ND : Not detected

Appendix C-3 - TABLE 95
Procedure 1 : Blend 1 Tailings (75% Sue C + 25% Cigar Lake)
Temperature 25°C Aging Time 48h

		Solution Fe/As 7,6 pH 7	Solution Fe/As 7,6 pH 8	Solution Fe/As 7,6 pH 9						
pH		6.74	7.18	7.5						
Eh(Ag/AgCl)	mV									
Conductivity	mS	6.45	6.18	4.7						
Alkalinity										
Al	mg/l									
As	mg/l	0.38	0.46	0.83						
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	< 0,1	< 0,1	< 0,1						
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 96
Procedure 1 : Blend 1 Tailings (75% Sue C + 25% Cigar Lake)
Temperature 25°C Aging Time 72h

	Solution Fe/As 7,6 pH 7	Solution Fe/As 7,6 pH 8	Solution Fe/As 7,6 pH 9						
pH	6.37	7.21	7.32						
Eh(Ag/AgCl) mV									
Conductivity mS	6.19	5.67	4.68						
Alkalinity									
Al mg/l									
As mg/l	0.23	0.35	0.78						
As ⁵⁺ mg/l									
As ³⁺ mg/l									
Ca mg/l									
Cl mg/l									
Fe mg/l	0.03	< 0,02	< 0,02						
Fe ²⁺ mg/l									
Fe ³⁺ mg/l									
H ⁺ N									
K mg/l									
Mg mg/l									
Na mg/l									
Ni mg/l									
NO ₃ mg/l									
P mg/l									
Ra Bq/l									
S ²⁻ g/l									
SO ₄ ²⁻ g/l									
Stot g/l									
U mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 97
Procedure 1 : Blend 1 Tailings (75% Sue C + 25% Cigar Lake)
Temperature 25°C Aging Time 120h

		Solution Fe/As 7,6 pH 7	Solution Fe/As 7,6 pH 8	Solution Fe/As 7,6 pH 9						
pH		6.31	6.62	6.76						
Eh(Ag/AgCl)	mV	265	253	239.8						
Conductivity	mS	6.63	6.16	4.86						
Si	mg/l	12.6	4.47	2.15						
Alkalinity	mM/l	0.11	0.35	0.44						
Al	mg/l	0.02	0.02	0.08						
As	mg/l	0.19	0.27	0.71						
As ⁵⁺	mg/l	<	< 0,2	< 0,2						
As ³⁺	mg/l	<	0.28	0.59						
Ca	mg/l	461	466	493						
Cl	mg/l	59.9	60.3	61.5						
Fe	mg/l	0.06	< 0,02	< 0,02						
Fe ²⁺	mg/l	<	<	<						
Fe ³⁺	mg/l	<	<	<						
H ⁺	N	—	—	—						
K	mg/l	124	105	90.5						
Mg	mg/l	647	576	190						
Na	mg/l	574	568	539						
Ni	mg/l	9.09	0.22	0.02						
NO ₃	mg/l	4	2.1	3.8						
P	mg/l	1.07	1.08	1.73						
Ra	Bq/l	80.59	23.01	23.61						
S ²⁻	g/l	ND	ND	ND						
SO ₄ ²⁻	g/l	5.435	4.88	3.169						
Stot	g/l	1.5	1.33	0.87						
U	mg/l	< 0,25	0.38	0.84						

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 98
Procedure 1 : Blend 1 Tailings (75% Sue C + 25% Cigar Lake)
Temperature 50°C Aging Time 2h

		Solution Fe/As 7,6 pH 7	Solution Fe/As 7,6 pH 8	Solution Fe/As 7,6 pH 9						
pH		7.03	7.29	7.77						
Eh(Ag/AgCl)	mV	195	181	167						
Conductivity	mS	5.77	5.48	4.4						
Alkalinity	mM/l	0.22	0.38	0.55						
Al	mg/l	0.04	0.07	0.36						
As	mg/l	0.41	0.48	0.78						
As ⁵⁺	mg/l	0.11	0.15	0.42						
As ³⁺	mg/l	0.3	0.33	0.36						
Ca	mg/l	460	469	489						
Cl	mg/l	57.8	56.8	57.1						
Fe	mg/l	0.04	< 0,02	< 0,02						
Fe ²⁺	mg/l	<	<	<						
Fe ³⁺	mg/l	<	<	<						
H ⁺	N	—	—	—						
K	mg/l	139	125	114						
Mg	mg/l	565	467	122						
Na	mg/l	546	541	529						
Ni	mg/l	5.78	0.41	0.11						
NO ₃	mg/l	12	12.4	12.5						
P	mg/l	0.47	0.41	0.26						
Ra	Bq/l	—	—	—						
S ²⁻	g/l	ND	ND	ND						
SO ₄ ²⁻	g/l	5.122	4.466	2.885						
Stot	g/l	3.02	2.8	1.93						
U	mg/l	< 0,2	< 0,2	0.51						

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 99
Procedure 1 : Blend 1 Tailings (75% Sue C + 25% Cigar Lake)
Temperature 50°C Aging Time 8h

		Solution Fe/As 7,6 pH 7	Solution Fe/As 7,6 pH 8	Solution Fe/As 7,6 pH 9						
pH		6.62	7.22	7.43						
Eh(Ag/AgCl) mV										
Conductivity mS		6.01	5.26	4.36						
Alkalinity										
Al mg/l										
As mg/l		0.39	0.53	0.94						
As ⁵⁺ mg/l										
As ³⁺ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		< 0,1	< 0,1	< 0,1						
Fe ²⁺ mg/l										
Fe ³⁺ mg/l										
H ⁺ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO ₃ mg/l										
P mg/l										
Ra Bq/l										
S ²⁻ g/l										
SO ₄ ²⁻ g/l										
Stot g/l										
U mg/l										

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 102
Procedure 1 : Blend 1 Tailings (75% Sue C + 25% Cigar Lake)
Temperature 50°C Aging Time 72h

		Solution Fe/As 7,6 pH 7	Solution Fe/As 7,6 pH 8	Solution Fe/As 7,6 pH 9						
pH		5.61	7.21	7.61						
Eh(Ag/AgCl)	mV									
Conductivity	mS	6.02	5.97	4.65						
Alkalinity										
Al	mg/l									
As	mg/l	0.41	1.04	1.04						
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	2.15	< 0,02	< 0,02						
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

_ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 103
Procedure 1 : Blend 1 Tailings (75% Sue C + 25% Cigar Lake)
Temperature 50°C Aging Time 120h

		Solution Fe/As 7,6 pH 7	Solution Fe/As 7,6 pH 8	Solution Fe/As 7,6 pH 9						
pH		5.75	6.7	7.37						
Eh(Ag/AgCl)	mV	177.3	178.8	156						
Conductivity	mS	6.28	5.88	4.82						
Si	mg/l	18.3	6.58	2.97						
Alkalinity	mM/l	< 0,05	0.26	0.46						
Al	mg/l	0.08	0.04	0.05						
As	mg/l	0.21	0.27	0.92						
As ⁵⁺	mg/l	<	< 0,2	0.41						
As ³⁺	mg/l	<	<	0.51						
Ca	mg/l	443	439	475						
Cl	mg/l	58	57.9	57.4						
Fe	mg/l	1.76	< 0,02	< 0,02						
Fe ²⁺	mg/l	1.8	<	<						
Fe ³⁺	mg/l	< 0,1	<	<						
H ⁺	N	—	—	—						
K	mg/l	112	83.4	82						
Mg	mg/l	682	596	253						
Na	mg/l	570	545	537						
Ni	mg/l	13.1	0.21	0.01						
NO ₃	mg/l	13.1	9.6	9.5						
P	mg/l	0.13	1.64	1.13						
Ra	Bq/l	189.44	19.95	24.31						
S ²⁻	g/l	ND	ND	ND						
SO ₄ ²⁻	g/l	5.588	4.84	3.279						
Stot	g/l	1.45	1.27	0.904						
U	mg/l	< 0,25	0.26	1.44						

— : Not analysed

ND : Not detected

Appendix C-3 - TABLE 104

Procedure 1 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30% Cigar)

Ores		CIGAR	Midwest Sue A+B
U	%	21.02	4.15
As	%	1.59	8.27
Ni	%	1.03	3.87
Mo	ppm	3193	1570
V	ppm	1029	1256
Zr	ppm	814	348
Fe	%	3.78	1.62
S-tot	%	2.25	0.39

		Solution Fe/As 1 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2 pH 8	Solution Fe/As 2.5 pH 8	Solution Fe/As 3 pH 8
Iron	kg/t	17.3	29	41.6	54.0	66.0
Slaked lime	kg/t	170	188	206	227	245

Appendix C-3 - TABLE 105

Procedure 1 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)

		Raffinate	Solution Fe/As 1 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2 pH 8	Solution Fe/As 2.5 pH 8		Solution Fe/As 3 pH 8			
pH		-	7.8	7.7	7.8	7.6		7.8			
Eh(Ag/AgCl)	mV	384	212	196	194	202		205			
Conductivity	mS	102	5.97	5.88	5.65	5.64		5.55			
Alkalinity	mM/l	-	0.35	0.24	0.22	0.2		0.17			
Al	mg/l	2620	<0.02	<0.02	<0.02	<0.2		<0.02			
As	mg/l	7090	10.7	3.13	0.86	0.55		0.28			
As5+	mg/l	2770	3.55	0.83	<1.0	<1.0		<1.0			
As3+	mg/l	4320	7.15	2.3	1.14	<1.0		<1.0			
Ca	mg/l	429	458	456	458	501		501			
Cl	mg/l	49.3	35.7	35.7	35.7	36.7		36.2			
Fe	mg/l	1530	<0.02	<0.02	<0.02	<0.02		<0.02			
Fe2+	mg/l	1140	<	<	<	<		<			
Fe3+	mg/l	390	<	<	<	<		<			
H+	N	0.52	-	-	-	-		-			
K	mg/l	177	71.9	75.9	80.1	93.2		91			
Mg	mg/l	1410	420	415	364	393		369			
Mo	mg/l	-	3.26	0.82	0.39	0.23		0.19			
Na	mg/l	48.4	625	517	505	506		509			
Ni	mg/l	5710	1.9	1.18	0.63	0.49		0.48			
NO3	mg/l	34.5	11.1	10.9	10.9	11		11.3			
P	mg/l	97.6	0.27	0.16	0.12	0.09		0.1			
Ra	Bq/l	117.38	217.37	296.51	327.92	525.81		510.19			
Si	mg/l	-	2.44	0.85	0.48	0.43		0.31			
S ²⁻	g/l	-	-	-	-	-		-			
SO ₄ ²⁻	g/l	54.7	4.166	4.215	3.925	3.927		3.826			
Stot	g/l	16.8	1.41	1.4	1.34	1.31		1.28			
U	mg/l	<0.2	<0.2	<0.2	<0.2	<0.2		<0.2			

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 106

Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)

Temperature 25°C Except Fe/As 3 4°C Aging Time 2h

		Solution Fe/As 1 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2 pH 8	Solution Fe/As 2.5 pH 8		Solution Fe/As 3 pH 8			
pH		7.2	7.1	7	6.9		7			
Eh(Ag/AgCl)	mV	223	220	223	219		217			
Conductivity	mS	6.06	5.97	5.75	5.83		5.55			
Alkalinity	mM/l	0.44	0.27	0.23	<0.05		<0.05			
Al	mg/l	<0.02	<0.02	<0.02	<0.02		<0.02			
As	mg/l	17.6	6.77	2.8	1.38		0.76			
As5+	mg/l	6	1.66	0.39	0.18		0.36			
As3+	mg/l	11.6	5.11	2.21	1.23		0.4			
Ca	mg/l	569	564	577	596		549			
Cl	mg/l	35.9	35.8	35.8	38.6		39.5			
Fe	mg/l	<0.02	<0.02	<0.02	<0.02		<0.02			
Fe2+	mg/l	<	<	<	<		<			
Fe3+	mg/l	<	<	<	<		<			
H+	N	NA	NA	NA	NA		NA			
K	mg/l	101	101	105	112		102			
Mg	mg/l	573	558	492	493		451			
Mo	mg/l	NA	NA	NA	NA		NA			
Na	mg/l	521	515	505	505		507			
Ni	mg/l	6.7	4.45	1.15	0.54		0.17			
NO3	mg/l	13.5	13.2	13.1	13.6		13.8			
P	mg/l	1.19	1.03	1	1.23		0.38			
Ra	Bq/l	379.74	340.59	400.48	366.3		249.94			
Si	mg/l	NA	NA	NA	NA		NA			
S ²⁻	g/l	NA	NA	NA	NA		NA			
SO ₄ ²⁻	g/l	4.768	4.696	4.371	4.453		4.078			
Stot	g/l	1.49	1.46	1.38	1.37		1.26			
U	mg/l	<0.2	<0.2	<0.2	<0.2		<0.2			

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 107

Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)

Temperature 25°C Except Fe/As 3 4°C Aging Time 6h

		Solution Fe/As 1 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2 pH 8	Solution Fe/As 2.5 pH 8		Solution Fe/As 3 pH 8			
pH		7.24	7.22	7.07	7.11		6.9			
Eh(Ag/AgCl)	mV									
Conductivity	mS	3.36	4.31	2.33	1.21		1.86			
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	15.4	6.57	2.09	0.79		0.19			
As5+	mg/l									
As3+	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	<0.02	<0.02	<0.02	<0.02		<0.02			
Fe2+	mg/l									
Fe3+	mg/l									
H+	N									
K	mg/l									
Mg	mg/l									
Mo	mg/l									
Na	mg/l									
Ni	mg/l									
NO3	mg/l									
P	mg/l									
Ra	Bg/l									
Si	mg/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C3 - TABLE 108

Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)

Temperature 25°C Except Fe/As 3 4°C Aging Time 24h

		Solution Fe/As 1 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2 pH 8	Solution Fe/As 2.5 pH 8		Solution Fe/As 3 pH 8			
pH		7.18	7.21	7	7.09		6.65			
Eh(Ag/AgCl)	mV	124	152	173	177		195			
Conductivity	mS	6.25	6.17	5.96	5.2		5.11			
Alkalinity	mM/l	0.48	0.35	0.25	0.37		0.33			
Al	mg/l	<0.02	<0.02	<0.02	<0.02		<0.02			
As	mg/l	18.4	7.34	3.48	1.32		0.41			
As5+	mg/l	6	2	0.89	0.08		<1.0			
As3+	mg/l	12.4	5.34	2.59	1.24		<1.0			
Ca	mg/l	518	503	523	468		447			
Cl	mg/l	33.4	33	34.8	32.6		35.9			
Fe	mg/l	<0.02	<0.02	<0.02	<0.02		<0.02			
Fe2+	mg/l	<	<	<	<		<			
Fe3+	mg/l	<	<	<	<		<			
H+	N	-	-	-	-		-			
K	mg/l	63.4	83.7	89	66.5		77.4			
Mg	mg/l	553	544	479	404		402			
Mo	mg/l	-	-	-	-		-			
Na	mg/l	524	512	508	422		443			
Ni	mg/l	9.39	6.02	0.53	0.83		0.64			
NO3	mg/l	12.4	11.9	12.5	11.4		13.5			
P	mg/l	0.73	0.17	0.44	0.29		0.19			
Ra	Bq/l	466.56	243.84	272.59	211.34		149.16			
Si	mg/l	-	-	-	-		-			
S ²⁻	g/l	-	-	-	-		-			
SO ₄ ²⁻	g/l	5.585	4.42	4.242	3.582		3.44			
Stot	g/l	1049	1.45	1.49	1.22		1.15			
U	mg/l	<0.2	<0.2	<0.2	<0.2		<0.2			

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 109
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 25°C Except Fe/As 3 4°C Aging Time 48h

		Solution Fe/As 1.0 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2.0 pH 8	Solution Fe/As 2.5 pH 8		Solution Fe/As 3 pH 8			
pH		7.3	7.32	7.33	7.26		6.9			
'Eh(Ag/AgCl)	mV									
Conductivity	mS	6.32	6	5.89	5.86		5.71			
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	16.4	7.11	2.5	0.96		0.3			
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	<0.02	<0.02	<0.02	<0.02		<0.02			
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Mo	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
Si	mg/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 110
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 25°C Except Fe/As 3 4°C Aging Time 72h

		Solution Fe/As 1.0 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2.0 pH 8	Solution Fe/As 2.5 pH 8		Solution Fe/As 3 pH 8			
pH		7.2	7.2	7.1	7		6.8			
Eh(Ag/AgCl)	mV									
Conductivity	mS	5.81	5.73	5.65	5.68		5.37			
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	16.2	6.44	2.95	1.49		0.6			
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	<0.02	<0.02	<0.02	<0.02		<0.02			
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Mo	mg/l									
Na	mg/l									
Ni	mg/l									
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
Si	mg/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 111

Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)

Temperature 25°C Except Fe/As 3 4°C Aging Time 144h

		Solution Fe/As 1.0 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2.0 pH 8	Solution Fe/As 2.5 pH 8		Solution Fe/As 3 pH 8			
pH		7.1	7.2	7.2	7		6.77			
'Eh(Ag/AgCl)	mV	183	177	166	181		201			
Conductivity	mS	6.3	5.99	5.82	5.75		5.49			
Alkalinity	mM/l	0.08	0.48	<0.05	0.36		<0.05			
Al	mg/l	0.04	0.03	0.03	0.03		0.04			
As	mg/l	21.8	8.45	4.1	2.43		0.67			
As ⁵⁺	mg/l	7.5	1.88	0.46	0.64		<1.0			
As ³⁺	mg/l	14.3	6.57	3.64	1.79		<1.0			
Ca	mg/l	522	496	507	520		456			
Cl	mg/l	33.5	31.2	34.7	36.2		39.3			
Fe	mg/l	<0.02	0.13	<0.02	<0.02		<0.02			
Fe ²⁺	mg/l	<	<	<	<		<			
Fe ³⁺	mg/l	<	<	<	<		<			
H ⁺	N	—	—	—	—		—			
K	mg/l	78.4	70.1	78.1	83		74.7			
Mg	mg/l	583	513	474	462		419			
Mo	mg/l	1.36	0.66	0.42	0.29		0.08			
Na	mg/l	522	486	492	498		484			
Ni	mg/l	12.4	7.64	3.96	3.47		2.07			
NO ₃	mg/l	12.1	2.2	2.2	2.1		13.5			
P	mg/l	2.86	1.29	1.8	1.97		1.2			
Ra	Bq/l	244.6	184.06	193.06	193.62		104.63			
Si	mg/l	14.2	11.3	8.66	7.75		3.31			
S ²⁻	g/l									
SO ₄ ²⁻	g/l	5.087	4.657	4.508	4.466		4.068			
Stot	g/l	1.63	1.5	1.47	1.48		1.37			
U	mg/l	<0.2	<0.2	<0.2	<0.2		<0.2			

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 112
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 25°C Except Fe/As 3 4°C Aging Time 336h

		Solution Fe/As 1.0 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2.0 pH 8	Solution Fe/As 2.5 pH 8		Solution Fe/As 3 pH 8			
pH		7.4	7.5	7.5	7.4		7.1			
Eh(Ag/AgCl)	mV	368	381	390	387		401			
Conductivity	mS									
Alkalinity	mM/l									
Al	mg/l									
As	mg/l	18.8	7.84	2.34	2.29		0.84			
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	<0.02	<0.02	<0.02	<0.02		<0.02			
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Mo	mg/l									
Na	mg/l									
Ni	mg/l	15.7	9.61	4.79	4.09		2.97			
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
Si	mg/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 113
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 25°C Except Fe/As 3 4°C Aging Time 840h

		Solution Fe/As 1.0 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2.0 pH 8	Solution Fe/As 2.5 pH 8		Solution Fe/As 3 pH 8			
pH		7	7.5	7.4	7.4		7.01			
'Eh(Ag/AgCl)	mV	451	458	455	457		450			
Conductivity	mS									
Alkalinity										
Al	mg/l									
As	mg/l	17.6	6.01	2.09	1.46		0.15			
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	0.02	<0.02	0.17	0.02		<0.02			
Fe ²⁺	mg/l									
Fe ³⁺	mg/l									
H ⁺	N									
K	mg/l									
Mg	mg/l									
Mo	mg/l									
Na	mg/l									
Ni	mg/l	28.3	13.6	6.34	5.29		0.1			
NO ₃	mg/l									
P	mg/l									
Ra	Bq/l									
Si	mg/l									
S ²⁻	g/l									
SO ₄ ²⁻	g/l									
Stot	g/l									
U	mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C-3 - TABLE 114

Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)

Temperature 25°C Except Fe/As 3 4°C Aging Time 1176h

		Solution Fe/As 1.0 pH 8	Solution Fe/As 1.5 pH 8	Solution Fe/As 2.0 pH 8	Solution Fe/As 2.5 pH 8		Solution Fe/As 3 pH 8			
pH		6.8	7.3	7.2	7.7		7.44			
Eh(Ag/AgCl)	mV	395	400	369	397		397			
Conductivity	mS	6.81	6.11	5.91	5.89		5.6			
Alkalinity										
Al	mg/l	0.03	<0.02	<0.02	<0.02		<0.02			
As	mg/l	19.5	7.32	1.58	1.18		0.95			
As ⁵⁺	mg/l									
As ³⁺	mg/l									
Ca	mg/l	475	480	475	468		447			
Cl	mg/l	32.3	31.8	31.6	34.8		34.7			
Fe	mg/l	0.06	<0.02	<0.02	<0.02		<0.02			
Fe ²⁺	mg/l	<	<	<	<		<			
Fe ³⁺	mg/l	<	<	<	<		<			
H ⁺	N	—	—	—	—		—			
K	mg/l	70.2	62.6	63.4	68.3		70.6			
Mg	mg/l	671	573	502	481		417			
Mo	mg/l	1.51	1.4	0.81	0.71		0.17			
Na	mg/l	520	509	490	483		468			
Ni	mg/l	46.3	15.4	8.23	5.81		2.69			
NO ₃	mg/l	4	4	3.6	3.8		3.7			
P	mg/l	3.35	2.5	0.86	0.37		0.36			
Ra	Bq/l	317.91	187.38	224.71	81.66		65.94			
Si	mg/l	19.4	13.8	12.1	10.7		4.39			
S ²⁻	g/l									
SO ₄ ²⁻	g/l	5.479	4.694	4.49	4.373		4.027			
Stot	g/l									
U	mg/l	<0.05	<0.05	<0.05	<0.05		<0.05			

NA, _ : Not analysed

ND : Not detected

Appendix C3 - TABLE 115

Procedure 1 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)

Ores		CIGAR	MID(78%) / SUEA+B(22%)
U	%	21.02	4.15
As	%	1.59	8.27
Ni	%	3.78	3.87
Mo	ppm	3193	1570
V	ppm	1029	1256
Zr	ppm	814	348
Fe	%	3.78	1.62
S-tot	%		0.39

Leaching efficiency, 99.39914 97.75180723
Weight loss, % 50.6 31.1

Blend 3 tailings			
U-tot	ppm	1032	
As-tot	%	1.553	
Ni-tot	ppm	5336	
Mo-tot	ppm	909.4	
Fe-HFO	ppm	3237.2	33%
As-HFO	ppm	5166.6	5%
Ni-HFO	ppm	289.75	
Al-HFO	ppm	1113.2	
SO4-HFO	%	2.59	

		Solution Fe/As0,3 pH 7	Solution Fe/As0,3 pH 8	Solution Fe/As0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
Iron	kg/t	0	0	0	77.0	77.0	77.0	134.0	134.0	134.0
Slaked lime	kg/t	175	197	208	284	306	326	383	394	438

Appendix C3 - TABLE 116
Procedure 1 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)

	Raffinate (calculat.)	Solution Fe/As0,3 pH 7	Solution Fe/As0,3 pH 8	Solution Fe/As0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.51	7.71	9.05	6.84	7.51	9.02	6.86	7.78	9.19
Eh(Ag/AgCl) mV	—	175	116	119	183	173	132	101	106	78
Conductivity mS	—	6.91	5.41	4.21	6.16	5.08	4.08	5.81	4.84	3.92
Alkalinity mM/l	—	0.32	0.97	1.63	0.16	0.25	0.88	0.1	0.26	1
Al mg/l	2490.8	0.05	0.08	0.31	0.03	0.07	0.33	< 0,02	0.06	0.26
As mg/l	6806.7	65.2	56.2	56.1	0.84	0.78	1.24	0.56	0.43	0.9
As5+ mg/l	—	5	30.4	44.2	0.13	0.2	0.74	0.13	0.12	0.5
As3+ mg/l	—	60.2	25.8	11.9	0.71	0.58	0.5	0.43	0.31	0.4
Ca mg/l	350.54	432	454	489	447	462	479	446	457	490
Cl mg/l	46.991	35.9	36.3	34.9	35.6	35.3	35.9	34.8	36.3	35.5
Fe mg/l	1492.1	0.05	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	2.05	< 0,02	< 0,02
Fe2+ mg/l	—	<	<	<	<	<	<	1.38	<	<
Fe3+ mg/l	—	<	<	<	<	<	<	0.67	<	<
H+ N	0.471	—	—	—	—	—	—	—	—	—
K mg/l	266.59	134	115	98.9	144	125	116	146	133	113
Mg mg/l	1206.78	712	385	83.2	631	298	44.7	561	255	32.1
Na mg/l	69.431	547	519	502	503	481	456	464	455	442
Ni mg/l	5165.27	369	5.41	0.27	52.7	1.56	0.08	39.6	0.74	0.05
NO3 mg/l	37.234	11.1	11.1	10.9	11.8	11.8	11.9	12.1	12.5	12.6
P mg/l	59.937	0.15	0.34	0.41	0.19	0.04	0.12	0.02	0.03	0.08
Ra Bq/l	26.9537	179.34	199.79	120.51	328.77	273.47	195.53	421.17	301.26	244.62
S2- g/l		ND	ND	ND	ND	ND	ND	ND	ND	ND
SO42- g/l	—	6.151	3.927	2.627	5.245	3.602	2.482	4.863	3.412	2.396
Stot g/l	16	1.91	1.29	0.873	1.62	1.19	0.835	1.56	1.09	0.814
U mg/l	1.2069	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2

NA, _ : Not analysed

ND : Not detected

Appendix C3 - TABLE 117
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 25°C Aging Time 2h

		Solution Fe/As 0,3 pH 7	Solution Fe/As 0,3 pH 8	Solution Fe/As 0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		7.02	7.56	8.05	7.05	7.34	8.38	7.19	7.3	8.66
Eh(Ag/AgCl)	mV	207	186	165	204	188	155	197	187	154
Conductivity	mS	5.95	4.73	3.79	5.15	4.31	3.64	4.9	4.2	3.48
Alkalinity		0.67	1.95	1.86	0.25	0.32	0.48	0.31	0.28	0.53
Al	mg/l	0.06	< 0,02	< 0,02	0.05	0.04	0.06	0.05	0.05	0.07
As	mg/l	121	107	104	1.68	1.32	2.02	0.99	0.67	1.41
As5+	mg/l	21	71.3	92.8	0.28	0.48	1.21	0.19	0.27	0.8
As3+	mg/l	100	35.7	11.2	1.4	0.84	0.81	0.8	0.4	0.61
Ca	mg/l	448	469	499	446	460	480	449	463	492
Cl	mg/l	43.2	41.2	40.9	44.6	39.6	35	41.3	40	39.4
Fe	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	0.03	< 0,02	< 0,02
Fe2+	mg/l	<	<	<	<	<	<	<	<	<
Fe3+	mg/l	<	<	<	<	<	<	<	<	<
H+	N	—	—	—	—	—	—	—	—	—
K	mg/l	115	92.4	86.1	134	118	110	134	124	113
Mg	mg/l	713	440	111	612	316	55.2	506	256	37.7
Na	mg/l	504	493	478	482	460	446	450	440	426
Ni	mg/l	476	9.85	0.29	46.9	1.27	0.06	23.7	0.55	0.02
NO3	mg/l	15.6	14.7	14.9	16.3	14.5	14.6	15.4	15.3	15.9
P	mg/l	1.57	1.18	0.82	0.98	0.21	0.14	0.21	0.15	0.13
Ra	Bq/l	—	—	—	—	—	—	—	—	—
S2-	g/l	—	—	—	—	—	—	—	—	—
SO42-	g/l	6.563	4.19	2.683	5.203	3.683	2.574	2.675	3.432	2.477
Stot	g/l	1.99	1.3	0.842	1.53	1.14	1.44	1.05	1.05	0.78
U	mg/l	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 118
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 25°C Aging Time 8h

		Solution Fe/As 0,3 pH 7	Solution Fe/As 0,3 pH 8	Solution Fe/As 0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		7.03	7.91	7.76	7.19	7.49	7.38	7.26	7.5	7.6
'Eh(Ag/AgCl) mV										
Conductivity mS		7.12	5.4	4.47	5.94	5.05	4.13	5.73	4.83	4.16
Alkalinity										
Al mg/l										
As mg/l		138	119	124	1.85	1.44	2.23	1.18	0.92	1.64
As ⁵⁺ mg/l										
As ³⁺ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	0.22	< 0,2	< 0,2
Fe ²⁺ mg/l										
Fe ³⁺ mg/l										
H ⁺ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO ₃ mg/l										
P mg/l										
Ra Bg/l										
S ²⁻ g/l										
SO ₄ ²⁻ g/l										
Stot g/l										
U mg/l										

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 119
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 25°C Aging Time 24h

		Solution Fe/As 0,3 pH 7	Solution Fe/As 0,3 pH 8	Solution Fe/As 0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.99	7.43	7.7	6.68	6.96	8.4	6.99	6.98	8.41
Eh(Ag/AgCl)	mV	194	177	161	199	199	154	207	195	151
Conductivity	mS	6.01	4.84	3.9	5.42	4.52	3.75	4.95	4.34	3.65
Alkalinity		0.64	2.06	2.02	0.29	0.38	0.53	0.36	0.29	0.61
Al	mg/l	0.05	< 0,02	0.03	0.03	0.03	0.05	0.03	0.04	0.05
As	mg/l	135	113	115	1.82	1.37	2.13	0.91	0.67	1.42
As5+	mg/l	24	72.6	103.5	0.39	0.49	1.28	0.35	0.33	0.85
As3+	mg/l	111	40.4	11.5	1.43	0.88	0.85	0.56	0.34	0.57
Ca	mg/l	442	473	506	444	460	491	448	475	496
Cl	mg/l	40.5	40.7	41.1	42.1	38.6	35.3	42.8	42.1	40.3
Fe	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Fe2+	mg/l	<	<	<	<	<	<	<	<	<
Fe3+	mg/l	<	<	<	<	<	<	<	<	<
H+	N	—	—	—	—	—	—	—	—	—
K	mg/l	121	90.6	89.1	134	113	104	136	123	108
Mg	mg/l	719	447	109	604	312	56.3	487	256	39.9
Na	mg/l	561	526	522	523	492	486	488	484	467
Ni	mg/l	519	10.5	0.31	51.2	1.24	0.04	24.7	0.5	< 0,01
NO3	mg/l	13.3	13.7	14.6	14.9	14.3	15	17.2	11.1	17.6
P	mg/l	0.57	0.73	0.71	0.22	0.15	0.15	0.21	0.31	0.2
Ra	Bq/l	—	—	—	—	—	—	—	—	—
S2-	g/l	—	—	—	—	—	—	—	—	—
SO42-	g/l	—	—	—	—	—	—	—	—	—
Stot	g/l	2.01	1.25	0.873	1.51	1.11	0.806	1.29	1.04	0.731
U	mg/l	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 120
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 25°C Aging Time 48h

		Solution Fe/As 0,3 pH 7	Solution Fe/As 0,3 pH 8	Solution Fe/As 0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.99	7.93	7.9	7.25	7.49	7.36	7.39	7.46	7.81
Eh(Ag/AgCl)	mV									
Conductivity	mS	6.6	5.13	4.06	5.54	4.64	3.96	5.24	4.56	3.86
Alkalinity										
Al	mg/l									
As	mg/l	150	119	125	2.04	1.53	2.34	1.33	0.94	1.86
As5+	mg/l									
As3+	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2
Fe2+	mg/l									
Fe3+	mg/l									
H+	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO3	mg/l									
P	mg/l									
Ra	Bg/l									
S2-	g/l									
SO42-	g/l									
Stot	g/l									
U	mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 121
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 25°C Aging Time 72h

		Solution Fe/As 0,3 pH 7	Solution Fe/As 0,3 pH 8	Solution Fe/As 0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.97	7.93	7.84	7.25	7.4	7.35	7.34	7.47	7.71
Eh(Ag/AgCl)	mV									
Conductivity	mS	6.41	5.01	4	5.43	4.77	3.78	5.22	4.41	3.74
Alkalinity										
Al	mg/l									
As	mg/l	150	115	121	1.98	1.19	2.28	0.89	0.63	1.47
As5+	mg/l									
As3+	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	0.55	< 0,02	< 0,02
Fe2+	mg/l									
Fe3+	mg/l									
H+	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO3	mg/l									
P	mg/l									
Ra	Bq/l									
S2-	g/l									
SO42-	g/l									
Stot	g/l									
U	mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 122

Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)

Temperature 25°C Aging Time 120h

		Solution Fe/As 0,3 pH 7	Solution Fe/As 0,3 pH 8	Solution Fe/As 0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		7.02	7.5	7.89	6.79	7.12	7.29	7.06	7.19	8.35
Eh(Ag/AgCl)	mV	145.1	136.4	125.3	178.7	158	162.1	192.7	190.5	151.3
Conductivity	mS	6.65	5.35	4.27	5.67	4.81	4.04	5.42	4.64	3.96
Si	mg/l	30.9	13.9	5.77	11.3	5.38	3.57	11.4	4.64	2.53
Alkalinity	mM/l	0.66	2.21	2.18	0.36	0.45	0.42	0.42	4.49	0.62
Al	mg/l	0.04	< 0,02	< 0,02	0.03	< 0,02	< 0,02	< 0,02	0.02	0.02
As	mg/l	155	118	126	2.16	1.52	2.71	1.24	0.76	1.76
As5+	mg/l	22	72.3	113	< 0,2	0.45	1.71	0.2	0.29	1.11
As3+	mg/l	133	45.7	12.7	2.14	1.07	1	1.07	0.47	0.65
Ca	mg/l	450	483	514	446	458	489	453	455	495
Cl	mg/l	39.1	40.6	38.1	41.2	37.9	32.8	40.4	40.3	37.4
Fe	mg/l	0.03	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	0.34	< 0,02	< 0,02
Fe2+	mg/l	<	<	<	<	<	<	<	<	<
Fe3+	mg/l	<	<	<	<	<	<	<	<	<
H+	N	—	—	—	—	—	—	—	—	—
K	mg/l	106	82.8	76.4	122	102	93.8	123	115	100
Mg	mg/l	762	484	138	644	339	67.7	537	274	45
Na	mg/l	552	539	515	517	488	488	489	474	468
Ni	mg/l	593	12.2	0.36	59.9	1.39	0.06	30.3	0.55	0.02
NO3	mg/l	12.4	12.4	11.8	13.7	5.8	2.9	7	1.9	14.3
P	mg/l	1.62	2.15	1.61	1.57	0.34	2.12	0.3	0.35	0.24
Ra	Bq/l	38.16	49.9	129.34	30.24	27.17	44.29	28.01	30.74	31.6
S2-	g/l	—	—	—	—	—	—	—	—	—
SO42-	g/l	7.149	4.391	2.758	5.425	3.786	2.635	4.768	3.454	2.475
Stot	g/l	1.78	1.11	0.682	1.37	1.2	0.866	1.44	1.06	0.846
U	mg/l	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 123
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 50°C Aging Time 2h

		Solution Fe/As 0,3 pH 7	Solution Fe/As 0,3 pH 8	Solution Fe/As 0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		7.04	7.64	7.96	7.17	7.48	8.36	7.39	7.48	8.48
Eh(Ag/AgCl)	mV	201	180	155	195	178	154	189	176	147
Conductivity	mS	5.76	4.58	3.76	5.05	4.46	3.71	4.87	4.27	3.56
Alkalinity	mM/l	0.85	2.04	1.95	0.34	0.5	0.59	0.56	0.39	0.48
Al	mg/l	0.06	0.03	0.04	0.04	0.05	0.1	0.05	0.05	0.06
As	mg/l	147	115	106	2.14	2.47	2.67	2.1	1.18	1.8
As5+	mg/l	29	69.5	91.8	0.5	0.83	1.57	0.37	0.51	0.91
As3+	mg/l	118	45.5	14.2	1.64	1.64	1.1	1.73	0.67	0.89
Ca	mg/l	461	476	510	452	496	499	485	491	503
Cl	mg/l	40.3	39.8	38.3	40.1	38.8	35.1	43.2	41.7	39.2
Fe	mg/l	0.03	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	0.04	< 0,02	< 0,02
Fe2+	mg/l	<	<	<	<	<	<	<	<	<
Fe3+	mg/l	<	<	<	<	<	<	<	<	<
H+	N	—	—	—	—	—	—	—	—	—
K	mg/l	126	99.8	93.9	136	131	121	146	136	116
Mg	mg/l	720	425	106	591	298	48.3	493	241	35.4
Na	mg/l	511	479	473	459	463	440	446	442	409
Ni	mg/l	481	9.72	0.32	46	1.5	0.09	25.3	0.69	0.69
NO3	mg/l	13.5	13.5	13.5	14.9	14.7	14.7	15.8	15.3	16.6
P	mg/l	0.97	0.82	0.73	0.56	0.34	0.23	0.61	0.26	0.26
Ra	Bg/l	—	—	—	—	—	—	—	—	—
S2-	g/l	—	—	—	—	—	—	—	—	—
SO42-	g/l	6.773	4.152	2.732	5.18	2.606	3.808	4.756	3.504	2.488
Stot	g/l	2.06	1.32	0.918	1.63	1.24	0.865	1.53	1.16	0.854
U	mg/l	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 124
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 50°C Aging Time 4h

	Solution Fe/As 0,3 pH 7	Solution Fe/As 0,3 pH 8	Solution Fe/As 0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH	6.9	8	7.86	7.47	7.68	7.87	7.67	7.67	7.51
Eh(Ag/AgCl) mV									
Conductivity mS	6.57	5.21	4.3	5.86	4.99	4.16	5.56	4.83	4.09
Alkalinity									
Al mg/l									
As mg/l	245	154	130	4.49	3.03	3.99	3.28	1.47	2.54
As5+ mg/l									
As3+ mg/l									
Ca mg/l									
Cl mg/l									
Fe mg/l	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2
Fe2+ mg/l									
Fe3+ mg/l									
H+ N									
K mg/l									
Mg mg/l									
Na mg/l									
Ni mg/l									
NO3 mg/l									
P mg/l									
Ra Bg/l									
S2- g/l									
SO42- g/l									
Stot g/l									
U mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 125
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 50°C Aging Time 24h

		Solution Fe/As 0,3 pH 7	Solution Fe/As 0,3 pH 8	Solution Fe/As 0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.83	7.71	7.9	7.2	7.44	7.96	7.16	7.54	8.23
Eh(Ag/AgCl)	mV	197	168	146	178	163	152	200	170	144
Conductivity	mS	5.79	4.72	3.88	5.48	4.56	3.88	4.98	4.36	3.72
Alkalinity		0.69	2.5	2.39	0.51	0.95	0.84	0.72	0.77	1
Al	mg/l	0.06	< 0,02	0.04	0.03	0.03	0.08	0.03	< 0,02	0.07
As	mg/l	289	182	135	8.21	4.6	5.67	4.45	1.95	3.23
As5+	mg/l	64	95.3	108	1.49	1.14	3.43	0.76	0.68	2.15
As3+	mg/l	225	86.7	27.1	6.72	3.46	2.24	3.69	1.27	1.08
Ca	mg/l	486	502	532	476	492	517	476	500	523
Cl	mg/l	39.5	39.7	38.5	41.2	38.4	34.2	43.2	41.2	36.6
Fe	mg/l	0.24	< 0,02	< 0,02	0.04	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Fe2+	mg/l	<	<	<	<	<	<	<	<	<
Fe3+	mg/l	<	<	<	<	<	<	<	<	<
H+	N	—	—	—	—	—	—	—	—	—
K	mg/l	138	108	104	149	131	124	146	130	128
Mg	mg/l	733	428	104	605	301	59.1	498	262	41.5
Na	mg/l	582	557	543	547	528	513	499	507	499
Ni	mg/l	566	10.2	0.33	71	1.76	0.09	38.4	0.87	0.08
NO3	mg/l	11.7	11.7	11.7	13	12.6	12.8	15.8	12.6	14.3
P	mg/l	0.68	0.83	0.75	0.11	0.11	0.16	0.27	0.11	1.57
Ra	Bq/l	—	—	—	—	—	—	—	—	—
S2-	g/l	—	—	—	—	—	—	—	—	—
SO42-	g/l	—	—	—	—	—	—	—	—	—
Stot	g/l	2.08	1.35	0.933	1.65	1.2	0.927	1.45	1.12	0.873
U	mg/l	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	0.26	< 0,25

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 126

Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)

Temperature 50°C Aging Time 48h

		Solution Fe/As 0,3 pH 7	Solution Fe/As 0,3 pH 8	Solution Fe/As 0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.43	7.93	7.89	7.44	7.88	7.64	7.67	7.92	7.82
Eh(Ag/AgCl)	mV									
Conductivity	mS	6.21	5.06	4.1	5.73	4.69	3.92	5.27	4.52	4
Alkalinity										
Al	mg/l									
As	mg/l	310	192	150	7.79	5.27	6.61	5.75	2.62	3.73
As5+	mg/l									
As3+	mg/l									
Ca	mg/l									
Cl	mg/l									
Fe	mg/l	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	2.67	< 0,2	< 0,2
Fe2+	mg/l									
Fe3+	mg/l									
H+	N									
K	mg/l									
Mg	mg/l									
Na	mg/l									
Ni	mg/l									
NO3	mg/l									
P	mg/l									
Ra	Bq/l									
S2-	g/l									
SO42-	g/l									
Stot	g/l									
U	mg/l									

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 127
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 50°C Aging Time 72h

		Solution Fe/As 0,3 pH 7	Solution Fe/As 0,3 pH 8	Solution Fe/As 0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.16	7.82	7.89	7.52	7.79	7.82	7.66	7.92	7.78
'Eh(Ag/AgCl) mV										
Conductivity mS		6.4	4.91	4.02	5.47	4.59	3.86	5.14	4.36	3.76
Alkalinity										
Al mg/l										
As mg/l		318	187	152	8.57	4.71	6.28	4.26	2.12	3.66
As5+ mg/l										
As3+ mg/l										
Ca mg/l										
Cl mg/l										
Fe mg/l		0.43	< 0,02	< 0,02	0.18	< 0,02	< 0,02	2.27	< 0,02	< 0,02
Fe2+ mg/l										
Fe3+ mg/l										
H+ N										
K mg/l										
Mg mg/l										
Na mg/l										
Ni mg/l										
NO3 mg/l										
P mg/l										
Ra Bq/l										
S2- g/l										
SO42- g/l										
Stot g/l										
U mg/l										

NA, _ : Not analysed

ND : Not detected

Appendix C - TABLE 128
Procedure 2 : Blend 2 Tailings (55%Midwest + 15%Sue A+B + 30%Cigar)
Temperature 50°C Aging Time 120h

		Solution Fe/As 0,3 pH 7	Solution Fe/As 0,3 pH 8	Solution Fe/As 0,3 pH 9	Solution Fe/As 3 pH 7	Solution Fe/As 3 pH 8	Solution Fe/As 3 pH 9	Solution Fe/As 5 pH 7	Solution Fe/As 5 pH 8	Solution Fe/As 5 pH 9
pH		6.37	7.34	7.83	7.1	7.62	7.3	6.97	7.75	8.11
Eh(Ag/AgCl)	mV	208.1	181.5	157.8	185	171	170.7	190.3	171.2	146.4
Conductivity	mS	6.39	5.17	4.23	5.74	4.85	4.08	5.34	4.71	4.05
Si	mg/l	55.6	29.8	15.1	35.9	17.5	10.3	32.9	14.4	9.6
Alkalinity	mM/l	0.57	2.29	2.68	0.63	1.54	0.85	0.79	1.52	1.18
Al	mg/l	0.04	< 0,02	< 0,02	0.04	< 0,02	< 0,02	0.02	< 0,02	< 0,02
As	mg/l	339	207	154	11.1	6.88	7.39	6.03	3.1	4.67
As5+	mg/l	94	102	126	1.1	1.45	4.21	0.63	0.89	3.28
As3+	mg/l	245	105	28.1	10	5.43	3.18	5.4	2.21	1.39
Ca	mg/l	474	492	531	479	493	523	479	499	522
Cl	mg/l	39.6	38.7	37.6	41.7	39.7	34.9	44	42.3	38.8
Fe	mg/l	0.42	< 0,02	< 0,02	0.11	< 0,02	< 0,02	0.42	< 0,02	< 0,02
Fe2+	mg/l	<	<	<	<	<	<	<	<	<
Fe3+	mg/l	<	<	<	<	<	<	<	<	<
H+	N	—	—	—	—	—	—	—	—	—
K	mg/l	115	94.4	85.6	122	109	99.5	133	119	114
Mg	mg/l	797	474	131	667	379	85.6	561	304	56.8
Na	mg/l	568	539	520	527	517	504	511	499	478
Ni	mg/l	632	9.99	0.36	90.5	2.44	0.13	50.9	1.17	0.11
NO3	mg/l	12.2	12	11.8	13.9	13.4	14.1	14.4	13	15
P	mg/l	2.13	1.54	1.01	1.45	0.81	0.49	0.48	0.71	0.38
Ra	Bq/l	62.17	82.42	242.18	72.89	67.13	62.47	47.09	66.53	57.88
S2-	g/l	—	—	—	—	—	—	—	—	—
SO42-	g/l	7.33	4.344	2.757	5.727	4.028	2.8	5.058	3.655	2.591
Stot	g/l	2.09	1.34	0.909	1.67	1.24	0.902	1.5	1.15	0.858
U	mg/l	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25	< 0,25

NA, — : Not analysed

ND : Not detected

Appendix C-3 - TABLE 129
Pore Water Analysis at the End of Procedure 1 (After Neutralization)

Chemical		Tailings							
		Jeb ¹	McClean ²	SUE C ³	SUE A + B	Blend 1 ⁵	Blend 2 ⁶	Blend 3 ⁷	Cigar Lake ⁸
Al	mg/l	0.07	0.15	<0.02	<0.02	0.04	0.32	<0.02	0.26
As	mg/l	0.88	0.87	0.07	0.07	1.61	0.34	0.28	0.69
As ⁵⁺	mg/l	-	0.54	-	-	0.25	0.17	-	0.14
As ³⁺	mg/l	-	0.33	-	-	1.36	0.17	-	0.55
Ba	mg/l	0.11	0.04	0.07	0.05	0.04	0.04	0.06	0.05
Bi	mg/l	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01
Ca	mg/l	496	492	474	450	488	447	501	421
Cd	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cl	mg/l	68.9	33.3	35.4	30.0	32.1	54.6	36.2	42.0
Co	mg/l	0.03	<0.01	<0.01	0.070	0.010	0.030	0.020	0.080
Cr	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cu	mg/l	<0.01	<0.01	<0.01	0.020	<0.01	<0.01	0.020	<0.01
Fe	mg/l	<0.02	<0.02	<0.02	0.170	<0.02	<0.02	<0.02	0.030
Fe ³⁺	mg/l	-	-	-	-	-	-	-	-
Fe ²⁺	mg/l	-	-	-	-	-	-	-	-
K	mg/l	110	103	92	186	91	117	91	194
Mg	mg/l	185	67.9	178	215	151	432	369	1060.0
Mn	mg/l	2.75	0.72	1.89	0.48	0.26	3.46	0.30	4.01
Mo	mg/l	1.92	8.64	0.57	1.23	2.26	0.35	0.17	0.11
Na	mg/l	545	621	592	538	579	539	509	452
NH ₄	mg/l	29.2	27.5	23.3	34.6	24.7	28.2	35.9	38.9
Ni	mg/l	0.73	0.2	0.0	0.4	<0.01	0.1	0.5	0.2
NO ₃	mg/l	27.3	10.7	8.4	10.8	11.3	9.2	11.3	10.6
P	mg/l	0.14	0.18	0.10	0.42	0.09	0.04	0.10	0.06
Pb	mg/l	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Se	mg/l	0.02	0.02	0.05	0.02	0.02	0.05	0.04	0.06
SO ₄	mg/l	2240	2800	3265	3967	3129	2817	3826	7210
Total-S	mg/l	1100	1020	1100	1380	1060	912	1280	2120
U	mg/l	<0.2	0.07	<0.2	0.07	<0.05	0.25	<0.2	<0.2
V	mg/l	<0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	mg/l	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ra-226	Bq/l	247.02	84.52	196.07	46.82	41.78	155.05	510.19	663.97
Pb-210	Bq/l	<10	<10	<10	<10	<10	<10	<10	<10
Th-230	Bq/l	<100	<100	<100	<100	<100	<100	<100	<100
pH		7.9	8.2	7.8	8.0	7.9	8.1	7.8	7.6
Eh	mV	406	427	422	422	376	389	413	337
Conductivity	mS/Cm	4.94	4.82	5.25	6.38	4.83	5.39	5.55	6.95
Alkalinity	mM/l	0.69	0.43	0.25	0.25	0.20	0.36	0.17	0.34

¹ Nominal pH 8, Fe/As = 5, 4 Celcius

² Nominal pH 8, Fe/As = 5, 25 Celcius

³ Nominal pH 8, Fe/As = 7.7, 4 Celcius

⁴ Nominal pH 8, Fe/As = 5, 25 Celcius

⁵ Nominal pH 8, Fe/As = 3, 25 Celcius

⁶ Nominal pH 8, Fe/As = 7.6, 25 Celcius

⁷ Nominal pH 8, Fe/As = 3, 4 Celcius

⁸ Nominal pH 8, Fe/As = 7.5, 25 Celcius

Appendix C-3 - TABLE 130
Procedure 2: Pore Water Analysis After 5 or 6 Days of Aging

Chemical		Tailings							
		Jeb ¹	McClean ²	SUE C ³	SUE A + B	Blend 1 ⁵	Blend 2 ⁶	Blend 3 ⁷	Cigar Lake ⁸
Al	mg/l	0.02	<0.02	0.02	<0.02	<0.02	0.02	0.04	0.03
As	mg/l	0.53	1.70	0.10	0.61	2.46	0.27	0.67	0.36
As ⁵⁺	mg/l	-	1.21	-	0.35	0.63	-	-	-
As ³⁺	mg/l	-	0.49	-	0.26	1.83	0.28	-	0.36
Ba	mg/l	0.05	0.04	0.04	0.07	0.03	0.03	0.06	0.05
Bi	mg/l	<0.01	<0.01	<0.01	<0.05	0.01	<0.01	<0.05	<0.01
Ca	mg/l	441	482	449	392	464	466	458	444
Cd	mg/l	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01	<0.05	<0.01
Cl	mg/l	47.2	34.8	37.4	28.7	35.8	60.3	39.3	34.3
Co	mg/l	0.04	<0.01	<0.01	0.10	<0.01	0.060	<0.05	0.220
Cr	mg/l	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01	<0.05	<0.01
Cu	mg/l	0.02	0.02	0.02	<0.05	0.01	0.020	<0.05	0.02
Fe	mg/l	<0.02	<0.02	0.08	<0.02	<0.02	<0.02	<0.02	0.05
Fe ³⁺	mg/l	-	-	-	-	-	-	-	-
Fe ²⁺	mg/l	-	-	-	-	-	-	-	-
K	mg/l	90	90	95	126	84	105	75	151
Mg	mg/l	202	77.9	237	233	160	576	419	1470
Mn	mg/l	4.78	1.25	2.51	0.85	0.36	10.6	0.57	19
Mo	mg/l	0.09	9.99	0.47	1.31	2.59	0.49	0.09	0.07
Na	mg/l	557	609	564	566	556	568	484	478
NH ₄	mg/l	23.1	24.0	17.7	21.9	19.8	19.2	27.5	23.1
Ni	mg/l	0.72	0.2	0.1	0.8	1.3	0.2	2.1	0.4
NO ₃	mg/l	9.5	2.2	10.2	5.1	4.0	2.1	13.5	3.7
P	mg/l	1.90	1.13	0.90	2.09	0.25	1.08	1.20	1.13
Pb	mg/l	<0.03	<0.03	<0.03	<0.05	<0.03	0.050	<0.05	0.060
Se	mg/l	0.03	0.02	0.04	<0.05	0.02	0.06	0.05	0.09
SO ₄	mg/l	3280	2595	3369	3464	4880	4068	4493	7210
Total-S	mg/l	1080	976	1080	1110	1110	1330	1370	1130
U	mg/l	<0.05	<0.05	<0.2	<0.05	<0.05	0.38	<0.2	<0.25
V	mg/l	<0.01	0.15	<0.01	<0.05	<0.01	<0.01	<0.05	<0.01
Zn	mg/l	0.02	0.01	<0.01	<0.05	0.020	0.020	<0.05	0.10
Ra-226	Bq/l	48.91	4.78	60.20	-	22.20	23.01	104.63	169.23
Pb-210	Bq/l	-	-	-	-	<10	<10	-	-
Th-230	Bq/l	-	-	-	-	<100	<100	-	-
pH		7.3	7.5	6.3	7.3	7.8	6.6	6.8	7.3
Eh	mV	443	411	457	500	427	497	409	343
Conductivity	mS/Cm	4.90	5.35	5.14	4.73	4.73	6.16	5.49	7.94
Alkalinity	mM/l	0.44	0.64	0.22	0.42	0.25	0.36	<0.05	0.37

¹ Nominal pH 8, Fe/As = 5, 4 Celcius

² Nominal pH 8, Fe/As = 5, 25 Celcius

³ Nominal pH 8, Fe/As = 7.7, 4 Celcius

⁴ Nominal pH 8, Fe/As = 5, 25 Celcius

⁵ Nominal pH 8, Fe/As = 3, 25 Celcius

⁶ Nominal pH 8, Fe/As = 7.6, 25 Celcius

⁷ Nominal pH 8, Fe/As = 3, 4 Celcius

⁸ Nominal pH 8, Fe/As = 7.5, 25 Celcius

Appendix C

Section C - Part A

Subsection D: Calculations Based on Results of the Large-Scale Tests at 4 and 25 C

D1. Solution Charge Balance Determinations

Charge balances were calculated for individual water analyses as part of an evaluation of the accuracy of analytical data. The charge balance calculation is based on the fact that all waters must be electrically neutral. Accordingly, the concentrations of cations and anions in a solution, measured in units of equivalents (eq) or milliequivalents (meq) per liter or per kilogram of solution must be exactly equal. The charge balance calculation, which is expressed as a percent difference may be computed from:

$$\% \text{ difference} = 100 \left[\frac{\Sigma \text{ cations} - \Sigma \text{ anions}}{\Sigma \text{ cations} + \Sigma \text{ anions}} \right]$$

where the total cation and anion sums are usually expressed in meq/L. According to Standard Methods (1995)¹, acceptable values of the percentage difference computed from a chemical analysis depend on the total salt content of the water. At the dissolved solids content of tailings raffinates and neutralized raffinates, which have a minimum salt content defined by the solubility of gypsum which is always present, the acceptable percent difference computed from a chemical analysis would be $\pm 5\%$. Larger values presumably indicate significant random or systematic errors in chemical analytical values.

For dilute waters of intermediate pH, the charge balance may be calculated by comparing the sums of the equivalents of cations and anions, using a spread sheet approach. This method works well when the aqueous species occur are largely uncomplexed. However, in solutions such as the tailings raffinates and neutralized raffinates, where most of the Al(III), Fe(III) and sulfate, for example occur in complexes such as AlOH^{2+} and HSO_4^- , a computer calculation of the charge balance becomes necessary.

The geochemical code MINTEQA2 (Allison et al., 1991) computes a charge balance for any chemical analysis input into the code. Accordingly, chemical analytical data for tailings raffinates and neutralized solutions for runs at 4 and 25°C and for the JEB tailings at 50°C (see Appendix C) were input into MINTEQA2. The results are summarized in the following tables. The largest charge balance differences are computed for the raffinates, which had an average charge balance of 11% excess anions. This apparent error may be an artifact of the MINTEQA2 calculation of ion activity coefficients. Raffinate pH values are generally below pH 1. Below pH 2, most sulfate is present as the bisulfate ion. MINTEQA2 computes the amounts of sulfate and bisulfate from the total sulfate analysis through the equation:

$$K_{eq} = \left(\frac{\gamma_H \gamma_{SO_4}}{\gamma_{HSO_4}} \right) \left(\frac{(mH^+)(mSO_4^{2-})}{(mHSO_4^-)} \right)$$

The relative amounts of sulfate (2-) versus bisulfate (1-) will greatly affect the results of a

¹Standard Methods for the Examination of Water and Wastewater, 19th ed., Am. Public Health Assoc., Washington, DC.

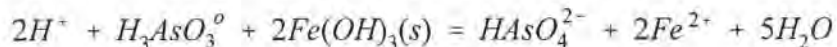
charge balance calculation. MINTEQA2 calculates these activity coefficients using the Davies Equation (cf. Langmuir, 1997), which is relatively inaccurate at these high ionic strengths (typically above 0.3 molal). For example, at an ionic strength (I) of 0.3 molal $\gamma_{\text{SO}_4} \approx 0.3$, a value that is lower than computed for this ionic strength using the more accurate specific ion interaction model for activity coefficients (Langmuir, 1997). Inspection of the above sulfate-bisulfate expression shows that for a fixed value of K_{eq} , too small a value of γ_{SO_4} by 10-20%, which is quite possible, results in too large a value for $m\text{SO}_4^{2-}$ computed by MINTEQA2. This could account for the observation that anions more often exceed cations than conversely for the raffinates.

Charge balances computed for neutralized tailings solutions are more nearly in balance, with average charge balances of 4 and 6% (excess anions) for the 4 and 25°C data. This reflects the fact that (1) the bisulfate calculation with possible errors in activity coefficients is no longer relevant, and (2) the precipitation of gypsum causes a reduction in sulfate concentrations and thus in the ionic strength. Assuming that the charge balance error could reflect excess sulfate, we examined the saturation index values for gypsum. These values are reproduced in the appendix tables. The closeness of the SI values to zero supports the relative accuracy of the chemical analytical data for calcium and sulfate. Assuming a few percent error (reduction) in the sulfate concentration improved but did not eliminate the charge imbalance, which in any case is close to the acceptable $\pm 5\%$ value.

D2. Redox Measurement and Calculations

Measurements of Eh or redox potential and pH were made for the raffinates and neutralized solutions at the Cogema's SEPA laboratory in Bessines, France. In this study it was assumed that the only redox species that were likely to respond electroactively at the indicator Pt electrode were those of Fe(III)/Fe(II) (cf. Langmuir, 1997). The measured Eh was therefore only used to interpret the redox chemistry of iron species. For example, the measured Eh and pH and Fe(II) and or Fe(III) concentrations were input into MINTEQA2 and used to compute the saturation state of the waters with respect to the ferric oxyhydroxides. The results of these calculations are tabulated in this appendix. Where dissolved Fe(II) or Fe(III) concentrations were below detection, the detection limite of 0.02 mg/L was entered. For these waters, the computed saturation indices of the Fe(III) oxyhydroxides can be considered as upper bounds.

The redox state of arsenic species was based entirely on their direct analysis as dissolved As(V) and As(III). Examination of the As(V)/As(III) ratio in the neutralized solutions during the aging tests, shows that the ratio increases with time and increasing pH, presumably because of As(III) oxidation by the Fe(III) in HFO, for example, which may be written:



for which the equilibrium constant (K_{eq}) equals $10^{4.49}$ at 25°C (cf. De Vitre et al., 1991, *Limnol. Oceanogr.*, 36, 1480-85)². That this oxidation is relatively complete during the aging tests is

²See also Section 3 of the JEB TMF Tailings Source Term report submitted to the AECB by Cogema Resources on Nov. 3, 1997.

evident from the lack of As(III) solids in the precipitated tailings/raffinate solids. (See Appendix B).

D3. Mineral Saturation State Determinations

Listed in this appendix are the saturation indices of the solid phases, gypsum, ferrihydrite, goethite, hematite, scorodite and annabergite. As listed, the indices have not been normalized to the number of chemical species (excluding molecular H₂O) in the mineral formulas (i.e. two chemical species in gypsum and scorodite, and five in annabergite). This may be accomplished by dividing the mineral SI values by their number of chemical species. Such normalization is justified in that K_{sp} and SI values and their uncertainties increase in direct proportion to the number of chemical species in the mineral formula³. If so normalized, and assuming an uncertainty of about $\pm 5\%$ of the log K_{sp} value in normalized SI units, as expected, gypsum is seen to be at saturation in most of the raffinates and neutralized solutions⁴. Goethite and hematite, which cannot equilibrate in these solutions for kinetic reasons, are generally supersaturated, except in the raffinates, in which they tend to be undersaturated. Ferrihydrite, which can nucleate with relative ease, is near saturation in the waters in which there is measureable dissolved Fe present. When iron concentrations were below the detection limit, resultant SI values for ferrihydrite, goethite and hematite have been computed using the detection limit of 0.02 mg/L. For these samples, the SI values for these minerals have been entered as less-than values.

The $-\log K_{sp}$ values for crystalline scorodite and annabergite are 25.87 and 28.38, respectively. Their SI values divided by 2 and 5 respectively, may be compared to ± 0.6 (5% of 25.87/2) and ± 0.3 (5% of 28.38/ 5) to judge their mineral saturation state. The scorodite SI values are upper bounds when they have been computed using the detection limit for total iron, Fe(III) or Fe(II) in their calculation. Based on these results, crystalline scorodite is close to saturation or supersaturated in the raffinates and in many of the lower pH runs. Annabergite is generally unsaturated, but is closest to saturation at the lowest measured pH values. Where the SI values for scorodite are upper bounds, plotted points on Figs. 30-38 have been drawn with downward arrows.

³This normalization or scaling approach is similar to that proposed by Wolery and Daveler (1992, Report UCRL-MA-110662 PT IV) in their documentation for the code EQ6.

⁴For gypsum $-\log K_{sp} = 4.49$, so that the SI value is compared to $\pm 5\%$ of $(4.49/2) = \pm 0.1$ units. For ferrihydrite, with $-\log K_{sp} = 37.1$, the SI value is compared to $\pm 5\%$ of $(37.1/4) = \pm 0.5$.

APPENDIX 3
Summary of Charge Balance Data Analysis

All charge balance data:									
4°C									
	JEB (raffinate)	Sue C (raffinate)	Blend 2 (raffinate)						
Average Value	14	7.7		Average =	11				
anions > cations	1	1		Sum =	2				
cations > anions	1	0		Sum =	1				
	JEB (tailings)	Sue C (tailings)	Blend 2 (tailings)						
Average Value	4.6	3.8	2.9	Average =	3.8				
anions > cations	7	4	2	Sum =	13				
cations > anions	0	0	2	Sum =	2				
25°C									
	JEB (raffinate)	McClellan Lake (raffinate)	Sue A+B (raffinate)	Sue C (raffinate)	Cigar Lake (raffinate)	Blend 1 (raffinate)	Blend 2 (raffinate)		
Average Value	24	3.4	10	7.7	16	10	6.3	Average =	11
anions > cations	1	0	0	1	1	1	0	Sum =	4
cations > anions	0	1	2	0	0	0	2	Sum =	5
	JEB (tailings)	McClellan Lake (tailings)	Sue A+B (tailings)	Sue C (tailings)	Cigar Lake (tailings)	Blend 1 (tailings)	Blend 2 (tailings)		
Average Value	7.3	3.7	8.5	5.4	8.5	4.8	4.8	Average =	6.1
anions > cations	26	23	51	12	12	12	38	Sum =	174
cations > anions	0	1	1	0	0	0	13	Sum =	15
50°C									
	JEB (tailings)								
Average Value	6.3								
anions > cations	17								
cations > anions	0								
All charge balance data less than 10%:									
4°C									
	JEB (raffinate)	Sue C (raffinate)	Blend 2 (raffinate)						
Average Value	14	7.7		Average =	11				
anions > cations	1	1		Sum =	2				
cations > anions	1	0		Sum =	1				
	JEB (tailings)	Sue C (tailings)	Blend 2 (tailings)						
Average Value	4.6	3.8	2.9	Average =	3.8				
anions > cations	7	4	2	Sum =	13				
cations > anions	0	0	2	Sum =	2				
25°C									
	JEB (raffinate)	McClellan Lake (raffinate)	Sue A+B (raffinate)	Sue C (raffinate)	Cigar Lake (raffinate)	Blend 1 (raffinate)	Blend 2 (raffinate)		
Average Value	24	3.4	10	7.7	16	10	6.3	Average =	11
anions > cations	1	0	0	1	1	1	0	Sum =	4
cations > anions	0	1	2	0	0	0	2	Sum =	5
	JEB (tailings)	McClellan Lake (tailings)	Sue A+B (tailings)	Sue C (tailings)	Cigar Lake (tailings)	Blend 1 (tailings)	Blend 2 (tailings)		
Average Value	5.8	3.7	5.5	5.4	4.9	4.8	4.2	Average =	4.9
anions > cations	19	23	28	12	6	12	36	Sum =	136
cations > anions	0	1	1	0	0	0	12	Sum =	14
50°C									
	JEB (tailings)								
Average Value	6.0								
anions > cations	16								
cations > anions	0								

Blend 1=75% Sue C + 25% Cigar Lake

Blend 2=55% Midwest + 15% Sue A+B + 30% Cigar Lake

APPENDIX 3
JEB Tailings Data
at all times and 4°C (Fe/As=3.0 and 5.0)

	Fe/As = 3.0 at Nominal pH=8					Fe/As = 5.0 at Nominal pH=8				
	Raffinate	initial time	2 hours	24 hours	144 hours	Raffinate	initial time	2 hours	24 hours	144 hours
pH		7.5	7	6.8	7.22		7.9	7.45	7.9	7.3
Em (measured) mV	411	120	172	152		181	198	306	189	235
Eh (calculated) mV ^{Note 1}	630.4	339.4	391.4	371.4		400.4	417.4	525.4	408.4	454.4
Alkalinity (mM/L)		0.28	0.31	0.22	0.28		0.69	0.61	0.59	
Concentration (mg/L)										
Al	648	0.03	<0.02	<0.02	<0.02	434	0.07	0.03	0.04	
As	413.5	1.24	1.27	1.21	1.24	366	0.88	0.6	0.62	
As ⁵⁺	264.5	0.28	0.46	0.39	<0.02	294				
As ³⁺	149	0.96	0.81	0.82	1.32	72				
Ca	518	454	429	428	432	590	496	435	448	
Cl	67.4	62.6	67.9	69.3	69.6	38.7	68.9	95.9	81.6	47.2
Fe	596	<0.02	<0.02	<0.02	<0.02	430	<0.2	<0.02	0.18	
Fe ²⁺	458.1	<	<	<	<	310				
Fe ³⁺	137.9	<	<	<	<	120				
H ⁺	370					170				
K	204	103	94.7	94.9	67.7	241	110	95.2	92.1	
Mg	374	227	238	248	254	341	185	186	195	
Na	150	582	590	588	583	148	545	528	552	
Ni	208	1.62	1.79	1.92	2.49	201	0.73	0.71	0.8	
NO ₃	50.3	8.1	10.2	10.2	9.9	25.3	27.3	46.2	30.8	9.5
P	110	0.18	1.58	0.3	0.84	91	0.14	0.68	1.12	
Ra (in Bq/L)	76.82	138.32			34.52	56.84	247.02	105.34	9.91	
S ²⁻	270									
SO ₄ ²⁻	18900	3328	3292	3400	3685	15300	3340	3050	3220	3280
S total	6570	1120	1100	995	1040	4950	1100	1060	1070	
U	<0.2	<0.2	<0.2	<0.2	<0.2	0.54	<0.2	<0.2	<0.2	
MINTEQA2 results										
Sum of Cations	0.33730	0.05181	0.05184	0.05205	0.05089	0.16460	0.04929	0.04694	0.04841	
Sum of Anions	0.21130	0.05398	0.05374	0.05539	0.06048	0.18240	0.05546	0.05215	0.05416	
Speciated Charge Balance (%)	-22.97	2.05	1.80	3.11	8.61	5.13	5.89	5.26	5.61	
Equilibrium pH	0.824	7.5	7	6.8	7.22	1.252	7.9	7.45	7.9	
Saturation Index										
Gypsum	-0.162	-0.041	-0.067	-0.063	-0.043	0.058	0.002	-0.067	-0.047	
Ferrihydrite	-7.425	<0.866	<-0.034	<-0.046	Note 4	-6.428	<1.92	<0.132	2.159	
Goethite	-3.029	<5.258	<4.358	<4.346	Note 4	-2.034	<6.312	<4.523	6.55	
Hematite	-1.045	<15.524	<13.724	<13.701	Note 4	0.943	<17.633	<14.055	18.109	
Scorodite	0.137	<-1.213	<-0.883	<-0.612	Note 4	1.111	<-0.769	<-1.452	-0.709	
Annabergite	-22.636	-8.473	-8.592	-9.044	-10.451	-20.286	-9.613	-9.216	-9.692	
pQ (calculated)										
Activity of Fe ³⁺	1.02E-05	1.82E-17	7.23E-17	2.80E-16	Note 4	5.19E-06	1.30E-17	4.73E-18	2.25E-17	
Activity of Al ³⁺	6.35E-04	7.02E-14	3.13E-12	1.48E-11	5.16E-13	3.11E-04	4.69E-15	1.09E-13	2.69E-15	
Activity of OH ⁻	6.62E-14	3.17E-07	1.00E-07	6.33E-08	1.67E-07	1.78E-13	7.97E-07	2.83E-07	7.97E-07	
pQ (Iron)	44.53	36.24	37.14	37.15	Note 4	43.53	35.18	36.97	34.94	
pQ (Aluminum)	42.73	32.65	32.50	32.43	32.62	41.75	32.62	32.61	32.87	
Eh (calculated) mV ^{Note 2}										
Fe ratio	--	--	--	--	--	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	--	258	340	373	304	--	192	266	139	--
As ratio	--	278	-14	282	--	--	--	--	--	--

Note 1: Eh = Em (from COGEMA) + 219.4 mV (for 4°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)^(s)=37.1

Note 4: Em value was not recorded and Fe was not speciated.

APPENDIX 3
JEB Tailings Data
at initial time and 25°C (Fe/As=2.6, 3.0, and 5.0)

		Fe/As = 2.6			Fe/As = 3.0			Fe/As = 5.0		
	Raffinate	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH		6.95	7.64	8.9	7.22	7.78	8.9	7.24	7.86	8.82
Em (measured) mV	374	299	176	199	255	229	182	238	201	155
Eh (calculated) mV ^{Note 1}	576	501	378	401	457	431	384	440	403	357
Alkalinity (mM/L)	NA	0.13	0.44	1.06	0.14	0.4	1.11	0.13	0.35	0.91
Concentration (mg/L)										
Al	503	<0.02	0.06	0.55	<0.02	0.05	0.39	<0.02	0.06	0.54
As	271	1.04	2.87	3.95	0.86	2.02	3.29	0.3	0.51	0.97
As ⁵⁺	218.1	NA	2.41	3.8	NA	1.89	3.16	NA	NA	NA
As ³⁺	52.9	NA	0.46	0.15	NA	0.13	0.13	NA	NA	NA
Ca	441	462	459	474	455	460	473	444	464	469
Cl	35.2	32.8	32.3	30.3	29.5	30.9	31.9	32.6	33	32
Fe	517	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	413	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe ³⁺	104	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
H ⁺	360	NA	NA	NA	NA	NA	NA	NA	NA	NA
K	219	111	101	91.6	112	100	92	113	102	97.6
Mg	303	227	182	84.1	226	179	109	228	188	95.1
Na	25.8	546	533	531	540	544	533	539	547	543
Ni	144	17.2	0.76	0.02	23.2	0.93	0.05	18.3	0.51	0.02
NO ₃	53.6	7	7.2	7	6.7	6.8	7.2	7.3	7.4	7.2
P	69	0.13	0.29	0.3	0.12	0.27	0.28	0.09	0.16	0.17
Ra (in Bq/L)	43	50.41	68.09	81.27	166.03	115.98	85.34	151.08	147.73	139.03
S ²⁻	1430	ND	ND	ND	ND	ND	ND	ND	ND	ND
SO ₄ ²⁻	26900	3963	3481	2632	3773	3395	3062	4099	3578	3151
S total	7550	1270	1050	989	1200	1150	1010	1170	1230	975
U	0.07	<0.05	0.11	0.15	<0.05	0.14	0.62	<0.05	0.06	0.11
MINTEQA2 results										
Sum of Cations	0.19840	0.04946	0.04673	0.04307	0.04949	0.04724	0.04358	0.04840	0.04766	0.04312
Sum of Anions	0.32360	0.06434	0.05714	0.04408	0.06077	0.05549	0.05154	0.06716	0.05859	0.05343
Speciated Charge Balance (%)	23.98	13.08	10.02	1.16	10.23	8.03	8.37	16.23	10.29	10.68
Equilibrium pH	1.047	6.95	7.64	8.9	7.22	7.78	8.9	7.24	7.86	8.82
Saturation Index										
Gypsum	-0.006	0.002	-0.017	-0.046	-0.013	-0.021	-0.021	-0.007	-0.009	-0.015
Ferrihydrite	-7.119	< -0.844	< -0.915	< 0.886	< -0.437	< -0.499	< 0.957	< 0.493	< 0.767	< 1.22
Goethite	-2.722	< 3.547	< 3.476	< 5.278	< 3.955	< 3.892	< 5.349	< 4.884	< 5.158	< 5.611
Hematite	-0.431	< 12.103	< 11.961	< 15.564	< 12.919	< 12.793	< 15.706	< 14.777	< 15.325	< 16.231
Scorodite	0.356	< -1.212	< -2.262	< -3.354	< -1.408	< -2.262	< -3.372	< -1.012	< -1.779	< -3.374
Annabergite	-22.277	-4.950	-7.605	-14.351	-4.146	-7.466	-13.396	-5.462	-9.389	-15.160
pQ (calculated)										
Activity of Fe ³⁺	4.46E-06	1.58E-17	1.14E-19	1.20E-21	6.26E-18	1.13E-19	1.41E-21	4.63E-17	1.20E-18	4.49E-21
Activity of Al ³⁺	2.62E-04	4.53E-12	4.10E-14	4.06E-18	5.13E-13	9.84E-15	2.86E-18	4.34E-13	5.75E-15	8.25E-18
Activity of OH ⁻	1.10E-13	8.94E-08	4.38E-07	7.97E-06	1.67E-07	6.05E-07	7.97E-06	1.74E-07	7.27E-07	6.63E-06
pQ (Iron)	44.22	37.95	38.02	36.22	37.54	37.60	36.15	36.61	36.34	35.88
pQ (Aluminum)	42.45	32.49	32.46	32.69	32.63	32.66	32.84	32.64	32.66	32.62
Eh (calculated) mV ^{Note 2}										
Fe ratio	--	--	--	--	--	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	--	208	85	-138	160	60	-138	156	46	-124
As ratio	--	--	-60	-201	--	-64	-201	--	--	--

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃) = 37.1

APPENDIX 3
JEB Tailings Data
at 2 hours and 25°C (Fe/As=2.6, 3.0, and 5.0)

	Fe/As = 2.6			Fe/As = 3.0			Fe/As = 5.0		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.78	7.35	8.49	6.78	7.52	8.12	6.79	7.24	7.98
Em (measured) mV	241	218	180	216	167	175	221	190	171
Eh (calculated) mV ^{Note 1}	443	420	382	418	369	377	423	392	373
Alkalinity (mM/L)									
Concentration (mg/L)									
Al	<0.02	<0.02	0.26	0.05	<0.02	0.22	<0.02	0.03	0.19
As	1.59	3.33	5.14	1.44	2.28	3.96	0.47	0.61	1.3
As ⁵⁺	0.25	2.49	4.8	0.48	1.7	3.63	<	<	0.77
As ³⁺	1.34	0.84	0.34	0.96	0.58	0.33	<	<	0.53
Ca	446	474	471	439	453	478	435	441	487
Cl	37.5	39.6	34.6	35.5	34.6	36.1	35.1	36.4	37.8
Fe	<0.02	<0.02	<0.02	0.04	<0.02	<0.02	<0.02	0.03	<0.02
Fe ²⁺	<0.02	<0.02	<0.02	<	<0.02	<0.02	<0.02	<	<0.02
Fe ³⁺	<0.02	<0.02	<0.02	<	<0.02	<0.02	<0.02	<	<0.02
H ⁺									
K	104	95.4	89.9	103	92.4	87.2	107	91.2	88.8
Mg	242	211	78	234	164	103	228	192	90.2
Na	580	588	538	537	527	532	534	527	531
Ni	18.5	0.78	0.02	27.3	0.84	0.03	19	0.58	0.02
NO ₃	8.5	9.1	8	8.3	8.3	8.7	8.3	0.4	10.1
P	<0.02	0.28	0.36	<0.02	0.21	0.34	<0.02	0.09	0.27
Ra (in Bq/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA
S ²⁻	ND	11.6	37.9	28.6	ND	ND	ND	160	5.47
SO ₄ ²⁻	3578	3381	2655	3527	3186	2958	3593	3087	2675
S total	1120	1140	924	1180	1040	682	1150	1190	985
U	<0.05	0.23	0.36	<0.05	0.26	1.54	<0.05	0.11	0.3
MINTEQA2 results									
Sum of Cations	0.05208	0.05144	0.04298	0.04983	0.04573	0.04362	0.04894	0.04732	0.04391
Sum of Anions	0.05712	0.05442	0.04511	0.05678	0.05185	0.04884	0.05785	0.05319	0.04395
Speciated Charge Balance (%)	4.62	2.82	2.42	6.52	6.27	5.65	8.34	5.84	0.05
Equilibrium pH	6.78	7.35	8.49	6.78	7.52	8.12	6.79	7.24	7.98
Saturation Index									
Gypsum	-0.035	-0.017	-0.043	-0.042	-0.035	-0.019	-0.04	-0.06	-0.03
Ferrihydrite	< 0.291	< -1.238	< -0.085	0.126	< -0.751	< -0.575	< -0.22	-0.19	< 0.566
Goethite	< 4.683	< 3.154	< 4.306	4.517	< 3.641	< 3.817	< 4.172	4.202	< 4.957
Hematite	< 14.375	< 11.316	< 13.621	14.043	< 12.29	< 12.642	< 13.353	13.412	< 14.923
Scorodite	< -0.455	< -1.989	< -3.096	-0.352	< -1.99	< -2.791	< -0.672	-1.34	< -2.016
Annabergite	-6.499	-7.183	-9.528	-5.447	-7.015	-9.681	-5.823	-8.978	-11.714
pQ (calculated)									
Activity of Fe ³⁺	6.99E-16	4.03E-19	2.17E-21	4.77E-16	3.82E-19	9.08E-21	2.01E-16	9.62E-18	3.30E-19
Activity of Al ³⁺	1.74E-11	1.70E-13	8.25E-17	4.27E-11	3.94E-14	2.03E-15	1.58E-11	6.55E-13	6.26E-15
Activity of OH ⁻	6.04E-08	2.25E-07	3.10E-06	6.05E-08	3.32E-07	1.32E-06	6.19E-08	1.74E-07	9.58E-07
pQ (Iron)	36.81	38.34	37.19	36.98	37.85	37.68	37.32	37.29	36.54
pQ (Aluminum)	32.42	32.72	32.61	32.03	32.84	32.33	32.43	32.46	32.26
Eh (calculated) mV ^{Note 2}									
Fe ratio	--	--	--	--	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	238	137	-66	220	107	0	236	146	25
As ratio	-3	281	304	418	369	305	--	--	293

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)⁽³⁾=37.1

APPENDIX 3
JEB Tailings Data
at 120 hours and 25°C (Fe/As=2.6, 3.0, and 5.0)

	Fe/As = 2.6			Fe/As = 3.0			Fe/As = 5.0		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.93	7.56	7.66	6.85	7.46	8	6.7	7.32	No data
Em (measured) mV	358	294	225	259	225	213	243	235	
Eh (calculated) mV ^{Note 1}	560	496	427	461	427	415	445	437	
Alkalinity (mM/L)	0.12	0.59	0.56	0.18	0.67	0.76	0.18	0.43	
Concentration (mg/L)									
Al	<0.02	<0.02	0.1	<0.02	<0.02	0.08	<0.02	<0.02	
As	2.39	3.81	5.64	1.96	2.66	4.68	0.75	0.79	
As ⁵⁺	0.53	2.62	5.14	0.36	1.75	4.19	<	<	
As ³⁺	1.86	1.19	0.5	1.6	0.91	0.49	<	<	
Ca	460	478	495	458	463	485	462	471	
Cl	37.3	35.2	36.8	36.1	34.5	34.5	35.1	34.2	
Fe	<0.02	<0.02	<0.02	0.15	<0.02	<0.02	0.1	<0.02	
Fe ²⁺	<0.02	<0.02	<0.02	<	<0.02	<0.02	<	<0.02	
Fe ³⁺	<0.02	<0.02	<0.02	<	<0.02	<0.02	<	<0.02	
H ⁺									
K	100	88.9	63.6	99.8	89.4	83.9	105	95.6	
Mg	253	208	85.4	257	207	109	252	221	
Na	548	541	541	546	553	526	551	546	
Ni	19.4	0.59	0.02	29.7	0.59	0.02	20.1	0.52	
NO ₃	1.6	8.8	9.6	3.1	8.7	9.5	2.7	1.2	
P	1.53	1.38	1.48	1.42	1.6	1.33	0.84	0.69	
Ra (in Bq/L)	7.04	12.11	59.35	50.66	50.39	40.88	26.79	66.9	
S ²⁻	ND	ND	ND	ND	ND	ND	ND	ND	
SO ₄ ²⁻	3807	3519	2907	3964	3450	2939	3790	3487	
S total	1240	1150	956	1280	1110	973	1250	1160	
U	<0.05	0.22	0.15	<0.05	0.25	1.23	<0.05	0.08	
MINTEQA2 results									
Sum of Cations	0.05107	0.04878	0.04306	0.05099	0.04893	0.04387	0.05141	0.04979	
Sum of Anions	0.06086	0.05718	0.04872	0.06360	0.05623	0.04900	0.06052	0.05600	
Speciated Charge Balance (%)	8.75	7.93	6.17	11.00	6.94	5.52	8.14	5.87	
Equilibrium pH	6.93	7.56	7.66	6.85	7.46	8	6.7	7.32	
Saturation Index									
Gypsum	-0.011	-0.004	-0.007	-0.006	-0.021	-0.017	-0.01	-0.013	
Ferrihydrite	< -0.221	< -1.054	< -1.615	1.495	< -0.82	< -0.896	0.298	< -0.242	
Goethite	< 4.171	< 3.337	< 2.777	5.886	< 3.572	< 3.496	4.689	< 4.15	
Hematite	< 13.35	< 11.683	< 10.562	16.781	< 12.153	< 12	14.387	< 13.308	
Scorodite	< -0.88	< -2.214	< -2.619	0.409	< -1.946	< -2.772	0.065	< -1.453	
Annabergite	-5.457	-8.124	-11.738	-6.270	-8.589	-12.429	-5.933	-9.351	
pQ (calculated)									
Activity of Fe ³⁺	7.62E-17	1.44E-19	1.99E-20	6.88E-15	4.94E-19	9.93E-21	1.23E-15	4.91E-18	
Activity of Al ³⁺	5.41E-12	2.76E-14	5.75E-14	1.03E-11	6.61E-14	2.19E-15	3.02E-11	2.21E-13	
Activity of OH ⁻	8.54E-08	3.64E-07	4.59E-07	7.10E-08	2.89E-07	1.00E-06	5.03E-08	2.10E-07	
pQ (Iron)	37.32	38.16	38.72	35.61	37.92	38.00	36.81	37.34	
pQ (Aluminum)	32.47	32.88	32.26	32.44	32.80	32.66	32.42	32.69	
Eh (calculated) mV ^{Note 2}									
Fe ratio	--	--	--	--	--	--	--	--	
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	211	99	82	174	117	21	211	142	
As ratio	-15	272	294	265	279	295	--	--	

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃) = 37.1

APPENDIX 3
JEB Tailings Data
at 2 hours and 50°C (Fe/As=2.6, 3.0, and 5.0)

	Fe/As = 2.6			Fe/As = 3.0			Fe/As = 5.0		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	7.04	7.39	8.05	6.96	6.93	7.77	6.8	7.39	7.96
Em (measured) mV	209	202	186	211	181	153	189	159	160
Eh (calculated) mV ^{Note 1}	382.3	375.3	359.3	384.3	354.3	326.3	362.3	332.3	333.3
Alkalinity (mM/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Concentration (mg/L)									
Al	<0.02	0.04	0.18	0.04	0.06	0.07	<0.02	0.04	0.14
As	3.6	3.96	5.71	2.91	3	4.5	0.99	1.03	1.64
As ⁵⁺	1.14	3.08	4.68	0.73	1.92	3.91	<	<	1.13
As ³⁺	2.48	0.88	1.03	2.18	1.08	0.59	<	<	0.51
Ca	474	410	459	482	478	508	483	482	485
Cl	36.3	32.7	36.7	40.3	37.8	36.1	37	37.6	37.1
Fe	<0.02	<0.02	<0.02	0.11	<0.02	<0.02	0.04	0.03	<0.02
Fe ²⁺	<0.02	<0.02	<0.02	<	<0.02	<0.02	<	<	<0.02
Fe ³⁺	<0.02	<0.02	<0.02	<	<0.02	<0.02	<	<	<0.02
H ⁺									
K	125	93.8	98.9	121	107	106	115	109	101
Mg	231	150	54.9	231	175	95.5	233	168	60.8
Na	548	457	502	535	522	549	544	535	528
Ni	16.8	0.68	0.04	25.8	1.37	0.29	18.5	0.63	0.03
NO ₃	9.5	9.4	14.9	11.1	9.5	10	9.3	47	14.9
P	1.24	0.68	0.67	0.47	4.81	2.49	1.7	0.29	0.38
Ra (in Bq/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA
S ²⁻	ND	22.9	56.9	53.5	ND	10.8	92.8	ND	31.6
SO ₄ ²⁻	3624	2724	2604	3585	3277	2883	3587	3249	2829
S total	1170	932	928	1250	1070	973	1290	1060	976
U	<0.05	0.06	0.29	<0.05	<0.05	0.72	<0.05	0.09	0.27
MINTEQA2 results									
Sum of Cations	0.05133	0.04156	0.04002	0.05130	0.04710	0.04558	0.05152	0.04759	0.04194
Sum of Anions	0.05783	0.04495	0.04561	0.05800	0.05314	0.04757	0.05844	0.05317	0.04838
Speciated Charge Balance (%)	5.95	3.92	6.53	6.13	6.03	2.14	6.29	5.54	7.13
Equilibrium pH	7.04	7.39	8.05	6.96	6.93	7.77	6.8	7.39	7.96
Saturation Index									
Gypsum	-0.006	-0.1	-0.051	-0.003	-0.012	-0.002	-0.002	-0.01	-0.014
Ferrihydrite	< -0.825	< -1.414	< -0.992	0.375	< -1.391	< -1.195	-0.897	-0.239	< 0.118
Goethite	< 3.567	< 2.977	< 3.4	4.767	< 3.001	< 3.196	3.495	4.152	< 4.509
Hematite	< 12.143	< 10.963	< 11.808	14.542	< 11.01	< 11.401	11.998	13.313	< 14.027
Scorodite	< -1.328	< -2.107	< -2.88	-0.308	< -1.431	< -2.576	-1.029	-1.458	< -2.205
Annabergite	-4.586	-6.887	-9.004	-4.857	-7.532	-7.130	-5.149	-8.136	-10.831
pQ (calculated)									
Activity of Fe ³⁺	8.88E-18	2.03E-19	5.63E-21	2.44E-16	5.15E-18	2.44E-20	3.95E-17	3.04E-18	1.35E-19
Activity of Al ³⁺	2.23E-12	2.43E-13	3.16E-15	8.55E-12	1.53E-11	1.52E-14	1.41E-11	2.43E-13	5.52E-15
Activity of OH ⁻	1.10E-07	2.46E-07	1.13E-06	9.15E-08	8.54E-08	5.91E-07	6.33E-08	2.46E-07	9.15E-07
pQ (Iron)	37.93	38.52	38.09	36.73	38.49	38.30	38.00	37.34	36.99
pQ (Aluminum)	32.53	32.44	32.35	32.18	32.02	32.51	32.45	32.44	32.37
Eh (calculated) mV ^{Note 2}									
Fe ratio	--	--	--	--	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	28	-39	-166	-4	50	-112	55	-50	-149
As ratio	253	280	275	257	275	290	--	--	294

Note 1: Eh = Em (from COGEMA) + 173.3 mV (for 50°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)⁽⁹⁾ = 37.1

APPENDIX 3
JEB Tailings Data
at 120 hours and 50°C (Fe/As=2.6, 3.0, and 5.0)

	Fe/As = 2.6			Fe/As = 3.0			Fe/As = 5.0		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.58	7.4	7.9	6.63	No data	7.84	6.64	7.44	7.88
Em (measured) mV	243	206	181	223		176	315	264	226
Eh (calculated) mV ^{Note 1}	416.3	379.3	354.3	396.3		349.3	488.3	437.3	399.3
Alkalinity (mM/L)	0.1	0.6	0.8	0.13		1.09	0.11	0.47	0.72
Concentration (mg/L)									
Al	<0.02	<0.02	0.06	0.03		0.05	0.03	<0.02	0.04
As	7.22	8.09	10.9	5.86		8.34	2.82	2.34	4.29
As ⁵⁺	2.38	5.6	10.31	2.31		7.54	0.98	1.56	4.29
As ³⁺	4.84	2.49	0.59	3.55		0.8	1.84	0.78	<0.02
Ca	482	490	516	485		512	467	492	504
Cl	30.3	35.5	35.5	34.5		35.8	35.4	35.8	36
Fe	0.22	<0.02	<0.02	0.73		<0.02	0.61	<0.02	<0.02
Fe ²⁺	<	<	<	<		<	<	<	<
Fe ³⁺	<	<	<	<		<	<	<	<
H ⁺									
K	110	93.3	92.4	108		90.2	110	97.8	90.9
Mg	268	205	90.7	266		108	269	224	106
Na	559	539	545	562		539	550	554	538
Ni	11.5	0.37	0.03	18.1		0.04	18.1	0.42	0.04
NO ₃	9.3	11	10	9		9.1	9.4	0.9	1.9
P	2.33	1.26	0.62	0.48		0.68	0.41	0.57	0.57
Ra (in Bq/L)	12.89	17.67	101.57	89.19		91.06	35.91	69.42	132.36
S ²⁻	ND	ND	ND	ND		ND	ND	ND	ND
SO ₄ ²⁻	3950	3474	3020	4131		2952	3961	3568	3004
S total	1360	1150	1010	1310		1040	1360	1210	1040
U	<0.05	<0.05	0.15	<0.05		0.92	<0.05	<0.05	0.35
MINTEQA2 results									
Sum of Cations	0.05285	0.04912	0.04467	0.05265		0.04541	0.05218	0.05086	0.04490
Sum of Anions	0.06280	0.05634	0.05061	0.06614		0.04922	0.06322	0.05716	0.04980
Speciated Charge Balance (%)	8.60	6.85	6.23	11.36		4.03	9.57	5.83	5.17
Equilibrium pH	6.58	7.4	7.9	6.63		7.84	6.64	7.44	7.88
Saturation Index									
Gypsum	0.012	0.003	0.013	0.023		0.002	0	0.007	0.002
Ferrihydrite	-0.466	< -1.905	< -1.87	1.075		< -1.654	1.935	< -0.717	< -1.112
Goethite	3.926	< 2.486	< 2.521	5.466		< 2.737	6.327	< 3.674	< 3.28
Hematite	12.86	< 9.981	< 10.051	15.941		< 10.483	17.662	< 12.357	< 11.568
Scorodite	0.049	< -2.398	< -3.112	0.977		< -2.913	1.211	< -1.87	< -2.703
Annabergite	-5.879	-8.141	-11.059	-6.252		-11.259	-7.415	-8.969	-11.348
pQ (calculated)									
Activity of Fe ³⁺	4.87E-16	6.13E-20	2.10E-21	1.20E-14		5.23E-21	8.09E-14	7.17E-19	1.38E-20
Activity of Al ³⁺	5.51E-11	1.10E-13	4.04E-15	7.37E-11		5.78E-15	7.36E-11	7.85E-14	3.23E-15
Activity of OH ⁻	3.81E-08	2.52E-07	7.97E-07	4.28E-08		6.94E-07	4.38E-08	2.76E-07	7.61E-07
pQ (Iron)	37.57	39.01	38.97	36.03		38.76	35.17	37.82	38.21
pQ (Aluminum)	32.52	32.76	32.69	32.24		32.71	32.21	32.78	32.85
Eh (calculated) mV ^{Note 2}									
Fe ratio	--	--	--	--		--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	50	-41	-137	7		-125	10	-49	-133
As ratio	236	253	-75	244		282	261	283	--

Note 1: Eh = Em (from COGEMA) + 173.3 mV (for 50°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)⁽⁵⁾=37.1

APPENDIX 3
Sue C Tailings Data
at all times and 4°C (Fe/As=7.7)

	Fe/As=7.7 at Nominal pH=8				
	Raffinate	initial time	2 hours	24 hours	144 hours
pH		7.8	7.1	6.72	6.27
Em (measured) mV	413	214	227	139	249
Eh (calculated) mV ^{Note 1}	632.4	433.4	446.4	358.4	468.4
Alkalinity (mM/L)		0.25	0.12	<0.05	0.22
Concentration (mg/L)					
Al	708	<0.02	<0.02	<0.02	0.02
As	141	0.07	0.07	0.07	0.1
As ⁵⁺	112	<0.1	<0.1	<0.1	<0.1
As ³⁺	29	<0.1	<0.1	<0.1	<0.1
Ca	629	474	500	379	449
Cl	31.1	35.4	36.8	29.2	37.4
Fe	811	<0.02	<0.02	<0.02	0.06
Fe ²⁺	633	<	<	<	<
Fe ³⁺	178	<	<	<	<
H ⁺	490				
K	209	92	99.3	59.3	95.3
Mg	455	178	231	166	237
Na	39.8	592	575	454	564
Ni	145	0.02	<0.01	<0.01	0.08
NO ₃	37.1	8.4	10	6.8	10.2
P	18.2	0.1	0.76	1.16	0.9
Ra (in Bq/L)	27.31	196.07	119.48	62.61	60.2
S ²⁻					
SO ₄ ²⁻	35000	3265	3870	2546	3369
S total	10900	1100	1030	887	1060
U	<0.05	<0.2	<0.2	<0.2	<0.2
MINTEQA2 results					
Sum of Cations	0.33840	0.04989	0.05174	0.04088	0.05109
Sum of Anions	0.39460	0.05287	0.06223	0.04110	0.05385
Speciated Charge Balance (%)	7.67	2.90	9.20	0.27	2.63
Equilibrium pH	0.799	7.8	7.1	6.72	6.27
Saturation Index					
Gypsum	0.096	-0.019	0.028	-0.145	-0.042
Ferrihydrite	-7.402	< 1.65	< 1.131	< 0.652	0.781
Goethite	-3.004	< 6.041	< 5.523	< 5.043	5.173
Hematite	-0.992	< 17.091	< 16.054	< 15.095	15.354
Scorodite	-0.184	< -1.637	< -0.768	< -0.494	0.353
Annabergite	-24.180	-15.125	-16.836	-17.290	-16.015
pQ (calculated)					
Activity of Fe ³⁺	1.30E-05	1.39E-17	5.30E-16	2.42E-15	7.31E-14
Activity of Al ³⁺	4.46E-04	3.29E-15	1.40E-12	2.78E-11	5.87E-10
Activity of OH ⁻	6.23E-14	6.33E-07	1.26E-07	5.27E-08	1.87E-08
pQ (Iron)	44.50	35.45	35.97	36.45	36.32
pQ (Aluminum)	42.97	33.08	32.55	32.39	32.42
Eh (calculated) mV ^{Note 2}					
Fe ratio	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	--	208	324	387	435
As ratio	544	--	--	--	--

Note 1: Eh = Em (from COGEMA) + 219.4 mV (for 4°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)^(s) = 37.1

APPENDIX 3
Sue C Tailings Data
at initial time and 25°C (Fe/As=7.7)

		Fe/As = 7.7		
	Raffinate	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH		7.15	7.76	8.92
Em (measured) mV	413	170	152	125
Eh (calculated) mV ^{Note 1}	615	372	354	327
Alkalinity (mM/L)		0.18	0.3	0.96
Concentration (mg/L)				
Al	708	0.03	0.09	0.57
As	141	0.12	0.26	0.56
As ⁵⁺	112	0.12	0.26	0.56
As ³⁺	29	<0.2	<0.2	<0.2
Ca	629	447	445	477
Cl	31.1	33.3	32.9	33.2
Fe	811	<0.02	<0.02	<0.02
Fe ²⁺	633	<0.02	<0.02	<0.02
Fe ³⁺	178	<0.02	<0.02	<0.02
H ⁺	490			
K	209	103	70.4	72.2
Mg	455	317	266	83.9
Na	39.8	546	555	544
Ni	145	12	0.38	<0.01
NO ₃	37.1	8.9	8.8	8.8
P	18.2	0.12	0.07	0.17
Ra (in Bq/L)	27.31	139.98	116.06	72.71
S ²⁻	ND	58.1	17.2	26.9
SO ₄ ²⁻	35000	3871	3574	2736
S total	10900	1350	1210	940
U	<0.05	<0.1	0.34	0.16
MINTEQA2 results				
Sum of Cations	0.33840	0.05404	0.05133	0.04308
Sum of Anions	0.39460	0.06201	0.05735	0.04677
Speciated Charge Balance (%)	7.67	6.87	5.54	4.11
Equilibrium pH	0.799	7.15	7.76	8.92
Saturation Index				
Gypsum	0.096	-0.029	-0.038	-0.035
Ferrihydrite	-7.402	< 0.303	< 1.201	< 1.191
Goethite	-3.004	< 4.695	< 5.592	< 5.582
Hematite	-0.992	< 14.398	< 16.194	< 16.174
Scorodite	-0.184	< -1.424	< -1.483	< -3.932
Annabergite	-24.180	-6.974	-10.385	-16.806
pQ (calculated)				
Activity of Fe ³⁺	1.30E-05	5.58E-17	6.51E-18	2.11E-21
Activity of Al ³⁺	4.46E-04	1.39E-12	2.11E-14	3.50E-18
Activity of OH ⁻	6.23E-14	1.42E-07	5.77E-07	8.35E-06
pQ (Iron)	44.50	36.80	35.90	35.91
pQ (Aluminum)	42.97	32.40	32.39	32.69
Eh (calculated) mV ^{Note 2}				
Fe ratio	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	--	172	64	-142
As ratio	544	--	--	--

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃^(s)) = 37.1

APPENDIX 3
Sue C Tailings Data
at 2 hours and 25°C (Fe/As=7.7)

	Fe/As = 7.7		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.42	7	8.19
Em (measured) mV	453	162	145
Eh (calculated) mV ^{Note 1}	655	364	347
Alkalinity (mM/L)	0.31	0.42	0.51
Concentration (mg/L)			
Al	0.04	0.03	0.11
As	0.3	0.34	0.71
As ⁵⁺	<0.2	0.34	0.71
As ³⁺	0.29	<0.02	<0.02
Ca	452	468	471
Cl	35.8	35.9	35.4
Fe	<0.02	<0.02	<0.02
Fe ²⁺	<0.02	<0.02	<0.02
Fe ³⁺	<0.02	<0.02	<0.02
H ⁺			
K	86.4	79.7	70
Mg	336	284	85
Na	569	552	537
Ni	18.8	0.58	0.01
NO ₃	10.6	10.6	10.9
P	3.04	1.98	2.38
Ra (in Bq/L)			
S ²⁻	8.96	39.8	54.9
SO ₄ ²⁻	4108	3716	2742
S total	1380	1280	970
U	0.08	0.23	0.35
MINTEQA2 results			
Sum of Cations	0.05536	0.05264	0.04265
Sum of Anions	0.06485	0.05972	0.04763
Speciated Charge Balance (%)	7.89	6.30	5.52
Equilibrium pH	6.42	7	8.19
Saturation Index			
Gypsum	-0.016	-0.014	-0.039
Ferrihydrite	< 0.615	< -0.068	< 0.917
Goethite	< 5.007	< 4.323	< 5.309
Hematite	< 15.023	< 13.655	< 15.626
Scorodite	< -0.951	< -1.057	< -2.186
Annabergite	-10.408	-10.461	-14.655
pQ (calculated)			
Activity of Fe ³⁺	1.77E-14	6.68E-17	1.74E-19
Activity of Al ³⁺	4.63E-10	4.70E-12	5.39E-16
Activity of OH ⁻	2.64E-08	1.00E-07	1.55E-06
pQ (Iron)	36.49	37.17	36.19
pQ (Aluminum)	32.07	32.32	32.69
Eh (calculated) mV ^{Note 2}			
Fe ratio	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	302	199	-12
As ratio	--	--	--

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming $-\log K_{sp}(\text{Fe}(\text{OH})_3) = 37.1$

APPENDIX 3
Sue C Tailings Data
at 24 hours and 25°C (Fe/As=7.7)

	Fe/As = 7.7		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.58	6.86	7.89
Em (measured) mV	464	190	171
Eh (calculated) mV ^{Note 1}	666	392	373
Alkalinity (mM/L)	0.21	0.29	0.42
Concentration (mg/L)			
Al	0.03	0.03	0.13
As	0.3	0.27	0.67
As ⁵⁺	<0.2	0.27	0.67
As ³⁺	0.3	<0.2	<0.2
Ca	439	452	476
Cl	37.8	36.5	36.8
Fe	0.02	<0.02	<0.02
Fe ²⁺	<	<0.02	<0.02
Fe ³⁺	<	<0.02	<0.02
H ⁺			
K	87.3	82.8	72.4
Mg	346	295	91.6
Na	592	583	555
Ni	22	0.6	<0.01
NO ₃	11.3	11.1	11.4
P	1.19	0.97	0.77
Ra (in Bq/L)			
S ²⁻	36.9	6.42	58.8
SO ₄ ²⁻	4264	3786	2820
S total	1460	1270	1000
U	<0.05	0.26	0.76
MINTEQA2 results			
Sum of Cations	0.05620	0.05398	0.04392
Sum of Anions	0.06750	0.06018	0.04877
Speciated Charge Balance (%)	9.14	5.43	5.23
Equilibrium pH	6.58	6.86	7.89
Saturation Index			
Gypsum	-0.022	-0.026	-0.03
Ferrihydrite	0.786	< 0.298	< 0.514
Goethite	5.177	< 4.69	< 4.906
Hematite	15.364	< 14.388	< 14.82
Scorodite		< -0.571	< -1.916
Annabergite		-10.904	-14.288
pQ (calculated)			
Activity of Fe ³⁺	8.69E-15	4.08E-16	5.45E-19
Activity of Al ³⁺	1.16E-10	1.42E-11	9.61E-15
Activity of OH ⁻	3.81E-08	7.27E-08	7.79E-07
pQ (Iron)	36.32	36.81	36.59
pQ (Aluminum)	32.19	32.27	32.34
Eh (calculated) mV ^{Note 2}			
Fe ratio	—	—	—
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	273	224	41
As ratio	—	—	—

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming $-\log K_{sp}(\text{Fe}(\text{OH})_3) = 37.1$

APPENDIX 3
Sue C Tailings Data
at 144 hours and 25°C (Fe/As=7.7)

	Fe/As = 7.7		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.46	7.25	8.18
Em (measured) mV	446	149	131
Eh (calculated) mV ^{Note 1}	648	351	333
Alkalinity (mM/L)	0.16	0.49	0.61
Concentration (mg/L)			
Al	0.21	<0.02	<0.02
As	0.35	0.3	0.69
As ⁵⁺	<	0.09	0.48
As ³⁺	<	0.21	0.21
Ca	478	481	490
Cl	36.2	35.3	34.4
Fe	0.19	<0.02	<0.02
Fe ²⁺	<	<0.02	<0.02
Fe ³⁺	<	<0.02	<0.02
H ⁺			
K	105	91.6	77.9
Mg	383	328	104
Na	581	565	523
Ni	22.8	0.58	0.02
NO ₃	5.9	2.3	2.4
P	1.27	1.39	0.48
Ra (in Bq/L)			
S ²⁻	(1410)	(1270)	(932)
SO ₄ ²⁻	4269	3796	2748
S total	1410	1270	932
U	<0.05	0.58	1.48
MINTEQA2 results			
Sum of Cations	0.05961	0.05628	0.04399
Sum of Anions	0.06577	0.05901	0.04512
Speciated Charge Balance (%)	4.91	2.37	1.27
Equilibrium pH	6.46	7.25	8.18
Saturation Index			
Gypsum	0.007	-0.006	-0.025
Ferrihydrite	1.335	< 1.212	< 1.222
Goethite	5.727	< 5.604	< 5.614
Hematite	16.462	< 16.216	< 16.236
Scorodite	0.833	< -0.91	< -2.062
Annabergite	-7.775	-11.455	-14.340
pQ (calculated)			
Activity of Fe ³⁺	7.05E-14	2.27E-16	3.76E-19
Activity of Al ³⁺	1.80E-09	4.00E-13	1.07E-16
Activity of OH ⁻	2.89E-08	1.78E-07	1.52E-06
pQ (Iron)	35.77	35.89	35.88
pQ (Aluminum)	31.36	32.64	33.42
Eh (calculated) mV ^{Note 2}			
Fe ratio	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	237	154	-11
As ratio	--	317	316

Note: S²⁻ data is considered questionable and was not used in MINTEQA2 analyses.

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)⁽⁹⁾ = 37.1

APPENDIX 3
McClellan Lake Tailings Data
at initial time and 25°C (Fe/As=4.6 and 5.0)

		Fe/As = 4.6			Fe/As = 5.0		
	Raffinate	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	0.75	7.13	8.13	9.37	7.46	8.24	9.35
Em (measured) mV	421	460	199	144	194	183	151
Eh (calculated) mV ^{Note 1}	623	662	401	346	396	385	353
Alkalinity (mM/L)		0.28	0.44	1.5	0.26	0.43	1.3
Concentration (mg/L)							
Al	393	0.03	0.14	0.67	0.02	0.15	0.78
As	275	0.7	1.16	2.52	0.6	0.87	1.5
As ⁵⁺	222.5	0.27	0.77	2.52	0.18	0.54	1.28
As ³⁺	52.5	0.43	0.39	<0.2	0.42	0.33	0.22
Ca	126	466	474	497	479	492	491
Cl	30.1	32.3	32	31.5	32.9	33.3	32.5
Fe	948 (950?)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	419	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe ³⁺	531	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
H ⁺							
K	174	109	103	91.3	111	103	96.4
Mg	61.7	90.4	66.5	30.1	94.2	67.9	29.9
Na	31.7	593	598	603	607	621	612
Ni	164	7.14	0.23	0.03	14.8	0.2	0.02
NO ₃	35.9	8	7.9	8.1	12	10.7	8.3
P	23	0.14	0.25	0.3	0.13	0.18	0.29
Ra (in Bq/L)	1.18	38.77	67.27	90.95	117.6	84.52	59.79
S ²⁻	ND	ND	72.2	93.9	7.42	85.5	79.3
SO ₄ ²⁻	26100	2944	2780	2550	3004	2600	2558
S total	7730	977	1000	945	1010	1020	933
U	<0.05	<0.05	<0.05	<0.05	<0.05	0.07	<0.05
MINTEQA2 results							
Sum of Cations	0.31720	0.04591	0.04514	0.04390	0.04723	0.04730	0.04424
Sum of Anions	0.29660	0.04904	0.04892	0.04674	0.04997	0.04578	0.04638
Speciated Charge Balance (%)	-3.36	3.30	4.02	3.13	2.82	-1.63	2.36
Equilibrium pH	0.75	7.13	8.13	9.37	7.46	8.24	9.35
Saturation Index							
Gypsum	-0.701	-0.031	-0.033	-0.035	-0.018	-0.036	-0.037
Ferrihydrite	-6.895	< 0.44	< 0.726	< 0.775	< 1.054	< 1.173	< 0.798
Goethite	-2.5	< 4.831	< 5.117	< 5.166	< 5.445	< 5.565	< 5.189
Hematite	0.011	< 14.671	< 15.243	< 15.341	< 15.899	< 16.138	< 15.387
Scorodite	0.599	< -0.842	< -2.177	< -4.926	< -1.082	< -2.174	< -5.135
Annabergite	-23.584	-6.853	-10.229	-15.347	-5.710	-10.846	-16.210
pQ (calculated)							
Activity of Fe ³⁺	5.72E-05	8.76E-17	1.69E-19	3.61E-23	3.69E-17	2.22E-19	4.37E-23
Activity of Al ³⁺	3.35E-04	1.65E-12	1.18E-15	6.57E-20	6.67E-14	4.66E-16	9.19E-20
Activity of OH ⁻	5.60E-14	1.35E-07	1.35E-06	2.35E-05	2.89E-07	1.74E-06	2.25E-05
pQ (Iron)	44.00	36.66	36.38	36.33	36.05	35.93	36.31
pQ (Aluminum)	43.23	32.39	32.53	33.07	32.79	32.61	32.98
Eh (calculated) mV ^{Note 2}							
Fe ratio	--	--	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	--	176	-2	-222	117	-21	-218
As ratio	548	298	301	--	299	305	315

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃) = 37.1

APPENDIX 3
McClellan Lake Tailings Data
at 2 hours and 25°C (Fe/As=4.6 and 5.0)

	Fe/As = 4.6			Fe/As = 5.0		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	7.2	7.46	8.83	7.07	7.27	8.62
Em (measured) mV	211	203	167	219	201	162
Eh (calculated) mV ^{Note 1}	413	405	369	421	403	364
Alkalinity (mM/L)	0.41	0.51	0.94	0.39	0.46	1.03
Concentration (mg/L)						
Al	0.03	0.05	0.39	<0.02	0.07	0.33
As	0.95	1.67	3.72	0.83	1.13	2.33
As ⁵⁺	<	1.14	3.47	<	0.73	2.04
As ³⁺	<	0.53	0.25	<	0.4	0.29
Cu	479	500	510	486	488	504
Cl	35.7	35.3	35	34	34.7	32.6
Fe	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe ³⁺	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
H ⁺						
K	106	98.2	86.4	102	94.6	90.8
Mg	94.3	72.6	25.7	96.2	70.5	28.7
Na	611	612	606	602	621	600
Ni	6.59	0.19	0.02	10.5	0.18	0.03
NO ₃	10.8	10.9	9.6	9.5	11.3	8.9
P	0.29	0.47	0.66	1.87	1.95	0.49
Ra (in Bq/L)						
S ²⁻	138	133	131	150	136	118
SO ₄ ²⁻	3001	2837	2532	3056	2799	2582
S total	1140	1080	976	1170	1070	960
U	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
MINTEQA2 results						
Sum of Cations	0.04723	0.04679	0.04439	0.04701	0.04663	0.04414
Sum of Anions	0.05321	0.05091	0.04730	0.05395	0.05019	0.04781
Speciated Charge Balance (%)	5.95	4.22	3.17	6.87	3.68	3.99
Equilibrium pH	7.2	7.46	8.83	7.07	7.27	8.62
Saturation Index						
Gypsum	-0.021	-0.013	-0.023	-0.012	-0.024	-0.022
Ferrihydrite	< -0.667	< -0.554	< 0.775	< -0.687	< -0.417	< 0.779
Goethite	< 3.725	< 3.837	< 5.167	< 3.705	< 3.975	< 5.171
Hematite	< 12.458	< 12.683	< 15.342	< 12.418	< 12.958	< 15.35
Scorodite	< -1.489	< -1.803	< -3.252	< -1.322	< -1.48	< -2.907
Annabergite	-5.772	-10.103	-14.035	-5.471	-10.660	-13.713
pQ (calculated)						
Activity of Fe ³⁺	4.23E-18	9.09E-19	1.51E-21	9.90E-18	4.63E-18	6.48E-21
Activity of Al ³⁺	9.12E-13	1.66E-13	5.48E-18	1.77E-12	1.19E-12	3.18E-17
Activity of OH ⁻	1.59E-07	2.89E-07	6.78E-06	1.18E-07	1.87E-07	4.18E-06
pQ (Iron)	37.77	37.66	36.33	37.79	37.52	36.32
pQ (Aluminum)	32.44	32.39	32.77	32.54	32.11	32.63
Eh (calculated) mV ^{Note 2}						
Fe ratio	--	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	163	117	-126	186	151	-89
As ratio	--	293	312	--	300	308

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃) = 37.1

APPENDIX 3
McClellan Lake Tailings Data
at 24 hours and 25°C (Fe/As=4.6 and 5.0)

	Fe/As = 4.6			Fe/As = 5.0		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.98	7.11	7.89	6.84	7.31	8.14
Em (measured) mV	190	236	151	466	135	125
Eh (calculated) mV ^{Note 1}	392	438	353	668	337	327
Alkalinity (mM/L)	0.23	0.6	1.03	0.34	0.51	1.11
Concentration (mg/L)						
Al	0.07	0.7	0.37	0.05	0.07	0.38
As	1.14	1.86	4.34	1.04	1.33	2.58
As ⁵⁺	0.68	1.23	4.09	0.28	0.83	2.31
As ³⁺	0.46	0.63	0.25	0.76	0.5	0.27
Ca	473	486	488	477	471	475
Cl	33.3	33.5	33.6	32.7	33	32.8
Fe	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe ³⁺	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
H ⁺						
K	101	94	86.3	104	95.2	85.5
Mg	99.7	74.9	25.8	103	73.1	28.3
Na	604	588	583	599	584	579
Ni	5.88	0.18	0.02	10.2	0.18	0.02
NO ₃	8.9	8.8	7.4	9	8.1	9
P	0.2	0.42	0.53	0.41	0.4	0.45
Ra (in Bq/L)						
S ²⁻	7.09	12.8	ND	53.4	61.5	32.9
SO ₄ ²⁻	2975	2829	2503	3046	2794	2532
S total	1000	957	807	1070	994	878
U	<0.05	<0.05	0.06	<0.05	<0.05	0.08
MINTEQA2 results						
Sum of Cations	0.04688	0.04522	0.04269	0.04701	0.04458	0.04216
Sum of Anions	0.04944	0.04775	0.04303	0.05139	0.04846	0.04476
Speciated Charge Balance (%)	2.66	2.72	0.40	4.45	4.17	2.99
Equilibrium pH	6.98	7.11	7.89	6.84	7.31	8.14
Saturation Index						
Gypsum	-0.025	-0.02	-0.034	-0.019	-0.034	-0.043
Ferrihydrite	< -0.484	< -0.906	< -1.158	< 0.197	< -0.532	< -0.255
Goethite	< 3.907	< 3.485	< 3.233	< 4.588	< 3.86	< 4.136
Hematite	< 12.823	< 11.979	< 11.475	< 14.185	< 12.728	< 13.281
Scorodite	< -1.05	< -1.443	< -2.721	< -0.547	< -1.608	< -2.648
Annabergite	-6.492	-10.531	-12.538	-6.992	-10.541	-13.414
pQ (calculated)						
Activity of Fe ³⁺	2.94E-17	4.53E-18	1.16E-20	3.71E-16	2.70E-18	1.65E-20
Activity of Al ³⁺	1.27E-11	4.45E-11	2.75E-14	2.75E-11	8.47E-13	2.95E-15
Activity of OH ⁻	1.22E-07	1.29E-07	7.79E-07	6.94E-08	2.05E-07	1.39E-06
pQ (Iron)	37.28	38.01	38.26	36.91	37.63	37.36
pQ (Aluminum)	31.64	31.02	31.89	32.04	32.14	32.11
Eh (calculated) mV ^{Note 2}						
Fe ratio	—	—	—	—	—	—
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	202	179	41	227	144	-4
As ratio	296	288	312	284	294	310

Note 1: Eh = Em (from COGEMA) +202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)⁽³⁾=37.1

APPENDIX 3
McClellan Lake Tailings Data
at 144 hours and 25°C (Fe/As=4.6 and 5.0)

	Fe/As = 4.6			Fe/As = 5.0		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	7.2	7.61	8.23	6.95	7.53	8.03
Em (measured) mV	168	156	135	188	167	147
Eh (calculated) mV ^{Note 1}	370	358	337	390	369	349
Alkalinity (mM/L)	0.25	0.67	0.88	0.17	0.64	0.74
Concentration (mg/L)						
Al	< 0.02	< 0.02	0.13	< 0.02	< 0.02	0.05
As	1.33	2.53	5.78	1.04	1.7	3.75
As ⁵⁺	0.54	1.92	5.41	0.46	1.21	3.42
As ³⁺	0.79	0.61	0.37	0.58	0.49	0.33
Ca	469	494	511	472	482	491
Cl	34.2	34.9	35	34.4	34.8	34.5
Fe	< 0.02	< 0.02	< 0.02	0.03	< 0.02	< 0.02
Fe ²⁺	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Fe ³⁺	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
H ⁺						
K	96.5	88	78	94.7	89.5	80.1
Mg	99.1	77.4	23.7	99.2	77.9	27.9
Na	605	607	590	590	609	600
Ni	6.62	0.19	0.02	10.9	0.2	0.02
NO ₃	2.1	2.2	2.9	2.2	2.2	4.7
P	1.16	1.11	0.62	1.73	1.13	1.23
Ra (in Bq/L)	11.58	14.15	47.07	8.46	4.78	38.82
S ²⁻	77.8	87.2	82.6	69.4	84.6	110
SO ₄ ²⁻	2973	2825	2545	3028	2862	2595
S total	1070	1030	932	1080	1040	976
U	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
MINTEQA2 results						
Sum of Cations	0.04668	0.04636	0.04338	0.04605	0.04602	0.04337
Sum of Anions	0.05106	0.04966	0.04589	0.05146	0.05034	0.04768
Speciated Charge Balance (%)	4.48	3.44	2.81	5.55	4.48	4.73
Equilibrium pH	7.2	7.61	8.23	6.95	7.53	8.03
Saturation Index						
Gypsum	-0.03	-0.018	-0.016	-0.023	-0.024	-0.029
Ferrihydrite	< -0.296	< -0.829	< -0.813	-0.177	< -0.532	< -0.79
Goethite	< 4.095	< 3.563	< 3.579	4.215	< 3.859	< 3.601
Hematite	< 13.199	< 12.134	< 12.166	13.438	< 12.727	< 12.211
Scorodite	< -1.368	< -2.158	< -3.063	-0.869	< -1.896	< -2.755
Annabergite	-6.121	-9.798	-12.532	-6.080	-10.109	-12.474
pQ (calculated)						
Activity of Fe ³⁺	9.92E-18	1.71E-19	2.45E-21	7.34E-17	5.90E-19	1.03E-20
Activity of Al ³⁺	6.11E-13	1.79E-14	4.44E-16	4.65E-12	3.62E-14	1.05E-15
Activity of OH ⁻	1.59E-07	4.09E-07	1.70E-06	8.94E-08	3.40E-07	1.08E-06
pQ (Iron)	37.40	37.93	37.92	37.28	37.64	37.89
pQ (Aluminum)	32.61	32.91	32.66	32.48	32.85	32.89
Eh (calculated) mV ^{Note 2}						
Fe ratio	--	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	163	91	-20	197	105	16
As ratio	282	289	302	290	295	305

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃) = 37.1

APPENDIX 3
Sue A + B Tailings Data
at initial time and 25°C (Fe/As=0.6, 3.0, and 5.0)

		Fe/As = 0.6			Fe/As = 3.0			Fe/As = 5.0		
	Raffinate	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH		7.23	8.01	9.01	7.31	8.08	9.12	7.5	7.99	9.11
Em (measured) mV	289	231	203	156	203	185	148	191	178	141
Eh (calculated) mV ^{Note 1}	491	433	405	358	405	387	350	393	380	343
Alkalinity (mM/L)		0.23	0.71	1.43	0.19	0.3	1.07	0.21	0.25	0.99
Concentration (mg/L)										
Al	1690	0.19	0.19	0.18	0.2	0.19	0.18	0.22	0.2	0.18
As	2430	19.9	22.2	21.4	1.04	0.58	0.82	0.37	0.34	0.52
As ⁵⁺	1937	3.4	13.9	18.4	0.21	0.27	0.82	<0.2	<0.2	<0.2
As ³⁺	493	16.5	8.31	3	0.83	0.31	<0.2	0.36	<0.2	<0.2
Ca	304	430	446	468	447	485	465	436	450	463
Cl	35.6	30.6	30.1	29.8	29.3	29.7	29.6	30	30	30.4
Fe	1080	0.16	0.17	0.16	0.18	0.16	0.17	0.18	0.17	0.16
Fe ²⁺	821	<	<	<	<	<	<	<	<	<
Fe ³⁺	259	<	<	<	<	<	<	<	<	<
H ⁺	520									
K	357	194	174	169	192	185	171	187	186	189
Mg	716	411	266	60.4	395	242	23.9	390	215	21.1
Na	46.8	583	554	545	574	546	519	545	538	489
Ni	2740	111	2.07	0.03	40.7	0.6	<0.01	33.6	0.42	<0.01
NO ₃	39.8	11.3	11.4	11.4	11.2	11.5	11.7	10.9	10.8	10.9
P	27.2	0.36	0.45	0.44	0.39	0.37	0.33	0.4	0.42	0.32
Ra (in Bq/L)	26.74	43.15	28.84	31.45	48.95	41.57	17.49	56.06	46.82	40.31
S ²⁻	ND	132	116	147	ND	162	107	ND	ND	ND
SO ₄ ²⁻	37100	4757	3817	2795	4688	3740	2796	4993	3967	2991
S total	11700	1720	1390	1080	1640	1410	1040	1620	1380	1040
U	0.2	0.1	<0.05	0.06	0.07	<0.05	<0.05	<0.05	0.07	0.05
MINTEQA2 results										
Sum of Cations	0.53730	0.06262	0.05302	0.04352	0.06036	0.05327	0.04051	0.05741	0.04957	0.03902
Sum of Anions	0.38060	0.07676	0.06542	0.05315	0.07321	0.06474	0.05213	0.07930	0.06525	0.05248
Speciated Charge Balance (%)	-17.07	10.14	10.47	9.96	9.62	9.72	12.54	16.01	13.66	14.71
Equilibrium pH	0.718	7.23	8.01	9.01	7.31	8.08	9.12	7.5	7.99	9.11
Saturation Index										
Gypsum	-0.262	-0.025	-0.031	-0.048	-0.005	0.003	-0.034	-0.001	-0.007	-0.018
Ferrihydrite	-7.459	-0.552	-0.869	0.832	2.236	2.377	1.94	2.524	2.451	1.926
Goethite	-3.059	3.84	3.522	5.223	6.628	6.769	6.332	6.916	6.843	6.318
Hematite	-1.101	12.688	12.054	15.455	18.265	18.547	17.672	18.841	18.695	17.644
Scorodite	0.979	-1.061	-2.346	-2.985	-0.037	-1.161	-3.478	-1.108	-0.859	-3.642
Annabergite	-18.281	-1.207	-5.389	-13.013	-5.601	-10.076	-16.822	-7.524	-10.374	-17.065
pQ (calculated)										
Activity of Fe ³⁺	2.02E-05	4.48E-18	9.86E-21	4.95E-22	1.58E-15	1.07E-17	2.97E-21	8.27E-16	2.37E-17	3.08E-21
Activity of Al ³⁺	1.23E-03	4.38E-12	4.68E-15	4.82E-19	2.39E-12	2.49E-15	1.76E-19	5.08E-13	5.91E-15	1.92E-19
Activity of OH ⁻	5.14E-14	1.70E-07	1.03E-06	1.03E-05	2.05E-07	1.21E-06	1.32E-05	3.17E-07	9.80E-07	1.29E-05
pQ (Iron)	44.56	37.66	37.97	36.27	34.87	34.73	35.16	34.58	34.65	35.18
pQ (Aluminum)	42.78	31.66	32.30	33.28	31.69	32.36	33.39	31.79	32.25	33.38
Eh (calculated) mV ^{Note 2}										
Fe ratio	--	--	--	--	--	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	--	105	-35	-211	87	-46	-232	54	-32	-229
As ratio	548	205	222	248	282	307	--	--	--	--

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃) = 37.1

APPENDIX 3
Sue A + B Tailings Data
at initial time and 25°C (Fe/As=1.0, 1.5, 2.0, and 2.5)

		Nominal pH = 8			
	Raffinate	Fe/As = 1.0	Fe/As = 1.5	Fe/As = 2.0	Fe/As = 2.5
pH		7.7	7.8	7.6	7.6
Em (measured) mV	394	126	127	144	142
Eh (calculated) mV ^{Note 1}	596	328	329	346	344
Alkalinity (mM/L)		0.55	0.38	0.34	0.28
Concentration (mg/L)					
Al	1610	<0.02	0.03	0.02	0.03
As	3310	14	4.59	3	1.87
As ⁵⁺	1770	6.08	1.32	0.86	0.6
As ³⁺	1540	7.92	3.27	2.14	1.24
Ca	351	448	452	449	457
Cl	73.8	30.1	30.5	32.4	29.3
Fe	1710	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	1303	<	<	<	<
Fe ³⁺	410	<	<	<	<
H ⁺	340				
K	264	141	140	144	148
Mg	679	269	269	247	238
Na	48.1	570	591	588	606
Ni	2810	4.78	2.68	2	1.94
NO ₃	42.3	10.4	9.4	9.6	9.6
P	136	0.23	0.18	0.15	0.12
Ra (in Bq/L)	33.85	17.54	16.92	18.76	25.86
S ²⁻					
SO ₄ ²⁻	34600	3537	3561	3454	3292
S total	13300	1190	1190	1150	1160
U	0.41	<0.2	<0.2	<0.2	<0.2
MINTEQA2 results					
Sum of Cations	0.38420	0.05388	0.05488	0.05375	0.05484
Sum of Anions	0.35630	0.05625	0.05641	0.05506	0.05206
Speciated Charge Balance (%)	-3.77	2.15	1.37	1.20	-2.60
Equilibrium pH	0.995	7.7	7.8	7.6	7.6
Saturation Index					
Gypsum	-0.11	-0.041	-0.036	-0.041	-0.044
Ferrihydrite	-6.727	< -1.551	< -0.057	< 0.028	< 0.359
Goethite	-2.329	< 2.841	< 4.335	< 4.42	< 4.751
Hematite	0.357	< 10.69	< 13.678	< 13.849	< 14.511
Scorodite	1.597	< -2.677	< -2.085	< -1.741	< -1.578
Annabergite	-16.986	-4.538	-6.422	-7.175	-7.434
pQ (calculated)					
Activity of Fe ³⁺	1.59E-05	1.75E-20	2.73E-19	1.32E-18	2.83E-18
Activity of Al ³⁺	8.28E-04	7.99E-15	4.92E-15	1.94E-14	2.92E-14
Activity of OH ⁻	9.76E-14	5.03E-07	6.33E-07	3.99E-07	3.99E-07
pQ (Iron)	43.83	38.65	37.16	37.07	36.74
pQ (Aluminum)	42.11	32.99	32.90	32.91	32.73
Eh (calculated) mV ^{Note 2}					
Fe ratio	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	--	75	57	92	92
As ratio	513	224	246	257	271

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)⁽¹⁾ = 37.1

APPENDIX 3
Sue A+B Tailings Data
at 2 hours and 25°C (Fe/As=0.6, 3.0, and 5.0)

	Fe/As = 0.6			Fe/As = 3.0			Fe/As = 5.0		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.77	7.63	8.5	7.31	7.33	8.4	7.1	7.39	8.37
Em (measured) mV	445.7	142.3	117.4	157.1	157.2	133.1	181.7	174.8	184
Eh (calculated) mV ^{Note 1}	647.7	344.3	319.4	359.1	359.2	335.1	383.7	376.8	386
Alkalinity (mM/L)	0.18	0.91	1.17	0.25	0.3	0.57	0.19	0.27	0.54
Concentration (mg/L)									
Al	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
As	26.4	29.5	26	1.49	0.82	1.2	0.51	0.39	0.67
As ⁵⁺	5.8	19.5	23.2	0.18	0.37	1	0.21	0.14	0.42
As ³⁺	20.6	10	2.77	1.31	0.45	0.2	0.3	0.25	0.25
Ca	440	441	478	467	482	471	464	464	464
Cl	31.7	30.8	31.8	33	32.6	32.3	33.5	33.7	32.5
Fe	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	<	<	<	<	<	<	<	<	<
Fe ³⁺	<	<	<	<	<	<	<	<	<
H ⁺									
K	168	146	146	176	158	146	166	158	155
Mg	419	264	61.5	405	259	27.1	411	228	28.5
Na	531	499	503	540	534	483	518	500	452
Ni	123	2.49	<0.01	33	0.61	<0.01	26.8	0.39	<0.01
NO ₃	13.2	14.1	13.4	14.4	13.9	13.4	14.3	15.6	17.4
P	1.16	0.81	0.29	0.67	0.32	0.3	1.02	0.37	0.22
Ra (in Bq/L)									
S ²⁻	90	82	64	ND	ND	84	ND	95	79
SO ₄ ²⁻	4944	3768	2985	4714	3979	2776	4719	3819	2729
S total	1740	1340	1060	1630	1390	1010	1620	1370	990
U	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
MINTEQA2 results									
Sum of Cations	0.06020	0.04969	0.04115	0.05943	0.05218	0.03886	0.05834	0.04882	0.03769
Sum of Anions	0.07807	0.06381	0.05390	0.07339	0.06391	0.05053	0.07346	0.06453	0.04959
Speciated Charge Balance (%)	12.92	12.44	13.41	10.51	10.10	13.06	11.47	13.86	13.63
Equilibrium pH	6.77	7.63	8.5	7.31	7.33	8.4	7.1	7.39	8.37
Saturation Index									
Gypsum	-0.007	-0.034	-0.019	0.014	0.015	-0.024	0.012	-0.004	-0.032
Ferrihydrite	< -2.383	< -2.704	< -1.534	< 1.003	< 0.445	< 0.868	< 0.712	< 0.485	< 1.344
Goethite	< 2.009	< 1.687	< 2.857	< 5.395	< 4.836	< 5.26	< 5.104	< 4.876	< 5.735
Hematite	< 9.026	< 8.383	< 10.723	< 15.799	< 14.681	< 15.528	< 15.217	< 14.762	< 16.479
Scorodite	< -1.738	< -3.154	< -3.842	< -0.962	< -1.162	< -2.527	< -0.767	< -1.613	< -2.36
Annabergite	-1.521	-4.844	-12.982	-5.307	-9.797	-14.623	-5.812	-11.003	-15.284
pQ (calculated)									
Activity of Fe ³⁺	1.59E-18	1.99E-21	7.22E-23	9.26E-17	2.23E-17	3.64E-20	2.02E-16	1.61E-17	1.34E-19
Activity of Al ³⁺	1.28E-11	1.47E-14	5.76E-18	2.39E-13	2.02E-13	1.45E-17	1.39E-12	1.21E-13	1.90E-17
Activity of OH ⁻	5.90E-08	4.28E-07	3.17E-06	2.05E-07	2.14E-07	2.52E-06	1.26E-07	2.46E-07	2.35E-06
pQ (Iron)	39.49	39.81	38.64	36.10	36.66	36.23	36.39	36.62	35.76
pQ (Aluminum)	32.58	32.94	33.73	32.69	32.70	33.64	32.55	32.74	33.61
Eh (calculated) mV ^{Note 2}									
Fe ratio	--	--	--	--	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	240	87	-67	144	140	-50	181	130	-44
As ratio	199	218	250	270	297	318	308	312	312

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃) = 37.1

APPENDIX 3
Sue A+B Tailings Data
at 2 hours and 25°C (Fe/As=1.0, 1.5, 2.0, and 2.5)

	Nominal pH = 8			
	Fe/As = 1.0	Fe/As = 1.5	Fe/As = 2.0	Fe/As = 2.5
pH	7	7.2	7	7
Em (measured) mV	161	149	153	155
Eh (calculated) mV ^{Note 1}	363	351	355	357
Alkalinity (mM/L)	0.9	0.59	0.51	0.48
Concentration (mg/L)				
Al	<0.02	<0.02	<0.02	<0.02
As	30.8	9.22	5.75	3.04
As ⁵⁺	12.6	1.66	1.72	0.87
As ³⁺	18.2	7.56	4.03	2.17
Ca	474	471	471	465
Cl	32.6	32.9	33.5	33.9
Fe	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	<	<	<	<
Fe ³⁺	<	<	<	<
H ⁺				
K	126	132	138	139
Mg	306	302	271	259
Na	584	585	600	597
Ni	12.3	5.75	2.94	2.17
NO ₃	12	11.2	11.3	11.7
P	1.07	1.9	1.32	0.15
Ra (in Bq/L)	23.29	18.87	22.72	24.7
S ²⁻				
SO ₄ ²⁻	3655	3659	3685	3661
S total	1290	1280	1280	1260
U	<0.2	<0.2	<0.2	<0.2
MINTEQA2 results				
Sum of Cations	0.05698	0.05678	0.05566	0.05473
Sum of Anions	0.05760	0.05745	0.05863	0.05852
Speciated Charge Balance (%)	0.54	0.59	2.60	3.35
Equilibrium pH	7	7.2	7	7
Saturation Index				
Gypsum	-0.02	-0.02	-0.014	-0.018
Ferrihydrite	< -2.914	< -0.966	< -1.201	< -0.603
Goethite	< 1.478	< 3.426	< 3.191	< 3.788
Hematite	< 7.965	< 11.861	< 11.39	< 12.586
Scorodite	< -2.315	< -1.643	< -1.46	< -1.165
Annabergite	-3.493	-5.856	-6.927	-7.914
pQ (calculated)				
Activity of Fe ³⁺	9.54E-20	2.13E-18	4.92E-18	1.95E-17
Activity of Al ³⁺	2.32E-12	6.01E-13	3.01E-12	3.08E-12
Activity of OH ⁻	1.00E-07	1.59E-07	1.00E-07	1.00E-07
pQ (Iron)	40.02	38.07	38.30	37.71
pQ (Aluminum)	32.63	32.62	32.52	32.51
Eh (calculated) mV ^{Note 2}				
Fe ratio	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	199	163	199	199
As ratio	202	225	241	257

Note 1:Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2:Eh (calc) values determined by MINTEQA2 and calculations.

Note 3:Assuming -log K_{sp}(Fe(OH)₃^(s))=37.1

APPENDIX 3
Sue A+B Tailings Data
at 24 hours and 25°C (Fe/As=0.6, 3.0, and 5.0)

	Fe/As = 0.6			Fe/As = 3.0			Fe/As = 5.0		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.95	7.06	8.41	7.15	7.47	8.66	7.17	7.45	8.51
Em (measured) mV	283.6	250.3	213.8	248.8	230.5	199.6	241.1	221.2	196.3
Eh (calculated) mV ^{Note 1}	485.6	452.3	415.8	450.8	432.5	401.6	443.1	423.2	398.3
Alkalinity (mM/L)	0.29	1.11	1.02	0.27	0.38	0.67	0.27	0.42	0.54
Concentration (mg/L)									
Al	0.04	0.03	0.03	0.03	0.04	0.03	0.04	0.03	0.03
As	29.2	32.7	27.2	1.78	0.89	1.55	0.58	0.49	1.07
As ⁵⁺	3.9	22.8	24.4	0.23	0.45	1.55	0.26	0.49	1.07
As ³⁺	25.3	9.95	2.81	1.55	0.44	<0.2	0.32	<0.2	<0.2
Ca	434	447	476	442	449	457	444	454	466
Cl	32.7	31.3	32.4	32.9	32.4	31.2	34.3	35.5	32.5
Fe	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03
Fe ²⁺	<	<	<	<	<	<	<	<	<
Fe ³⁺	<	<	<	<	<	<	<	<	<
H ⁺									
K	167	141	156	168	154	141	167	159	164
Mg	430	296	64.1	412	272	29.2	412	246	35.6
Na	546	536	537	563	542	506	540	528	497
Ni	138	3.81	1.05	40.1	1.78	1.01	32.3	1.66	1.01
NO ₃	13.7	13.7	13.9	13.7	13.9	13.7	14.2	14.4	14
P	0.69	0.59	0.35	0.57	0.36	0.21	0.64	0.57	0.23
Ra (in Bq/L)									
S ²⁻	15	ND	70	ND	ND	53	ND	ND	78
SO ₄ ²⁻	5109	3945	2995	4819	3961	2778	4711	3814	2792
S total	1720	1380	1070	1600	1350	980	1590	1320	1010
U	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
MINTEQA2 results									
Sum of Cations	0.06106	0.05275	0.04296	0.05970	0.05214	0.03933	0.05885	0.05070	0.04020
Sum of Anions	0.07965	0.06407	0.05411	0.07550	0.06387	0.04983	0.07363	0.06189	0.05046
Speciated Charge Balance (%)	13.21	9.69	11.49	11.69	10.11	11.78	11.16	9.94	11.32
Equilibrium pH	6.95	7.06	8.41	7.15	7.47	8.66	7.17	7.45	8.51
Saturation Index									
Gypsum	-0.008	-0.024	-0.023	-0.005	-0.016	-0.037	-0.007	-0.015	-0.03
Ferrihydrite	-1.738	-3.251	-1.597	1.107	0.654	1.137	1.046	2.431	1.186
Goethite	2.654	1.14	2.795	5.499	5.046	5.528	5.438	6.823	5.578
Hematite	10.317	7.289	10.598	16.007	15.1	16.065	15.885	18.654	16.165
Scorodite	-1.601	-2.490	-3.652	-0.505	-1.173	-2.740	-0.544	0.106	-2.478
Annabergite	-1.350	-4.577	-6.502	-5.294	-8.199	-8.772	-5.414	-9.425	-8.609
pQ (calculated)									
Activity of Fe ³⁺	2.02E-18	2.90E-20	1.16E-22	3.55E-16	1.37E-17	1.12E-20	2.69E-16	9.42E-16	3.54E-20
Activity of Al ³⁺	8.30E-12	1.96E-12	1.97E-17	1.38E-12	1.21E-13	2.01E-18	1.56E-12	1.08E-12	7.92E-18
Activity of OH ⁻	8.94E-08	1.15E-07	2.58E-06	1.42E-07	2.96E-07	4.59E-06	1.48E-07	2.83E-07	3.25E-06
pQ (Iron)	38.84	40.35	38.70	36.00	36.45	35.97	36.06	34.67	35.92
pQ (Aluminum)	32.23	32.52	33.47	32.41	32.50	33.71	32.29	31.61	33.57
Eh (calculated) mV ^{Note 2}									
Fe ratio	--	--	--	--	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	197	178	-62	154	105	-106	151	109	-80
As ratio	194	218	250	266	298	--	306	--	--

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)⁽⁶⁾=37.1

APPENDIX 3
Sue A + B Tailings Data
at 24 hours and 25°C (Fe/As=1.0, 1.5, 2.0, and 2.5)

	Nominal pH = 8			
	Fe/As = 1.0	Fe/As = 1.5	Fe/As = 2.0	Fe/As = 2.5
pH	7.4	7.3	7.1	7.2
Em (measured) mV	161	163	169	170
Eh (calculated) mV ^{Note 1}	363	365	371	372
Alkalinity (mM/L)	1	0.7	0.58	0.47
Concentration (mg/L)				
Al	<0.02	<0.02	<0.02	<0.02
As	37.8	12.7	6.18	3.77
As ⁵⁺	15.3	2.1	0.65	0.7
As ³⁺	22.5	10.6	5.53	3.07
Ca	478	479	479	477
Cl	32.6	33.3	33.8	37
Fe	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	<	<	<	<
Fe ³⁺	<	<	<	<
H ⁺				
K	125	136	138	147
Mg	318	313	288	280
Na	591	600	593	622
Ni	15.7	7.01	3.31	2.66
NO ₃	11.4	10.9	10.9	13.9
P	0.45	0.35	0.29	0.17
Ra (in Bq/L)	24.35	24.54	3.75	14
S ²⁻				
SO ₄ ²⁻	3898	3951	3914	3815
S total	1120	1110	1080	1060
U	<0.2	<0.2	0.22	<0.2
MINTEQA2 results				
Sum of Cations	0.05735	0.05766	0.05602	0.05725
Sum of Anions	0.06164	0.06237	0.06226	0.06072
Speciated Charge Balance (%)	3.61	3.92	5.28	2.94
Equilibrium pH	7.4	7.3	7.1	7.2
Saturation Index				
Gypsum	-0.005	0	0.003	-0.004
Ferrihydrite	< -2.712	< -1.088	< -0.25	< -0.226
Goethite	< 1.679	< 3.304	< 4.142	< 4.166
Hematite	< 8.368	< 11.616	< 13.292	< 13.341
Scorodite	< -2.82	< -1.861	< -1.15	< -1.283
Annabergite	-2.640	-5.384	-7.585	-7.578
pQ (calculated)				
Activity of Fe ³⁺	9.57E-21	8.04E-19	2.20E-17	1.17E-17
Activity of Al ³⁺	1.07E-13	2.59E-13	1.38E-12	6.06E-13
Activity of OH ⁻	2.52E-07	2.00E-07	1.26E-07	1.59E-07
pQ (Iron)	39.82	38.19	37.35	37.33
pQ (Aluminum)	32.77	32.68	32.55	32.61
Eh (calculated) mV ^{Note 2}				
Fe ratio	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	128	146	181	163
As ratio	197	216	233	248

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)⁽⁶⁾=37.1

APPENDIX 3
Sue A + B Tailings Data
at 144 hours and 25°C (Fe/As=0.6, 3.0, and 5.0)

	Fe/As = 0.6			Fe/As = 3.0			Fe/As = 5.0		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.58	7.55	7.77	7.01	7.35	7.58	6.84	7.31	7.33
Em (measured) mV	258.5	264.5	216.5	248.8	238.8	212.3	209.8	256.4	232.2
Eh (calculated) mV ^{Note 1}	460.5	466.5	418.5	450.8	440.8	414.3	411.8	458.4	434.2
Alkalinity (mM/L)	0.34	1.35	1.49	NA	NA	0.56	0.21	0.42	0.49
Concentration (mg/L)									
Al	0.06	<0.02	0.03	0.03	0.03	0.03	0.04	<0.02	<0.02
As	37.2	29.4	30.6	1.03	1.11	3.1	0.52	0.61	1.71
As ⁵⁺	5.9	18.8	27.8	0.44	0.61	2.74	0.15	0.35	1.55
As ³⁺	31.3	10.6	2.78	0.59	0.5	0.36	0.37	0.26	0.16
Ca	460	409	448	411	385	454	393	392	434
Cl	35.2	28.5	29.1	31	28.3	29.2	29.7	28.7	28
Fe	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	<	<	<	<	<	<	<	<	<
Fe ³⁺	<	<	<	<	<	<	<	<	<
H ⁺									
K	179	111	126	131	128	124	135	126	136
Mg	462	288	68.2	372	249	43.1	369	233	50.1
Na	726	592	618	604	571	631	595	566	571
Ni	171	2.97	0.09	44.8	0.92	0.06	40	0.77	0.06
NO ₃	4	4.2	3.5	5.1	5	5.6	5.2	5.1	8.2
P	0.69	3.15	1.39	3.95	3.42	0.81	2.61	2.09	2.09
Ra (in Bq/L)	NA	NA	NA	NA	NA	15.38	NA	NA	NA
S ²⁻			ND					ND	ND
SO ₄ ²⁻	5677	3612	2780	4363	3489	2816	4241	3464	2647
S total	1860	1120	900	1320	1050	883	1300	1110	850
U	<0.05	<0.05	0.12	<0.05	<0.05	<0.05	<0.05	<0.05	0.1
MINTEQA2 results									
Sum of Cations	0.07105	0.05345	0.04550	0.05860	0.05040	0.04493	0.05774	0.04952	0.04271
Sum of Anions	0.08800	0.05885	0.04859	0.06843	0.05633	0.04835	0.06670	0.05653	0.04531
Speciated Charge Balance (%)	10.66	4.81	3.28	7.74	5.56	3.67	7.20	6.61	2.95
Equilibrium pH	6.58	7.55	7.77	7.01	7.35	7.58	6.84	7.31	7.33
Saturation Index									
Gypsum	0.026	-0.079	-0.062	-0.05	-0.099	-0.043	-0.073	-0.09	-0.071
Ferrihydrite	< -2.488	< -2.75	< -3.002	< 0.045	< 0.014	< -1.255	< 0.657	< 0.456	< -0.997
Goethite	< 1.904	< 1.642	< 1.39	< 4.436	< 4.406	< 3.136	< 5.049	< 4.848	< 3.394
Hematite	< 8.816	< 8.292	< 7.788	< 13.882	< 13.821	< 11.281	< 15.106	< 14.704	< 11.797
Scorodite	< -1.526	< -3.054	< -3.476	< -0.893	< -1.374	< -2.317	< -0.471	< -1.111	< -1.806
Annabergite	-1.687	-4.993	-9.240	-4.460	-8.267	-10.769	-6.058	-9.593	-11.312
pQ (calculated)									
Activity of Fe ³⁺	4.63E-18	3.11E-21	3.81E-22	8.09E-17	7.20E-18	7.90E-20	1.07E-15	2.62E-17	8.04E-19
Activity of Al ³⁺	1.09E-10	2.96E-14	6.45E-15	4.31E-12	2.57E-13	3.50E-14	2.21E-11	2.41E-13	2.04E-13
Activity of OH ⁻	3.81E-08	3.56E-07	5.91E-07	1.03E-07	2.25E-07	3.82E-07	6.94E-08	2.05E-07	2.15E-07
pQ (Iron)	39.59	39.85	40.10	37.06	37.09	38.36	36.45	36.65	38.10
pQ (Aluminum)	32.22	32.88	32.88	32.33	32.54	32.71	32.13	32.68	32.70
Eh (calculated) mV ^{Note 2}									
Fe ratio	—	—	—	—	—	—	—	—	—
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	273	101	62	197	137	96	227	144	140
As ratio	189	216	250	291	294	303	303	311	323

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming $-\log K_{sp}(\text{Fe}(\text{OH})_3) = 37.1$

APPENDIX 3
Sue A+B Tailings Data
at 144 hours and 25°C (Fe/As=1.0, 1.5, 2.0, and 2.5)

	Nominal pH = 8			
	Fe/As = 1.0	Fe/As = 1.5	Fe/As = 2.0	Fe/As = 2.5
pH	7.4	7.2	7.4	7.3
Em (measured) mV	196.6	193.8	186.8	185.2
Eh (calculated) mV ^{Note 1}	398.6	395.8	388.8	387.2
Alkalinity (mM/L)	0.9	0.79	0.62	0.59
Concentration (mg/L)				
Al	<0.02	<0.02	<0.02	<0.02
As	37.2	12.9	6.6	4.09
As ⁵⁺	12.7	2.2	0.96	0.89
As ³⁺	24.5	10.7	5.62	3.2
Ca	474	468	469	464
Cl	32.6	33.2	33.3	34.6
Fe	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	<	<	<	<
Fe ³⁺	<	<	<	<
H ⁺				
K	112	121	128	128
Mg	326	327	298	291
Na	575	591	605	602
Ni	19	9.29	3.97	2.87
NO ₃	5.2	1.5	2.8	1.5
P	0.6	0.7	0.37	0.38
Ra (in Bq/L)	20.34	10.88	10.77	12.13
S ²⁻				
SO ₄ ²⁻	4202	4222	4084	4046
S total				
U	<0.2	<0.2	<0.2	<0.2
MINTEQA2 results				
Sum of Cations	0.05590	0.05662	0.05607	0.05547
Sum of Anions	0.06675	0.06706	0.06517	0.06474
Speciated Charge Balance (%)	8.85	8.44	7.51	7.71
Equilibrium pH	7.4	7.2	7.4	7.3
Saturation Index				
Gypsum	0.007	0.003	0.001	-0.004
Ferrihydrite	< -2.569	< -1.243	< -0.31	< -0.356
Goethite	< 1.823	< 3.149	< 4.081	< 4.036
Hematite	< 8.654	< 11.306	< 13.172	< 13.081
Scorodite	< -2.755	< -1.794	< -1.627	< -1.499
Annabergite	-2.465	-5.147	-6.706	-7.260
pQ (calculated)				
Activity of Fe ³⁺	1.33E-20	1.12E-18	2.42E-18	4.34E-18
Activity of Al ³⁺	1.07E-13	5.97E-13	1.11E-13	2.60E-13
Activity of OH ⁻	2.52E-07	1.59E-07	2.52E-07	2.00E-07
pQ (Iron)	39.67	38.35	37.41	37.46
pQ (Aluminum)	32.77	32.62	32.75	32.68
Eh (calculated) mV ^{Note 2}				
Fe ratio	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	128	163	128	146
As ratio	195	216	233	247

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming $-\log K_{sp}(\text{Fe}(\text{OH})_3^{(s)}) = 37.1$

APPENDIX 3
Cigar Lake Tailings Data
at initial time and 25°C (Fe/As=7.5)

		Fe/As = 7.5		
	Raffinate	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH		5.63	7.58	8.69
Em (measured) mV	386	100	93	79
Eh (calculated) mV ^{Note 1}	588	302	295	281
Alkalinity (mM/L)		<0.05	0.34	0.97
Concentration (mg/L)				
Al	4280	0.05	0.26	1.16
As	580	0.29	0.69	1.48
As ⁵⁺	454	0.16	0.14	0.61
As ³⁺	126	0.13	0.55	0.87
Ca	724	423	421	461
Cl	81	40.3	42	40.5
Fe	3260	32.5	0.03	<0.02
Fe ²⁺	2670	32.5	<	<
Fe ³⁺	590	<0.1	<	<
H ⁺	400			
K	388	219	194	163
Mg	2330	1370	1060	222
Na	129	466	452	439
Ni	453	9.22	0.18	0.03
NO ₃	40.5	10.4	10.6	10.7
P	156	0.03	0.08	0.15
Ru (in Bq/L)	82.71	826.44	663.97	320.73
S ²⁻	ND	ND	ND	ND
SO ₄ ²⁻	67200	8891	7210	3180
S total	19900	2660	2120	952
U	1.64	<0.2	<0.2	<0.2
MINTEQA2 results				
Sum of Cations	0.44240	0.09709	0.08332	0.04727
Sum of Anions	0.61470	0.12270	0.10250	0.05134
Speciated Charge Balance (%)	16.30	11.65	10.32	4.13
Equilibrium pH	1.073	5.63	7.58	8.69
Saturation Index				
Gypsum	0.367	0.021	-0.002	-0.04
Ferrihydrite	-6.54	0.033	1.603	< 1.354
Goethite	-2.137	4.425	5.995	< 5.745
Hematite	0.747	13.859	16.999	< 16.499
Scorodite	1.124	0.549	-1.204	< -3.222
Annabergite	-20.494	-12.255	-12.715	-15.101
pQ (calculated)				
Activity of Fe ³⁺	1.48E-05	1.09E-12	5.72E-17	1.50E-20
Activity of Al ³⁺	1.22E-03	1.52E-08	2.93E-13	5.83E-17
Activity of OH ⁻	1.16E-13	4.27E-09	3.81E-07	4.91E-06
pQ (Iron)	43.64	37.07	35.50	35.75
pQ (Aluminum)	41.73	32.93	31.79	32.16
Eh (calculated) mV ^{Note 2}				
Fe ratio	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	--	252	85	-101
As ratio	520	330	293	280

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃^(s))=37.1

APPENDIX 3
Cigar Lake Tailings Data
at 2 hours and 25°C (Fe/As=7.5)

	Fe/As = 7.5		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	5.7	7.19	7.72
Em (measured) mV	163	147	142
Eh (calculated) mV ^{Note 1}	365	349	344
Alkalinity (mM/L)	<0.05	0.39	0.47
Concentration (mg/L)			
Al	0.04	0.04	0.13
As	0.19	0.45	1.25
As ⁵⁺	0.09	0.13	0.35
As ³⁺	0.1	0.32	0.9
Ca	419	435	456
Cl	40.2	40.1	36.9
Fe	30.1	0.03	<0.02
Fe ²⁺	20.5	<	<
Fe ³⁺	9.6	<	<
H ⁺			
K	188	166	152
Mg	1400	1250	361
Na	465	466	446
Ni	6.39	0.27	0.08
NO ₃	12.9	14.7	13.6
P	0.58	0.94	0.36
Ra (in Bq/L)			
S ²⁻			
SO ₄ ²⁻	9102	8257	3761
S total	5300	4810	2400
U	<0.2	<0.2	<0.2
MINTEQA2 results			
Sum of Cations	0.09686	0.09070	0.05380
Sum of Anions	0.12590	0.11560	0.05815
Speciated Charge Balance (%)	13.04	12.07	3.89
Equilibrium pH	5.7	7.19	7.72
Saturation Index			
Gypsum	0.021	0.026	-0.03
Ferrihydrite	2.572	1.291	< 1.035
Goethite	6.964	5.683	< 5.427
Hematite	18.938	16.375	< 15.863
Scorodite	1.063	-0.772	< -1.477
Annabergite	-16.379	-12.861	-12.565
pQ (calculated)			
Activity of Fe ³⁺	2.33E-10	4.13E-16	5.87E-18
Activity of Al ³⁺	1.12E-08	1.30E-12	4.34E-14
Activity of OH ⁻	5.02E-09	1.55E-07	5.26E-07
pQ (Iron)	34.53	35.81	36.07
pQ (Aluminum)	32.85	32.31	32.20
Eh (calculated) mV ^{Note 2}			
Fe ratio	452	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	251	155	71
As ratio	69	307	280

Note 1=Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2=Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)⁽⁶⁾ = 37.1

APPENDIX 3
Cigar Lake Tailings Data
at 24 hours and 25°C (Fe/As=7.5)

	Fe/As = 7.5		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	4.74	7.3	7.18
Em (measured) mV	223	176	164
Eh (calculated) mV ^{Note 1}	425	378	366
Alkalinity (mM/L)	<0.05	0.71	0.6
Concentration (mg/L)			
Al	0.06	0.02	0.09
As	0.17	0.45	1.13
As ⁵⁺	0.06	0.15	0.24
As ³⁺	<1	0.3	0.89
Ca	442	454	458
Cl			
Fe	34.8	0.02	<0.02
Fe ²⁺	34.8	<	<
Fe ³⁺	<0.1	<	<
H ⁺			
K	194	173	158
Mg	1500	1360	411
Na	493	482	449
Ni	6.91	0.34	0.03
NO ₃			
P	0.49	0.82	0.38
Ra (in Bq/L)			
S ²⁻	2960	2750	1380
SO ₄ ²⁻	8867.81	8238.68	4134.32
S total	2960	2750	1380
U	<0.2	<0.2	<0.2
MINTEQA2 results			
Sum of Cations	0.10570	0.09849	0.05594
Sum of Anions	0.11720	0.11100	0.06244
Speciated Charge Balance (%)	5.16	5.97	5.49
Equilibrium pH	4.74	7.3	7.18
Saturation Index			
Gypsum	0.03	0.035	-0.016
Ferrihydrite	-0.522	1.195	< 0.727
Goethite	3.87	5.588	< 5.119
Hematite	12.75	16.185	< 15.246
Scorodite	0.454	-1.029	< -0.851
Annabergite	-17.029	-12.474	-14.696
pQ (calculated)			
Activity of Fe ³⁺	1.42E-10	1.55E-16	1.20E-16
Activity of Al ³⁺	3.05E-08	2.56E-13	3.23E-12
Activity of OH ⁻	5.50E-10	2.00E-07	1.52E-07
pQ (Iron)	37.63	35.91	36.38
pQ (Aluminum)	35.29	32.69	31.95
Eh (calculated) mV ^{Note 2}			
Fe ratio	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	408	146	167
As ratio	--	309	280

Value :Calculated based on total S.

Note 1:Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3:Assuming -log K_{sp}(Fe(OH)₃)⁽¹⁾=37.1

APPENDIX 3
Cigar Lake Tailings Data
at 128 hours and 25°C (Fe/As=7.5)

	Fe/As = 7.5		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	5.73	7.31	7.45
Em (measured) mV	111.9	99	98.1
Eh (calculated) mV ^{Note 1}	313.9	301	300.1
Alkalinity (mM/L)	<0.05	0.37	0.57
Concentration (mg/L)			
Al	0.08	0.03	0.06
As	0.28	0.36	1.27
As ⁵⁺	<	<0.2	<0.2
As ³⁺	<	0.36	1.12
Ca	439	444	471
Cl	40.6	34.3	34.5
Fe	58.3	0.05	<0.02
Fe ²⁺	56.1	<	<
Fe ³⁺	2.2	<	<
H ⁺			
K	181	151	134
Mg	1600	1470	512
Na	495	478	464
Ni	9.57	0.36	0.02
NO ₃	11.4	3.7	1.8
P	0.31	1.13	2.35
Ra (in Bq/L)	265.27	169.23	107.89
S ²⁻			
SO ₄ ²⁻	10383	9204	4493
S total	2560	2240	1130
U	<0.25	<0.25	<0.25
MINTEQA2 results			
Sum of Cations	0.10570	0.09996	0.06127
Sum of Anions	0.14160	0.12560	0.06735
Speciated Charge Balance (%)	14.52	11.37	4.73
Equilibrium pH	5.73	7.31	7.45
Saturation Index			
Gypsum	0.056	0.044	-0.002
Ferrihydrite	1.924	1.683	< 1.236
Goethite	6.316	6.075	< 5.628
Hematite	17.642	17.16	< 16.264
Scorodite	1.514		< -1.132
Annabergite	-13.548		-15.467
pQ (calculated)			
Activity of Fe ³⁺	4.26E-11	4.45E-16	6.02E-17
Activity of Al ³⁺	1.93E-08	3.53E-13	2.15E-13
Activity of OH ⁻	5.38E-09	2.04E-07	2.83E-07
pQ (Iron)	35.18	35.42	35.87
pQ (Aluminum)	32.52	32.52	32.31
Eh (calculated) mV ^{Note 2}			
Fe ratio	384	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	220	120	119
As ratio	--	--	274

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃^(s))=37.1

APPENDIX 3
Blend 1 (75% Sue C + 25% Cigar Lake) Tailings Data
at initial time and 25°C (Fe/As=7.6)

		Fe/As = 7.6		
	Raffinate Note1	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH		7.03	8.05	9.07
Em (measured) mV		160	145	110
Eh (calc) mV ^{Note 2}		362	347	312
Alkalinity (mM/L)		0.15	0.36	1.16
Concentration (mg/L)				
Al	1601	0.04	0.32	1.83
As	251	0.26	0.34	0.64
As ⁵⁺	198	<0.03	0.17	0.48
As ³⁺	53	0.25	0.17	0.16
Ca	653	438	447	479
Cl	44	54.2	54.6	53.6
Fe	1423	0.03	<0.02	
Fe ²⁺	1142	<	<	<
Fe ³⁺	281	<	<	<
H ⁺	468			
K	254	131	117	104
Mg	924	558	432	109
Na	62	559	539	527
Ni	222	5.47	0.14	0.03
NO ₃	38	9.1	9.2	9.1
P	53	0.02	0.04	0.16
Ra (in Bq/L)	41	85.56	155.05	97.61
S ²⁻	ND	ND	ND	ND
SO ₄ ²⁻	43050	4943	4344	2817
S total	13150	1580	1230	912
U	<1	<0.2	<0.2	0.25
MINTEQA2 results				
Sum of Cations	0.37360	0.06574	0.05916	0.04442
Sum of Anions	0.45730	0.07493	0.06743	0.04755
Speciated Charge Balance (%)	10.07	6.53	6.53	3.40
Equilibrium pH	0.878	7.03	8.05	9.07
Saturation Index				
Gypsum	0.184	-0.019	-0.021	-0.034
Ferrihydrite	-7.132	1.325	< 1.623	< 1.061
Goethite	-2.733	5.717	< 6.015	< 5.453
Hematite	-0.449	16.442	< 17.039	< 15.914
Scorodite	0.287	-1.340	< -1.972	< -4.586
Annabergite	-22.855	-10.675	-12.394	-16.080
pQ (calculated)				
Activity of Fe ³⁺	1.42E-05	1.34E-15	2.33E-18	5.55E-22
Activity of Al ³⁺	7.96E-04	4.93E-12	5.46E-15	2.82E-18
Activity of OH ⁻	7.43E-14	1.07E-07	1.13E-06	1.18E-05
pQ (Iron)	44.24	35.78	35.48	36.04
pQ (Aluminum)	42.49	32.21	32.11	32.33
Eh (calculated) mV ^{Note 3}				
Fe ratio	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 4}	--	183	12	--
As ratio	--	--	323	323

Note 1: Calculated by weighted average based on component raffinate.

Note 2: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 3: Eh (calc) values determined by MINTEQA2 and calculations.

Note 4: Assuming $-\log K_{sp}(\text{Fe}(\text{OH})_3) = 37.1$

APPENDIX 3
Blend 1 (75% Sue C + 25% Cigar Lake) Tailings Data
at 2 hours and 25°C (Fe/As=7.6)

	Fe/As = 7.6		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.04	7.1	7.73
Em (measured) mV	180	172	158
Eh (calc) mV ^{Note 1}	382	374	360
Alkalinity (mM/L)	0.15	0.21	0.41
Concentration (mg/L)			
Al	0.03	0.04	0.23
As	0.35	0.36	0.69
As ⁵⁺	0.2	0.15	0.35
As ³⁺	0.15	0.21	0.34
Ca	437	419	463
Cl	57.4	54	55
Fe	<0.02	<0.02	<0.02
Fe ²⁺	<	<	<
Fe ³⁺	<	<	<
H ⁺			
K	131	103	95.8
Mg	574	455	131
Na	548	510	524
Ni	5.68	0.22	0.04
NO ₃	11	10.9	10.6
P	0.42	0.35	0.23
Ra (in Bq/L)			
S ²⁻	ND	ND	ND
SO ₄ ²⁻	5167	4184	2792
S total	3210	2500	1830
U	<0.2	<0.2	0.43
MINTEQA2 results			
Sum of Cations	0.06549	0.05841	0.04509
Sum of Anions	0.07871	0.06432	0.04627
Speciated Charge Balance (%)	9.17	4.82	1.29
Equilibrium pH	6.04	7.1	7.73
Saturation Index			
Gypsum	-0.012	-0.056	-0.049
Ferrihydrite	< -0.66	< 0.922	< 0.91
Goethite	< 3.732	< 5.313	< 5.302
Hematite	< 12.472	< 15.636	< 15.613
Scorodite	< -0.394	< -0.724	< -1.501
Annabergite	-10.657	-12.388	-13.090
pQ (calculated)			
Activity of Fe ³⁺	1.30E-14	3.27E-16	4.10E-18
Activity of Al ³⁺	2.76E-09	2.79E-12	7.13E-14
Activity of OH ⁻	1.10E-08	1.26E-07	5.39E-07
pQ (Iron)	37.76	36.18	36.19
pQ (Aluminum)	32.44	32.25	31.95
Eh (calculated) mV ^{Note 2}			
Fe ratio	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	369	181	69
As ratio	326	317	304

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming $-\log K_{sp}(\text{Fe}(\text{OH})_3) = 37.1$

APPENDIX 3
Blend 1 (75% Sue C + 25% Cigar Lake) Tailings Data
at 24 hours and 25°C (Fe/As=7.6)

	Fe/As = 7.6		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.84	7.05	7.25
Em (measured) mV	171	162	156
Eh (calculated) mV ^{Note 1}	373	364	358
Alkalinity (mM/L)	0.25	0.34	0.5
Concentration (mg/L)			
Al	< 0.02	0.03	0.16
As	0.23	0.32	0.65
As ⁵⁺	< 0.03	0.12	0.29
As ³⁺	< 1	0.2	0.36
Ca	447	461	485
Cl			
Fe	< 0.02	< 0.02	< 0.02
Fe ²⁺	<	<	<
Fe ³⁺	<	<	<
H ⁺			
K	138	120	105
Mg	595	522	148
Na	583	570	542
Ni	6.78	0.26	0.02
NO ₃			
P	0.25	0.22	0.21
Ra (in Bq/L)			
S ²⁻	1670	1590	1090
SO ₄ ²⁻	5003.13	4763.45	3265.51
S total	1670	1590	1090
U	< 0.2	0.24	0.58
MINTEQA2 results			
Sum of Cations	0.06920	0.06499	0.04662
Sum of Anions	0.07328	0.07073	0.05253
Speciated Charge Balance (%)	2.86	4.23	5.96
Equilibrium pH	6.84	7.05	7.25
Saturation Index			
Gypsum	-0.013	-0.001	-0.002
Ferrihydrite	< 0.456	< 0.951	< 0.529
Goethite	< 4.848	< 5.343	< 4.92
Hematite	< 14.705	< 15.695	< 14.849
Scorodite	< -0.54	< -0.713	< -0.986
Annabergite	-8.206	-12.630	-14.611
pQ (calculated)			
Activity of Fe ³⁺	6.76E-16	4.95E-16	4.69E-17
Activity of Al ³⁺	1.10E-11	3.14E-12	3.22E-12
Activity of OH ⁻	6.94E-08	1.13E-07	1.78E-07
pQ (Iron)	36.65	36.15	36.57
pQ (Aluminum)	32.43	32.35	31.74
Eh (calculated) mV ^{Note 2}			
Fe ratio	—	—	—
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	227	190	154
As ratio	--	319	303

Value = Calculated based on total S.

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming $-\log K_{sp}(\text{Fe}(\text{OH})_3) = 37.1$

APPENDIX 3

Blend 1 (75% Sue C + 25% Cigar Lake) Tailings Data
at 128 hours and 25°C (Fe/As=7.6)

	Fe/As = 7.6		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	6.31	6.62	6.76
Em (measured) mV	265	253	239.8
Eh (calculated) mV ^{Note 1}	467	455	441.8
Alkalinity (mM/L)	0.11	0.35	0.44
Concentration (mg/L)			
Al	0.02	0.02	0.08
As	0.19	0.27	0.71
As ⁵⁺	<	< 0.2	< 0.2
As ³⁺	<	0.26	0.59
Ca	461	466	493
Cl	59.9	60.3	61.5
Fe	0.06	< 0.02	< 0.02
Fe ²⁺	<	<	<
Fe ³⁺	<	<	<
H ⁺			
K	124	105	90.5
Mg	647	576	190
Na	574	566	539
Ni	9.09	0.22	0.02
NO ₃	4	2.1	3.8
P	1.07	1.08	1.73
Ra (in Bq/L)	80.59	23.01	23.61
S ²⁻	ND	ND	ND
SO ₄ ²⁻	5435	4880	3169
S total	1500	1330	870
U	< 0.25	0.38	0.84
MINTEQA2 results			
Sum of Cations	0.07069	0.06746	0.04915
Sum of Anions	0.08116	0.07329	0.05148
Speciated Charge Balance (%)	6.89	4.14	2.32
Equilibrium pH	6.31	6.62	6.76
Saturation Index			
Gypsum	0.011	0.001	-0.011
Ferrihydrite	0.686	< 0.799	< 0.674
Goethite	5.078	< 5.191	< 5.065
Hematite	15.164	< 15.391	< 15.139
Scorodite	0.397	< -1.133	< -0.365
Annabergite	-9.558	-15.847	-16.222
pQ (calculated)			
Activity of Fe ³⁺	4.46E-14	6.81E-15	1.94E-15
Activity of Al ³⁺	4.42E-10	5.77E-11	8.18E-11
Activity of OH ⁻	2.05E-08	4.18E-08	5.77E-08
pQ (Iron)	36.42	36.30	36.43
pQ (Aluminum)	32.42	32.37	31.80
Eh (calculated) mV ^{Note 2}			
Fe ratio	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	293	266	241
As ratio	--	312	290

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming $-\log K_{sp}(\text{Fe}(\text{OH})_3^{(s)}) = 37.1$

APPENDIX 3

Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) Tailings Data
at all times and 4° C (Fe/As=3.0)

	Fe/As = 3.0 at Nominal pH = 8			
	initial time	2 hours	24 hours	144 hours
pH	7.8	7	6.65	6.77
Em (measured) mV	205	217	195	201
Eh (calculated) mV ^{Note 1}	424.4	436.4	414.4	420.4
Alkalinity (mM/L)	0.17	<0.05	0.33	<0.05
Concentration (mg/L)				
Al	<0.02	<0.02	<0.02	0.04
As	0.28	0.76	0.41	0.67
As ⁵⁺	<1.0	0.36	<1.0	<1
As ³⁺	<1.0	0.4	<1.0	<1
Ca	501	549	447	458
Cl	36.2	39.5	35.9	39.3
Fe	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	<	<	<	<
Fe ³⁺	<	<	<	<
H ⁺				
K	91	102	77.4	74.7
Mg	369	451	402	419
Na	509	507	443	484
Ni	0.48	0.17	0.64	2.07
NO ₃	11.3	13.8	13.5	13.5
P	0.1	0.38	0.19	1.2
Ra (in Bq/L)	510.19	249.94	149.16	104.63
S ²⁻				
SO ₄ ²⁻	3826	4078	3440	4068
S total	1280	1280	1150	1370
U	<0.2	<0.2	<0.2	<0.2
MINTEQA2 results				
Sum of Cations	0.05687	0.06289	0.05500	0.05611
Sum of Anions	0.05808	0.06003	0.05154	0.06194
Speciated Charge Balance (%)	1.05	-2.33	-3.25	4.94
Equilibrium pH	7.8	7	6.65	6.77
Saturation Index				
Gypsum	0.008	0.045	-0.063	-0.02
Ferrihydrite	< 1.283	< 0.303	< -0.079	< -0.435
Goethite	< 5.675	< 4.695	< 4.313	< 3.956
Hematite	< 16.358	< 14.398	< 13.635	< 12.922
Scorodite	< -1.523	< -0.766	< -0.426	< -0.761
Annabergite	-9.821	-12.004	-10.922	-8.643
pQ (calculated)				
Activity of Fe ³⁺	5.97E-18	1.57E-16	7.32E-16	1.41E-16
Activity of Al ³⁺	3.27E-15	3.13E-12	4.43E-11	3.62E-11
Activity of OH ⁻	6.33E-07	1.00E-07	4.48E-08	5.91E-08
pQ (Iron)	35.82	36.80	37.18	37.54
pQ (Aluminum)	33.08	32.50	32.40	32.13
Eh (calculated) mV ^{Note 2}				
Fe ratio	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	--	340	398	378
As ratio	--	301	--	--

Note 1: Eh = Em (from COGEMA) + 219.4 mV (for 4°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)⁽⁶⁾ = 37.1

APPENDIX 3

**Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) Tailings Data
at initial time and 25°C (Fe/As=0.3, 3.0, and 5.0)**

		Fe/As = 0.3			Fe/As = 3.0			Fe/As = 5.0		
	Raffinate Note 1	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH		6.51	7.71	9.05	6.84	7.51	9.02	6.86	7.78	9.19
Em (measured) mV		175	116	119	183	173	132	101	106	78
Eh (calculated) mV ^{Note 2}		377	318	321	385	375	334	303	308	280
Alkalinity (mM/L)		0.32	0.97	1.63	0.16	0.25	0.88	0.1	0.26	1
Concentration (mg/L)										
Al	2491	0.05	0.08	0.31	0.03	0.07	0.33	<0.02	0.06	0.26
As	6807	65.2	56.2	56.1	0.84	0.78	1.24	0.56	0.43	0.9
As ⁵⁺	5727	5	30.4	44.2	0.13	0.2	0.74	0.13	0.12	0.5
As ³⁺	1080	60.2	25.8	11.9	0.71	0.58	0.5	0.43	0.31	0.4
Ca	351	432	454	489	447	462	479	446	457	490
Cl	47	35.9	36.3	34.9	35.6	35.3	35.9	34.8	36.3	35.5
Fe	1492	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	2.05	<0.02	<0.02
Fe ²⁺	1240	<	<	<	<	<	<	1.38	<	<
Fe ³⁺	252	<	<	<	<	<	<	0.67	<	<
H ⁺	470									
K	267	134	115	98.9	144	125	116	146	133	113
Mg	1207	712	385	83.2	631	298	44.7	561	255	32.1
Na	69	547	519	502	503	481	456	464	455	442
Ni	5165	369	5.41	0.27	52.7	1.56	0.08	39.6	0.74	0.05
NO ₃	37	11.1	11.1	10.9	11.8	11.8	11.9	12.1	12.5	12.6
P	60	0.15	0.34	0.41	0.19	0.04	0.12	0.02	0.03	0.08
Ra (in Bq/L)	27	179.34	199.79	120.51	328.77	273.47	195.53	421.17	301.26	244.62
S ²⁻	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
SO ₄ ²⁻	49400	6151	3927	2627	5245	3602	2482	4863	3412	2396
S total	16000	1910	1290	873	1620	1190	835	1560	1090	814
U	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
MINTEQA2 results										
Sum of Cations	0.55900	0.07839	0.05661	0.04167	0.06826	0.05162	0.03867	0.06345	0.04849	0.03777
Sum of Anions	0.48600	0.08825	0.06149	0.04536	0.07732	0.05635	0.04212	0.07231	0.05405	0.04070
Speciated Charge Balance (%)	-6.99	5.92	4.13	4.24	6.22	4.38	4.27	6.53	5.42	3.73
Equilibrium pH	0.838	6.51	7.71	9.05	6.84	7.51	9.02	6.86	7.78	9.19
Saturation Index										
Gypsum	-0.064	-0.010	-0.032	-0.048	-0.007	-0.025	-0.041	-0.014	-0.032	-0.038
Ferrihydrite	-7.426	-1.835	< -2.855	< -0.602	< 0.735	< 1.143	< 1.105	2.539	< 1.555	< 0.954
Goethite	-3.024	2.557	< 1.537	< 3.789	< 5.127	< 5.535	< 5.496	6.930	< 5.947	< 5.346
Hematite	-1.029	10.124	< 8.082	< 12.587	< 15.263	< 16.079	< 16.000	18.870	< 16.903	< 15.7
Scorodite	1.479	-0.909	< -3.358	< -4.192	< -0.526	< -1.149	< -4.137	0.643	< -1.507	< -4.937
Annabergite	-15.948	-1.167	-3.586	-9.699	-6.036	-8.874	-13.842	-7.504	-10.066	-15.239
pQ (calculated)										
Activity of Fe ³⁺	9.63E-06	3.38E-17	8.09E-22	1.38E-23	1.29E-15	3.21E-17	8.65E-22	7.11E-14	1.28E-17	1.89E-22
Activity of Al ³⁺	1.16E-03	1.55E-10	2.89E-14	5.77E-19	1.66E-11	1.50E-13	8.13E-19	9.52E-12	1.18E-14	1.34E-19
Activity of OH ⁻	6.75E-14	3.24E-08	5.14E-07	1.13E-05	6.94E-08	3.25E-07	1.05E-05	7.26E-08	6.05E-07	1.55E-05
pQ (Iron)	44.53	38.94	39.96	37.71	36.37	35.96	36.00	34.56	35.55	36.15
pQ (Aluminum)	42.45	32.28	32.41	33.08	32.26	32.29	33.03	32.44	32.58	33.30
Eh (calculated) mV ^{Note 3}										
Fe ratio	--	--	--	--	--	--	--	307	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 4}	--	262	73	-165	227	108	-160	115	60	-190
As ratio	544	172	193	213	286	291	294	-30	307	300

Note 1: Calculated by weighted average based on component raffinates.

Note 2: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 3: Eh (calc) values determined by MINTEQA2 and calculations.

Note 4: Assuming -log K_{sp}(Fe(OH)₃)⁽⁶⁾=37.1

APPENDIX 3

Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) Tailings Data
at initial time and 25°C (Fe/As=1.0, 1.5, 2.0, and 2.5)

	Raffinate	Nominal pH = 8			
		Fe/As = 1.0	Fe/As = 1.5	Fe/As = 2.0	Fe/As = 2.5
pH		7.8	7.7	7.8	7.8
Em (measured) mV	364	212	196	194	202
Eh (calculated) mV ^{Note 1}	566	414	398	396	404
Alkalinity (mM/L)		0.35	0.24	0.22	0.2
Concentration (mg/L)					
Al	2620	<0.02	<0.02	<0.02	<0.02
As	7090	10.7	3.13	1.0 ^{Note 4}	0.55
As ⁵⁺	2770	3.55	0.83	Note 4	<1.0
As ³⁺	4320	7.15	2.3	Note 4	<1.0
Ca	429	458	455	458	501
Cl	49.3	35.7	35.7	35.7	36.7
Fe	1530	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	1140	<	<	<	<
Fe ³⁺	390	<	<	<	<
H ⁺	520				
K	177	71.9	75.9	80.1	93.2
Mg	1410	420	415	364	393
Na	48.4	525	517	505	506
Ni	5710	1.9	1.18	0.63	0.49
NO ₃	34.5	11.1	10.9	10.9	11
P	97.6	0.27	0.16	0.12	0.09
Ra (in Bq/L)	117.38	217.37	296.51	327.92	525.81
S ²⁻					
SO ₄ ²⁻	54700	4166	4215	3925	3927
S total	16800	1410	1400	1340	1310
U	<0.2	<0.2	<0.2	<0.2	<0.2
MINTEQA2 results					
Sum of Cations	0.58620	0.05755	0.05679	0.05432	0.05791
Sum of Anions	0.52400	0.06384	0.06474	0.06068	0.05937
Speciated Charge Balance (%)	-5.60	5.18	6.54	5.53	1.24
Equilibrium pH	0.82	7.8	7.7	7.8	7.8
Saturation Index					
Gypsum	0.043	-0.017	-0.016	-0.02	0.01
Ferrihydrite	-7.262	< -0.822	< 0.301	< 0.265	< 0.819
Goethite	-2.859	< 3.57	< 4.693	< 4.657	< 5.211
Hematite	-0.698	< 12.149	< 14.395	< 14.322	< 15.431
Scorodite	1.328	< -2.483	< -1.781	< -1.938	< -1.687
Annabergite	-16.567	-6.127	-7.886	-8.401	-9.277
pQ (calculated)					
Activity of Fe ³⁺	1.61E-05	4.69E-20	1.24E-18	5.73E-19	2.05E-18
Activity of Al ³⁺	1.27E-03	3.25E-15	7.94E-15	3.26E-15	3.26E-15
Activity of OH ⁻	6.45E-14	6.33E-07	5.03E-07	6.33E-07	6.33E-07
pQ (Iron)	44.37	37.92	36.80	36.84	36.84
pQ (Aluminum)	42.47	33.08	33.00	33.08	33.08
Eh (calculated) mV ^{Note 2}					
Fe ratio	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	--	57	75	57	57
As ratio	518	226	253	--	--

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2.

Note 3: Assuming -log K_{sp}(Fe(OH)₃)^(s)=37.1

Note 4: COGEMA reported 0.86 (As), <1.0 (As⁵⁺), 1.14 (As³⁺), thus As=1.0 was used in MINTEQA2.

APPENDIX 3

Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) Tailings Data at 2 hours and 25°C (Fe/As=0.3, 3.0, and 5.0)

	Fe/As = 0.3			Fe/As = 3.0			Fe/As = 5.0		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	7.02	7.56	8.05	7.05	7.34	8.38	7.19	7.3	8.66
Em (measured) mV	207	186	165	204	188	155	197	187	154
Eh (calculated) mV ^{Note 1}	409	388	367	406	390	357	399	389	356
Alkalinity (mM/L)	0.67	1.95	1.86	0.25	0.32	0.48	0.31	0.28	0.53
Concentration (mg/L)									
Al	0.06	<0.02	<0.02	0.05	0.04	0.06	0.05	0.05	0.07
As	121	107	104	1.68	1.32	2.02	0.99	0.67	1.41
As ⁵⁺	21	71.3	92.8	0.28	0.48	1.21	0.19	0.27	0.8
As ³⁺	100	35.7	11.2	1.4	0.84	0.81	0.8	0.4	0.61
Ca	448	469	499	446	460	480	449	463	492
Cl	43.2	41.2	40.9	44.6	39.6	35	41.3	40	39.4
Fe	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	<0.02	<0.02
Fe ²⁺	<	<	<	<	<	<	<	<	<
Fe ³⁺	<	<	<	<	<	<	<	<	<
H ⁺									
K	115	92.4	86.1	134	118	110	134	124	113
Mg	713	440	111	612	316	55.2	506	256	37.7
Na	504	493	478	462	460	446	450	440	428
Ni	476	9.85	0.29	46.9	1.27	0.06	23.7	0.55	0.02
NO ₃	15.6	14.7	14.9	16.3	14.5	14.6	15.4	15.3	15.9
P	1.57	1.18	0.82	0.98	0.21	0.14	0.21	0.15	0.13
Ra (in Bq/L)									
S ²⁻	NA	NA	NA	NA	NA	NA	NA	NA	NA
SO ₄ ²⁻	6563	4190	2683	5203	3683	2574	2675	3432	2477
S total	1990	1300	842	1530	1140	1440	1050	1050	780
U	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
MINTEQA2 results									
Sum of Cations	0.07723	0.05744	0.04203	0.06502	0.05128	0.03863	0.06759	0.04782	0.03751
Sum of Anions	0.09473	0.06648	0.04715	0.07755	0.05767	0.04329	0.03705	0.05449	0.04188
Speciated Charge Balance (%)	10.18	7.30	5.74	8.79	5.87	5.69	-29.19	6.52	5.50
Equilibrium pH	7.02	7.56	8.05	7.05	7.34	8.38	7.19	7.3	8.66
Saturation Index									
Gypsum	0.015	-0.016	-0.042	-0.006	-0.024	-0.032	-0.152	-0.025	-0.027
Ferrihydrite	< -3.193	< -3.783	< -3.493	< 0.541	< 0.301	< 0.804	1.208	< 0.711	< 1.284
Goethite	< 1.199	< 0.609	< 0.898	< 4.933	< 4.692	< 5.195	5.6	< 5.103	< 5.675
Hematite	< 7.408	< 6.226	< 6.805	< 14.874	< 14.393	< 15.399	16.208	< 15.214	< 16.359
Scorodite	< -2.555	< -3.605	< -4.138	< -0.77	< -1.233	< -2.509	-0.606	< -0.991	< -2.927
Annabergite	1.579	-2.697	-7.348	-5.074	-8.612	-11.975	-5.853	-10.192	-14.298
pQ (calculated)									
Activity of Fe ³⁺	4.38E-20	2.69E-22	1.78E-23	1.93E-16	1.49E-17	3.60E-20	3.40E-16	5.06E-17	1.57E-20
Activity of Al ³⁺	5.81E-12	2.60E-14	3.48E-16	5.21E-12	3.72E-13	5.23E-17	1.66E-12	6.57E-13	4.71E-18
Activity of OH ⁻	1.05E-07	3.64E-07	1.13E-06	1.13E-07	2.20E-07	2.41E-06	1.55E-07	2.00E-07	4.59E-06
pQ (Iron)	40.30	40.89	40.60	36.56	36.80	36.30	35.89	36.39	35.82
pQ (Aluminum)	32.17	32.90	33.30	32.13	32.41	33.14	32.21	32.28	33.34
Eh (calculated) mV ^{Note 2}									
Fe ratio	—	—	—	—	—	—	—	—	—
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	195	99	12	190	138	-46	155	146	-96
As ratio	159	185	-104	269	281	282	282	300	289

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃) = 37.1

APPENDIX 3

Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) Tailings Data
at 2 hours and 25° C (Fe/As=1.0, 1.5, 2.0, and 2.5)

	Nominal pH = 8			
	Fe/As = 1.0	Fe/As = 1.5	Fe/As = 2.0	Fe/As = 2.5
pH	7.2	7.1	7	6.9
Em (measured) mV	223	220	223	219
Eh (calculated) mV ^{Note 1}	425	422	425	421
Alkalinity (mM/L)	0.44	0.27	0.23	<0.05
Concentration (mg/L)				
Al	<0.02	<0.02	<0.02	<0.02
As	17.6	6.77	2.6	1.38
As ⁵⁺	6	1.66	0.39	0.18
As ³⁺	11.6	5.11	2.21	1.23
Ca	569	564	577	596
Cl	35.9	35.8	35.6	38.6
Fe	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	<	<	<	<
Fe ³⁺	<	<	<	<
H ⁺				
K	101	101	105	112
Mg	573	558	492	493
Na	521	515	505	505
Ni	6.7	4.45	1.15	0.54
NO ₃	13.5	13.2	13.1	13.6
P	1.19	1.03	1	1.23
Ra (in Bq/L)	379.74	340.59	400.48	366.3
S ²⁻				
SO ₄ ²⁻	4768	4698	4371	4453
S total	1490	1460	1380	1370
U	<0.2	<0.2	<0.2	<0.2
MINTEQA2 results				
Sum of Cations	0.06917	0.06810	0.06533	0.06594
Sum of Anions	0.06935	0.06832	0.06388	0.06493
Speciated Charge Balance (%)	0.13	0.16	-1.12	-0.77
Equilibrium pH	7.2	7.1	7	6.9
Saturation Index				
Gypsum	0.076	0.072	0.074	0.09
Ferrihydrite	< -1.95	< -0.921	< 0.247	< 0.68
Goethite	< 2.442	< 3.471	< 4.639	< 5.071
Hematite	< 9.893	< 11.951	< 14.286	< 15.152
Scorodite	< -2.168	< -1.504	< -0.797	< -0.538
Annabergite	-4.704	-6.409	-9.610	-11.435
pQ (calculated)				
Activity of Fe ³⁺	2.21E-19	4.71E-18	1.38E-16	7.47E-16
Activity of Al ³⁺	5.81E-13	1.36E-12	3.12E-12	6.93E-12
Activity of OH ⁻	1.59E-07	1.26E-07	1.00E-07	7.97E-08
pQ (Iron)	39.05	38.02	36.86	36.42
pQ (Aluminum)	32.63	32.56	32.50	32.46
Eh (calculated) mV ^{Note 2}				
Fe ratio	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	163	181	199	217
As ratio	214	235	257	272

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming $-\log K_{sp}(\text{Fe}(\text{OH})_3) = 37.1$

APPENDIX 3

Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) Tailings Data
at 24 hours and 25°C (Fe/As=1.0, 1.5, 2.0, and 2.5)

	Nominal pH = 8			
	Fe/As = 1.0	Fe/As = 1.5	Fe/As = 2.0	Fe/As = 2.5
pH	7.18	7.21	7	7.09
Em (measured) mV	124	152	153	177
Eh (calculated) mV ^{Note 1}	326	354	355	379
Alkalinity (mM/L)	0.48	0.35	0.25	0.37
Concentration (mg/L)				
Al	<0.02	<0.02	<0.02	<0.02
As	18.4	7.34	3.48	1.32
As ⁶⁺	6	2	0.89	0.08
As ³⁺	12.4	5.34	2.59	1.24
Ca	518	503	523	468
Cl	33.4	33	34.8	32.6
Fe	<0.02	<0.02	<0.02	<0.02
Fe ²⁺	<	<	<	<
Fe ³⁺	<	<	<	<
H ⁺				
K	83.4	83.7	89	68.5
Mg	553	544	479	404
Na	524	512	508	422
Ni	9.39	6.02	0.53	0.63
NO ₃	12.4	11.9	12.5	11.4
P	0.73	0.17	0.44	0.29
Ra (in Bq/L)	466.56	243.84	272.59	211.34
S ²⁻				
SO ₄ ²⁻	4565	4442	4242	3582
S total	1490	1450	1430	1220
U	<0.2	<0.2	<0.2	<0.2
MINTEQA2 results				
Sum of Cations	0.06664	0.06547	0.06280	0.05421
Sum of Anions	0.06692	0.06502	0.06270	0.05356
Speciated Charge Balance (%)	0.21	-0.34	-0.08	-0.60
Equilibrium pH	7.18	7.21	7	7.09
Saturation Index				
Gypsum	0.032	0.017	0.031	-0.035
Ferrihydrite	< -1.98	< -0.982	< -0.482	< 1.116
Goethite	< 2.412	< 3.41	< 3.91	< 5.508
Hematite	< 9.833	< 11.829	< 12.828	< 16.025
Scorodite	< -2.147	< -1.692	< -1.128	< -0.771
Annabergite	-4.269	-5.682	-9.827	16.867
pQ (calculated)				
Activity of Fe ³⁺	2.37E-19	1.91E-18	2.58E-17	5.49E-16
Activity of Al ³⁺	6.84E-13	5.50E-13	3.09E-12	1.52E-12
Activity of OH ⁻	1.52E-07	1.63E-07	1.00E-07	1.23E-07
pQ (Iron)	39.08	38.09	37.58	35.99
pQ (Aluminum)	32.62	32.63	32.51	32.54
Eh (calculated) mV ^{Note 2}				
Fe ratio	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	167	162	199	183
As ratio	212	234	253	271

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming $-\log K_{sp}(\text{Fe}(\text{OH})_3) = 37.1$

APPENDIX 3
Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) Tailings Data
at 128 hours and 25°C (Fe/As=0.3, 3.0, and 5.0)

	Fe/As = 0.3			Fe/As = 3.0			Fe/As = 5.0		
	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9	Nominal pH = 7	Nominal pH = 8	Nominal pH = 9
pH	7.02	7.5	7.89	6.79	7.12	7.29	7.06	7.19	8.35
Em (measured) mV	145.1	136.4	125.3	178.7	158	162.1	192.7	190.5	151.3
Eh (calculated) mV ^{Note 1}	347.1	338.4	327.3	380.7	360	364.1	394.7	392.5	353.3
Alkalinity (mM/L)	0.66	2.21	2.18	0.38	0.45	0.42	0.42	4.49	0.62
Concentration (mg/L)									
Al	0.04	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	0.02	0.02
As	155	118	126	2.16	1.52	2.71	1.24	0.76	1.76
As ⁵⁺	22	72.3	113	<0.2	0.45	1.71	0.2	0.29	1.11
As ³⁺	133	45.7	12.7	2.14	1.07	1	1.07	0.47	0.65
Ca	450	483	514	446	458	489	453	455	495
Cl	39.1	40.6	38.1	41.2	37.9	32.8	40.4	40.3	37.4
Fe	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	0.34	<0.02	<0.02
Fe ²⁺	<	<	<	<	<	<	<	<	<
Fe ³⁺	<	<	<	<	<	<	<	<	<
H ⁺									
K	106	82.8	76.4	122	102	93.8	123	115	100
Mg	762	484	138	644	339	67.7	537	274	45
Na	552	539	515	517	468	488	489	474	468
Ni	593	12.2	0.36	59.9	1.39	0.06	30.3	0.55	0.02
NO ₃	12.4	12.4	11.8	13.7	5.8	2.9	7	1.9	14.3
P	1.62	2.15	1.61	1.57	0.34	2.12	0.3	0.35	0.24
Ra (in Bq/L)	38.16	49.9	129.34	30.24	27.17	44.29	28.01	30.74	31.6
S ²⁻									
SO ₄ ²⁻	7149	4391	2758	5425	3786	2635	4768	3454	2475
S total	1760	1110	662	1370	1200	866	1440	1060	646
U	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
MINTEQA2 results									
Sum of Cations	0.08264	0.06166	0.04517	0.06856	0.05221	0.04094	0.06276	0.04982	0.03948
Sum of Anions	0.10230	0.06899	0.04826	0.08056	0.05896	0.04378	0.07155	0.05864	0.04166
Speciated Charge Balance (%)	10.63	5.61	3.31	8.05	6.07	3.35	6.54	8.13	2.69
Equilibrium pH	7.02	7.5	7.89	6.79	7.12	7.29	7.06	7.19	8.35
Saturation Index									
Gypsum	0.026	-0.002	-0.034	-0.003	-0.023	-0.025	-0.009	-0.041	-0.028
Ferrihydrite	-3.048	< -3.851	< -3.894	< 0.907	< 0.145	< -1.059	2.361	< 0.547	< 0.823
Goethite	1.344	< 0.541	< 0.498	< 5.299	< 4.537	< 3.333	6.753	< 4.939	< 5.215
Hematite	7.697	< 6.091	< 6.004	< 15.606	< 14.082	< 11.674	18.515	< 14.886	< 15.438
Scorodite	-2.404	< -3.557	< -4.105		< -0.989	< -1.775	0.391	< -0.908	< -2.451
Annabergite	1.877	-2.523	-6.918		-8.982	-11.236	-6.951	-12.095	-13.739
pQ (calculated)									
Activity of Fe ³⁺	6.12E-20	3.49E-22	2.13E-23	2.69E-15	4.76E-17	9.20E-19	1.19E-14	7.42E-17	4.63E-20
Activity of Al ³⁺	3.86E-12	4.28E-14	1.46E-15	2.45E-11	1.18E-12	2.86E-13	1.93E-12	6.63E-13	2.30E-17
Activity of OH ⁻	1.05E-07	3.17E-07	7.79E-07	6.18E-08	1.32E-07	1.96E-07	1.15E-07	1.55E-07	2.25E-06
pQ (Iron)	40.15	40.95	41.00	36.20	36.96	38.16	34.74	36.56	36.28
pQ (Aluminum)	32.35	32.87	33.16	32.24	32.56	32.67	32.53	32.60	33.58
Eh (calculated) mV ^{Note 2}									
Fe ratio	--	--	--	--	--	--	--	--	--
Fe ²⁺ /Fe(OH) ₃ ratio ^{Note 3}	185	110	41	236	178	147	115	165	-41
As ratio	152	179	211	--	275	276	275	296	287

Note 1: Eh = Em (from COGEMA) + 202 mV (for 25°C).

Note 2: Eh (calc) values determined by MINTEQA2 and calculations.

Note 3: Assuming -log K_{sp}(Fe(OH)₃) = 37.1

Appendix C

Section C - Part A

Subsection E: Arsenic and Nickel Concentrations in Tailings Pore Waters as a Function of Time and their Statistical Significance, Based on Results of the Large-Scale Laboratory Tests

**Arsenic concentrations in tailings pore-waters and their statistical significance including *t*-test results at 4°C:
Results of the large scale laboratory tests.**

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of trend (R^2) ^{Note 1} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
JEB	3.0	4	8	6.8-7.22	1.3 ± 0.08	1.62	2.57	random
JEB	5.0	4	8	7.3-7.9	0.68 ± 0.13	0.31	2.36	random
Sue C	7.7	4	8	6.27-7.95	0.10 ± 0.05	2.01	2.36	random
Blend 2	3.0	4	8	6.65-7.44	0.54 ± 0.3	0.57	2.31	random

Note 1: Linear regression equation where $x = \log$ time (hours) and $y =$ concentration of arsenic (mg/L)

Blend 1 = 75% Sue C + 25% Cigar Lake

Blend 2 = 55% Midwest + 15% Sue A+B + 30% Cigar Lake

Arsenic concentrations in tailings pore-waters and their statistical significance including *t*-test results at 25°C:
Results of the large scale laboratory tests.
(page 1 of 3)

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of trend (R^2) ^{Note 1} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
JEB	2.6	25	7	6.58-6.93	$y=0.4418x+1.373$ (0.909)	7.07	2.45	significant
JEB	2.6	25	8	7.35-7.58	$y=0.2075x+3.259$ (0.705)	3.46	2.45	significant
JEB	2.6	25	9	7.44-8.49	$y=0.5211x+4.7988$ (0.638)	2.97	2.45	significant
JEB	3.0	25	7	6.61-7.09	$y=0.2804x+1.2917$ (0.865)	5.66	2.45	significant
JEB	3.0	25	8	7.4-7.52	$y=0.1999x+2.1814$ (0.582)	2.64	2.45	significant
JEB	3.0	25	9	7.65-8.12	$y=0.458x+3.6154$ (0.819)	4.76	2.45	significant
JEB	5.0	25	7	6.41-6.93	$y=0.1432x+0.3957$ (0.836)	5.05	2.45	significant
JEB	5.0	25	8	7.0-7.36	$y=0.0735x+0.5833$ (0.641)	2.99	2.45	significant
JEB	5.0	25	9	7.68-7.98	1.3 ± 0.03	0.00	4.30	random
Sue C	7.7	25	7	6.42-6.99	0.31 ± 0.07	0.83	2.45	random
Sue C	7.7	25	8	6.86-7.46	$y=-0.0471x+0.3672$ (0.738)	4.44	2.31	significant
Sue C	7.7	25	9	7.57-8.35	0.70 ± 0.06	1.77	2.45	random
McClean Lake	4.6	25	7	6.48-7.2	$y=0.1813x+0.857$ (0.687)	3.31	2.45	significant
McClean Lake	4.6	25	8	7.11-7.66	1.76 ± 0.5	1.96	2.45	random
McClean Lake	4.6	25	9	7.48-8.83	4.35 ± 0.8	1.38	2.45	random
McClean Lake	5.0	25	7	6.64-7.14	0.91 ± 0.2	1.38	2.45	random
McClean Lake	5.0	25	8	7.27-7.57	1.19 ± 0.3	1.33	2.45	random

Note 1: Linear regression equation where x=log time (hours) and y=concentration of arsenic (mg/L)

Blend 1=75% Sue C + 25% Cigar Lake

Blend 2=55% Midwest + 15% Sue A+B + 30% Cigar Lake

Arsenic concentrations in tailings pore-waters and their statistical significance including *t*-test results at 25°C:
Results of the large scale laboratory tests.
 (page 2 of 3)

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of trend (R^2) ^{Note 1} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
McClean Lake	5.0	25	9	7.52-8.62	$y=0.7748x+1.691$ (0.675)	5.65	2.45	significant
Sue A+B	0.6	25	7	6.58-6.95	$y=5.7067x+23.972$ (0.854)	5.41	2.45	significant
Sue A+B	0.6	25	8	7.06-7.88	32 ± 3.2	0.93	2.45	random
Sue A+B	0.6	25	9	7.77-8.5	$y=2.8181x+24.652$ (0.854)	5.40	2.45	significant
Sue A+B	1.0	25	8	7.0-7.4	$y=2.9534x+30.909$ (0.688)	2.97	2.57	significant
Sue A+B	1.5	25	8	7.2-7.5	$y=1.9306x+9.0076$ (0.872)	5.23	2.57	significant
Sue A+B	2.0	25	8	7.0-7.4	$y=0.5129x+5.4038$ (0.815)	4.20	2.57	significant
Sue A+B	2.5	25	8	7.0-7.4	$y=0.471x+2.9574$ (0.881)	5.43	2.57	significant
Sue A+B	3.0	25	7	6.9-7.31	1.6 ± 0.4	0.40	2.45	random
Sue A+B	3.0	25	8	7.25-7.47	$y=0.1494x+0.7189$ (0.783)	4.24	2.45	significant
Sue A+B	3.0	25	9	7.46-8.66	$y=0.9071x+0.6517$ (0.816)	4.71	2.45	significant
Sue A+B	5.0	25	7	6.79-7.17	0.49 ± 0.08	1.35	2.45	random
Sue A+B	5.0	25	8	7.09-7.45	$y=0.1337x+0.2961$ (0.859)	5.52	2.45	significant
Sue A+B	5.0	25	9	7.33-8.51	$y=0.507x+0.458$ (0.941)	8.95	2.45	significant
Cigar Lake	7.5	25	7	4.74-5.98	0.32 ± 0.15	0.25	2.57	random
Cigar Lake	7.5	25	8	7.19-7.31	0.49 ± 0.11	0.73	2.57	random

Note 1: Linear regression equation where x =log time (hours) and y =concentration of arsenic (mg/L)

Blend 1=75% Sue C + 25% Cigar Lake

Blend 2=55% Midwest + 15% Sue A+B + 30% Cigar Lake

Arsenic concentrations in tailings pore-waters and their statistical significance including *t*-test results at 25°C:
Results of the large scale laboratory tests.
 (page 3 of 3)

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of trend (R^2) ^{Note 1} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
Cigar Lake	7.5	25	9	7.18-7.72	1.3 ± 0.18	0.22	2.57	random
Blend 1	7.6	25	7	6.04-6.84	0.29 ± 0.09	1.63	2.57	random
Blend 1	7.6	25	8	6.62-7.21	0.38 ± 0.08	0.77	2.57	random
Blend 1	7.6	25	9	6.76-7.91	0.76 ± 0.09	0.05	2.57	random
Blend 2	0.3	25	7	6.97-7.03	$y = 17.967x + 116.85$ (0.902)	6.05	2.57	significant
Blend 2	0.3	25	8	7.43-7.93	115 ± 4.7	1.70	2.57	random
Blend 2	0.3	25	9	7.7-8.05	119 ± 8.4	2.40	2.57	random
Blend 2	1.0	25	8	6.8-7.4	18 ± 1.9	1.34	2.31	random
Blend 2	1.5	25	8	7.1-7.5	7.1 ± 0.73	0.41	2.31	random
Blend 2	2.0	25	8	7-7.5	2.6 ± 0.77	0.64	2.31	random
Blend 2	2.5	25	8	6.9-7.7	1.5 ± 0.55	1.04	2.31	random
Blend 2	3.0	25	7	6.68-7.25	$y = 0.2375x + 1.5959$ (0.853)	4.82	2.57	significant
Blend 2	3.0	25	8	6.96-7.49	1.4 ± 0.13	0.44	2.57	random
Blend 2	3.0	25	9	7.29-8.4	$y = 0.2838x + 1.8957$ (0.642)	2.68	2.57	significant
Blend 2	5.0	25	7	6.99-7.39	1.1 ± 0.19	0.50	2.57	random
Blend 2	5.0	25	8	6.98-7.5	0.77 ± 0.14	0.06	2.57	random
Blend 2	5.0	25	9	7.6-8.66	1.6 ± 0.19	1.16	2.57	random

Note 1: Linear regression equation where x = log time (hours) and y = concentration of arsenic (mg/L)

Blend 1 = 75% Sue C + 25% Cigar Lake

Blend 2 = 55% Midwest + 15% Sue A+B + 30% Cigar Lake

**Arsenic concentrations in tailings pore-waters and their statistical significance including *t*-test results at 50°C;
Results of the large scale laboratory tests.
(page 1 of 3)**

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of trend (R^2) ^{Note 1} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
JEB	2.6	50	7	6.37-7.1	$y=2.0338x+2.1578$ (0.819)	4.75	2.45	significant
JEB	2.6	50	8	7.39-7.65	$y=2.3505x+2.9151$ (0.945)	9.29	2.45	significant
JEB	2.6	50	9	7.51-8.05	$y=3.7591x+3.7264$ (0.908)	7.01	2.45	significant
JEB	3.0	50	7	6.08-6.96	$y=1.6733x+1.8068$ (0.840)	5.12	2.45	significant
JEB	3.0	50	8	6.93-7.87	3.0 ± 0.02	1.73	4.3	random
JEB	3.0	50	9	7.68-7.9	$y=2.4431x+3.0259$ (0.909)	7.05	2.45	significant
JEB	5.0	50	7	6.27-7.47	$y=0.9403x+0.3945$ (0.759)	3.97	2.45	significant
JEB	5.0	50	8	7.34-7.67	$y=0.6518x+0.776$ (0.758)	3.96	2.45	significant
JEB	5.0	50	9	7.52-7.96	$y=1.5762x+0.8204$ (0.939)	8.74	2.45	significant
Sue C	7.7	50	7	6.13-7	0.6 ± 0.14	0.505	2.45	random
Sue C	7.7	50	8	7.17-7.47	0.5 ± 0.08	1.01	2.45	random
Sue C	7.7	50	9	7.54-8.11	$y=0.2787x+0.7949$ (0.724)	8.1	2.45	significant
McClean Lake	4.6	50	7	6.57-7.34	$y=1.8925x+0.9155$ (0.821)	4.79	2.45	significant
McClean Lake	4.6	50	8	7.27-7.6	$y=2.3095x+1.0406$ (0.799)	4.46	2.45	significant
McClean Lake	4.6	50	9	7.72-8.15	$y=3.1325x+3.0347$ (0.874)	5.88	2.45	significant

Note 1: Linear regression equation where $x = \log$ time (hours) and $y =$ concentration of arsenic (mg/L)

Blend 1 = 75% Sue C + 25% Cigar Lake

Blend 2 = 55% Midwest + 15% Sue A+B + 30% Cigar Lake

Arsenic concentrations in tailings pore-waters and their statistical significance including *t*-test results at 50°C:
Results of the large scale laboratory tests.
 (page 2 of 3)

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of trend (R^2) ^{Note 1} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
McClellan Lake	5.0	50	7	6.71-7.17	$y = 1.9914x + 0.5457$ (0.695)	3.37	2.45	significant
McClellan Lake	5.0	50	8	6.85-7.55	$y = 1.7431x + 0.7894$ (0.884)	6.18	2.45	significant
McClellan Lake	5.0	50	9	7.4-8.64	$y = 2.4556x + 2.138$ (0.905)	6.89	2.45	significant
Sue A + B	0.6	50	7	6.3-7.07	$y = 10.577x + 45.806$ (0.845)	5.23	2.45	significant
Sue A + B	0.6	50	8	7.1-7.77	45 ± 2.0	1.76	2.45	random
Sue A + B	0.6	50	9	7.54-8.45	$y = 11.254x + 25.846$ (0.941)	8.97	2.45	significant
Sue A + B	3.0	50	7	6.79-7.33	$y = 1.3357x + 3.1092$ (0.723)	3.62	2.45	significant
Sue A + B	3.0	50	8	7.48-7.65	$y = 0.7801x + 1.2829$ (0.737)	3.75	2.45	significant
Sue A + B	3.0	50	9	7.31-8.63	$y = 2.8474x + 1.1294$ (0.964)	11.5	2.45	significant
Sue A + B	5.0	50	7	6.78-7.33	$y = 0.701x + 0.7689$ (0.777)	4.18	2.45	significant
Sue A + B	5.0	50	8	7.06-7.61	$y = 0.5382x + 0.5841$ (0.844)	5.2	2.45	significant
Sue A + B	5.0	50	9	7.28-8.39	$y = 1.2714x + 0.878$ (0.940)	8.82	2.45	significant
Cigar Lake	7.5	50	7	4.63-5.79	0.5 ± 0.3	0.63	2.57	random
Cigar Lake	7.5	50	8	7.19-7.75	0.5 ± 0.1	1.48	2.57	random
Cigar Lake	7.5	50	9	7.41-7.84	1.4 ± 0.2	1.27	2.57	random
Blend 1	7.6	50	7	5.59-7.03	0.4 ± 0.12	0.42	2.57	random

Note 1: Linear regression equation where x = log time (hours) and y = concentration of arsenic (mg/L)

Blend 1 = 75% Sue C + 25% Cigar Lake

Blend 2 = 55% Midwest + 15% Sue A + B + 30% Cigar Lake

Arsenic concentrations in tailings pore-waters and their statistical significance including *t*-test results at 50°C:
Results of the large scale laboratory tests.
 (page 3 of 3)

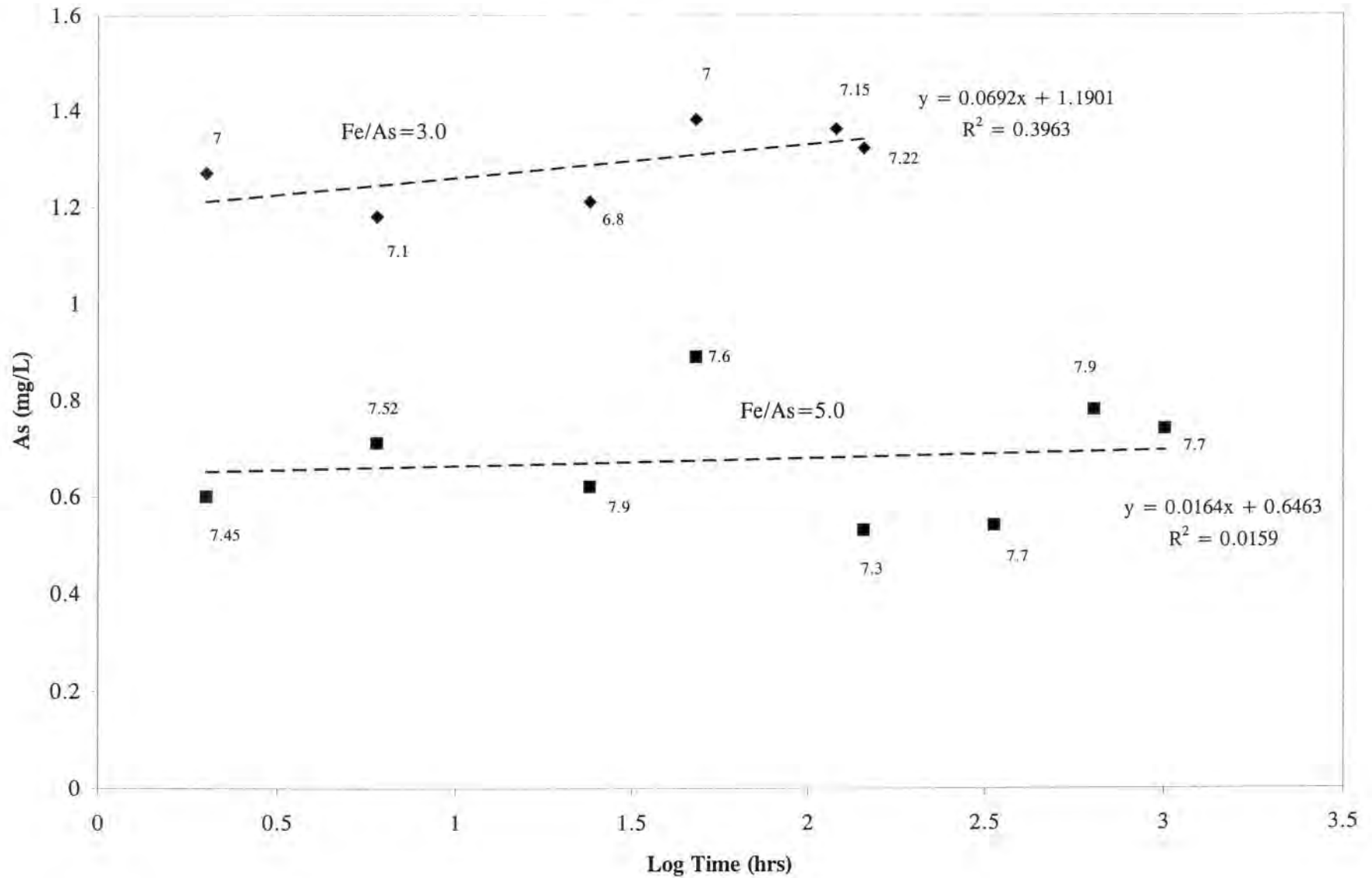
Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of trend (R^2) ^{Note 1} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
Blend 1	7.6	50	8	6.7-7.36	0.5 ± 0.26	0.28	2.57	random
Blend 1	7.6	50	9	7.32-7.77	0.9 ± 0.12	1.69	2.57	random
Blend 2	0.3	50	7	6.16-7.04	$y = 103.82x + 132.74$ (0.961)	9.95	2.57	significant
Blend 2	0.3	50	8	7.34-8	$y = 49.047x + 105.78$ (0.958)	9.56	2.57	significant
Blend 2	0.3	50	9	7.83-7.96	$y = 27.212x + 100.63$ (0.962)	9.99	2.57	significant
Blend 2	3.0	50	7	7.1-7.52	$y = 4.6855x + 0.6448$ (0.941)	8.01	2.57	significant
Blend 2	3.0	50	8	7.44-7.88	$y = 2.2234x + 1.4539$ (0.863)	5.02	2.57	significant
Blend 2	3.0	50	9	7.3-8.36	$y = 2.6372x + 1.8299$ (0.973)	12.1	2.57	significant
Blend 2	5.0	50	7	6.97-7.67	$y = 2.042x + 1.5202$ (0.833)	4.47	2.57	significant
Blend 2	5.0	50	8	7.48-7.92	$y = 0.981x + 0.7322$ (0.835)	4.51	2.57	significant
Blend 2	5.0	50	9	7.51-8.48	$y = 1.4731x + 1.2579$ (0.950)	8.75	2.57	significant

Note 1: Linear regression equation where $x = \log$ time (hours) and $y =$ concentration of arsenic (mg/L)

Blend 1 = 75% Sue C + 25% Cigar Lake

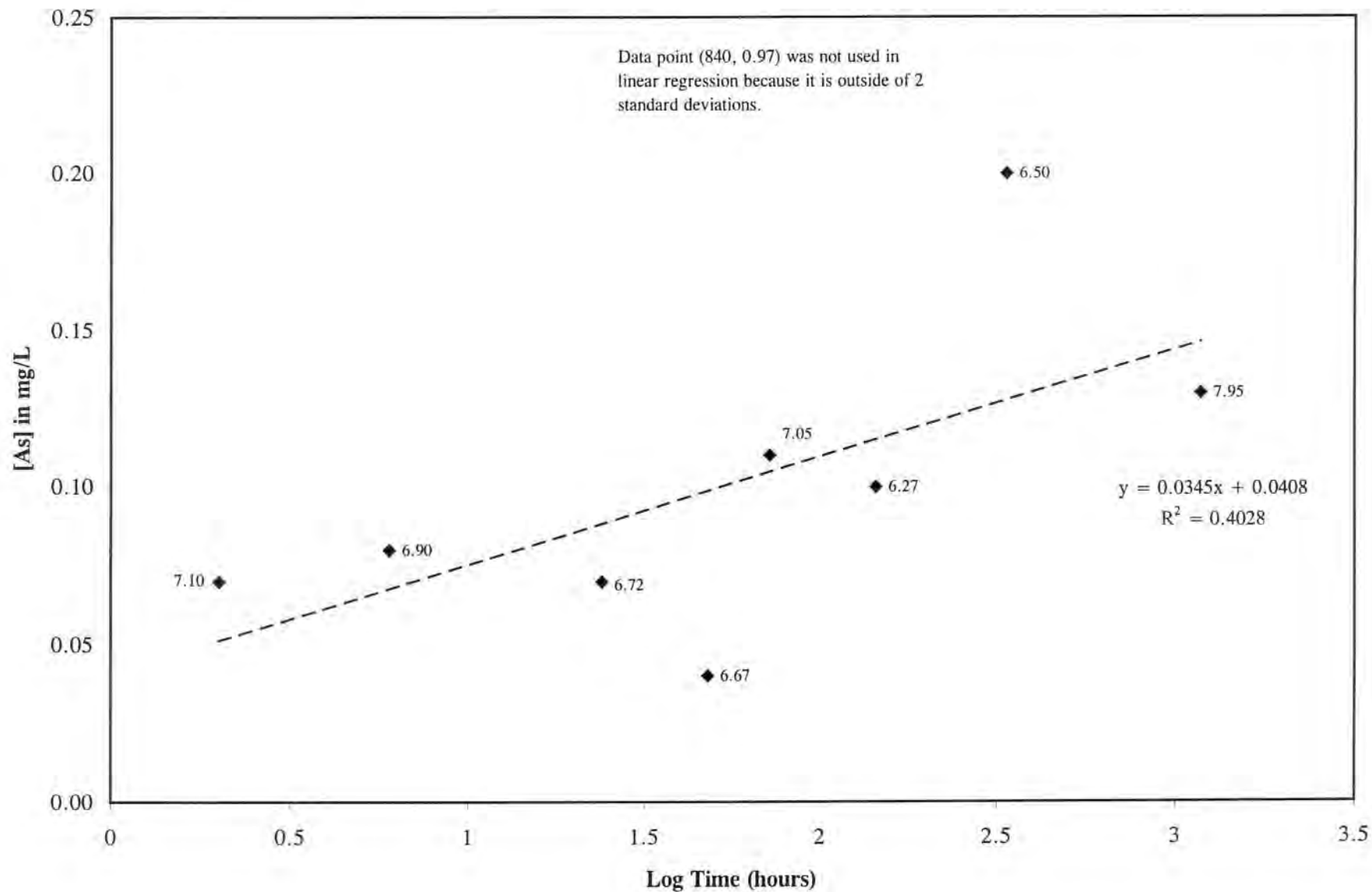
Blend 2 = 55% Midwest + 15% Sue A+B + 30% Cigar Lake

Arsenic concentration as a function of time during long-term tests of JEB tailings at 4°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 8. ^{Note 1}



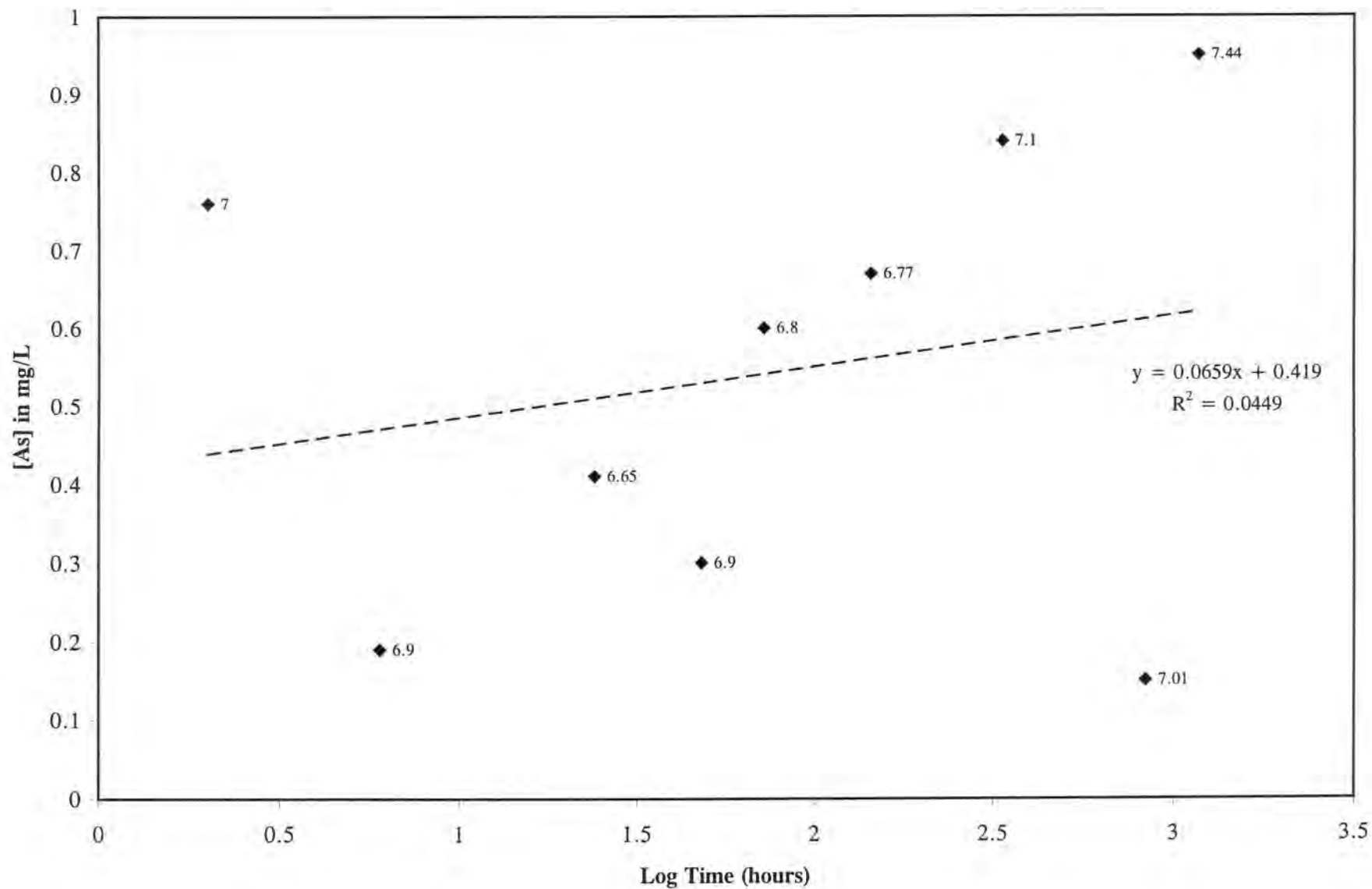
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Sue C tailings at 4°C, for molar Fe/As ratio of 7.7 and nominal pH 8. ^{Note 1}



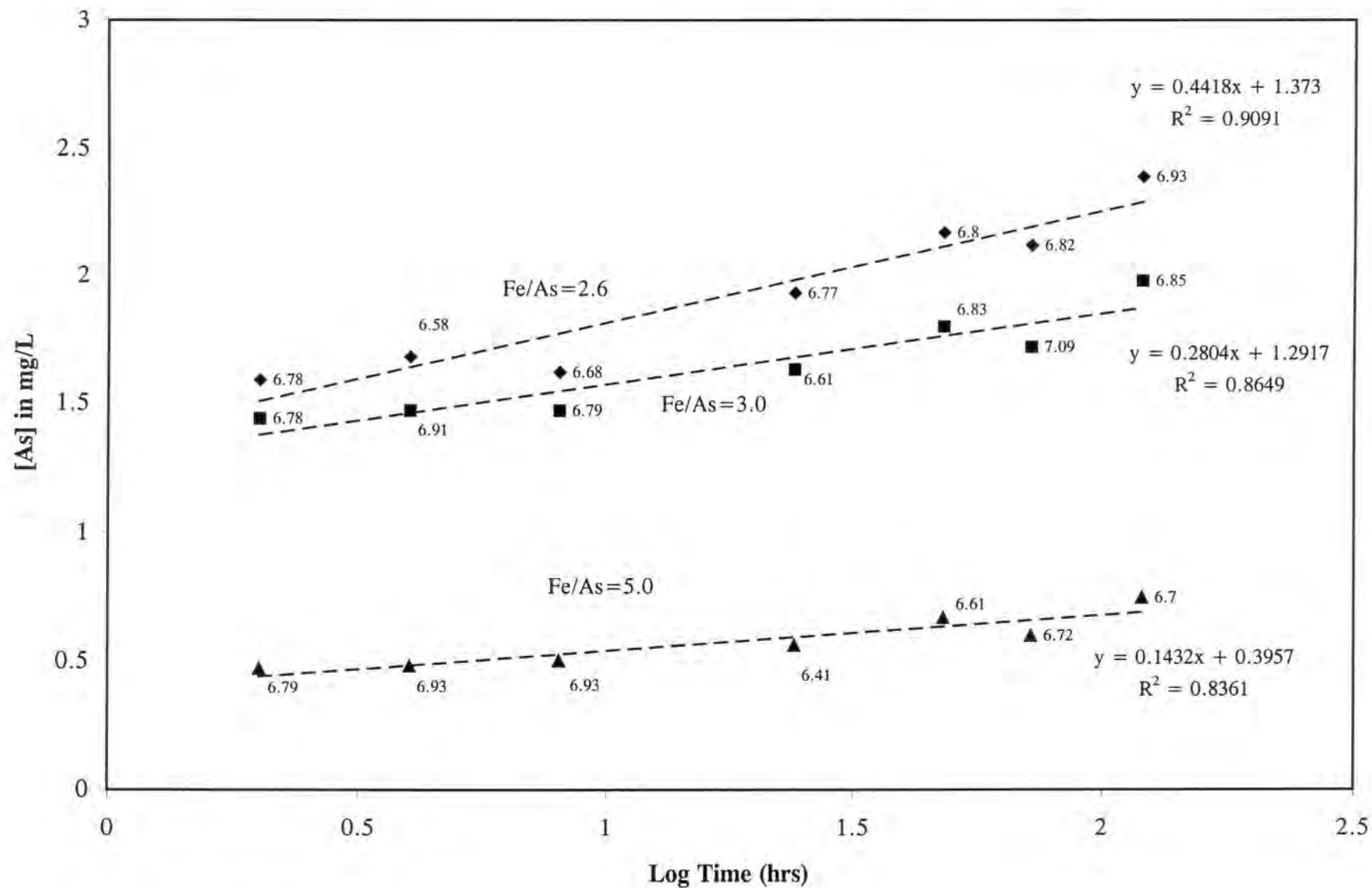
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 4°C, for molar Fe/As ratio of 3.0 and nominal pH 8. ^{Note 1}



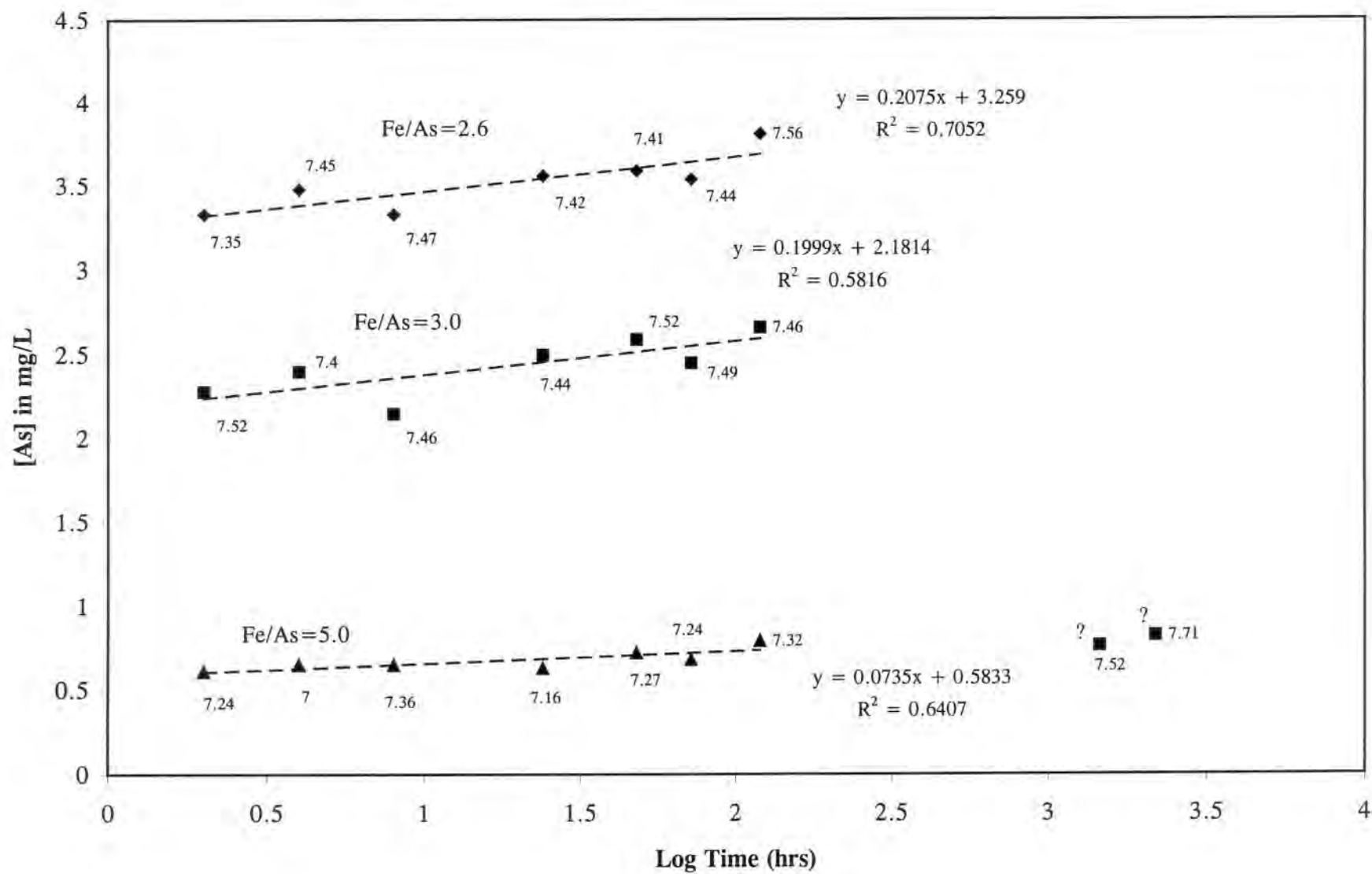
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of JEB tailings at 25°C, for molar Fe/As ratios of 2.6, 3.0, and 5.0 and nominal pH 7. ^{Note 1}



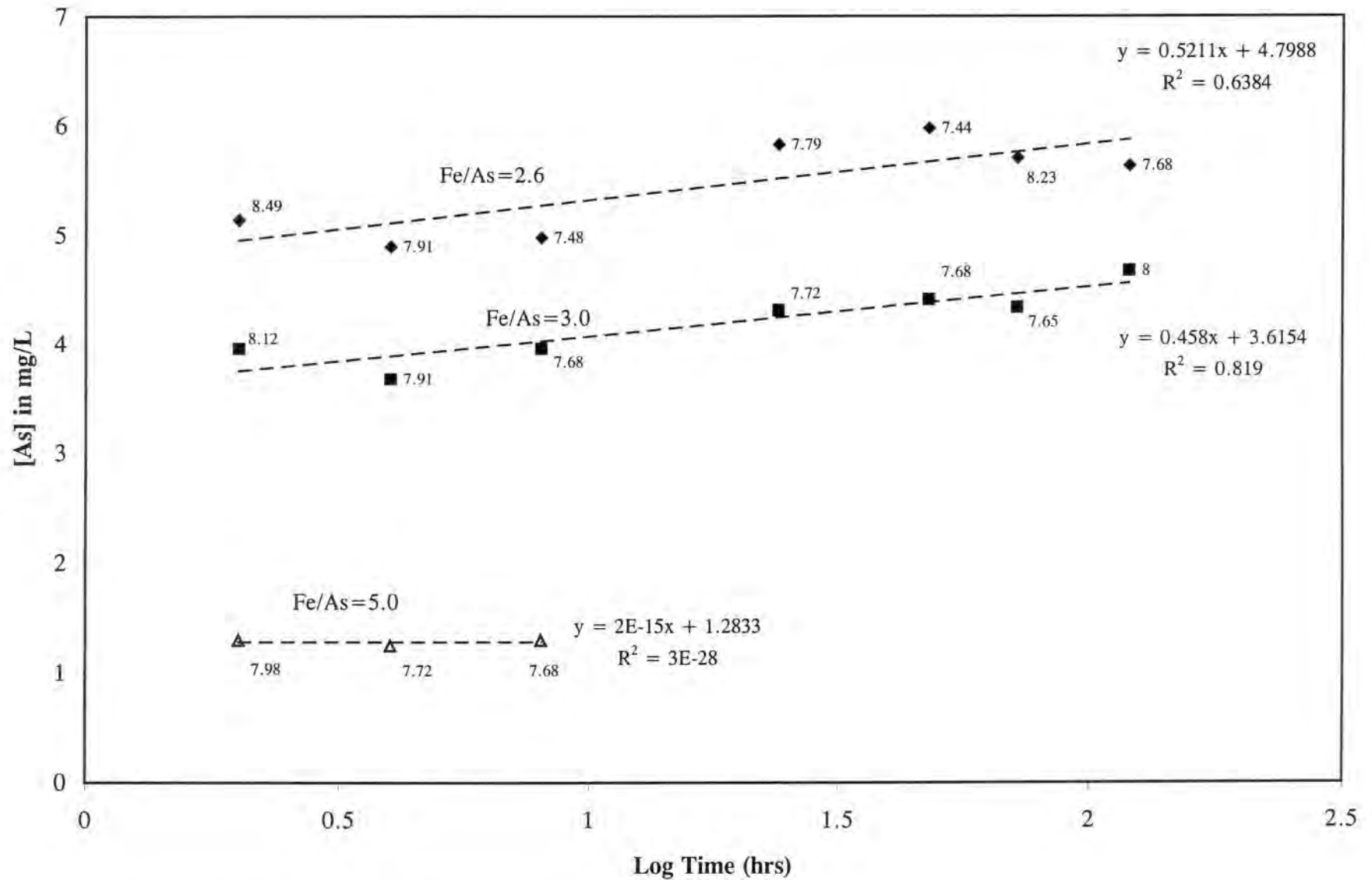
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of JEB tailings at 25°C, for molar Fe/As ratios of 2.6, 3.0, and 5.0 and nominal pH 8. ^{Note 1}



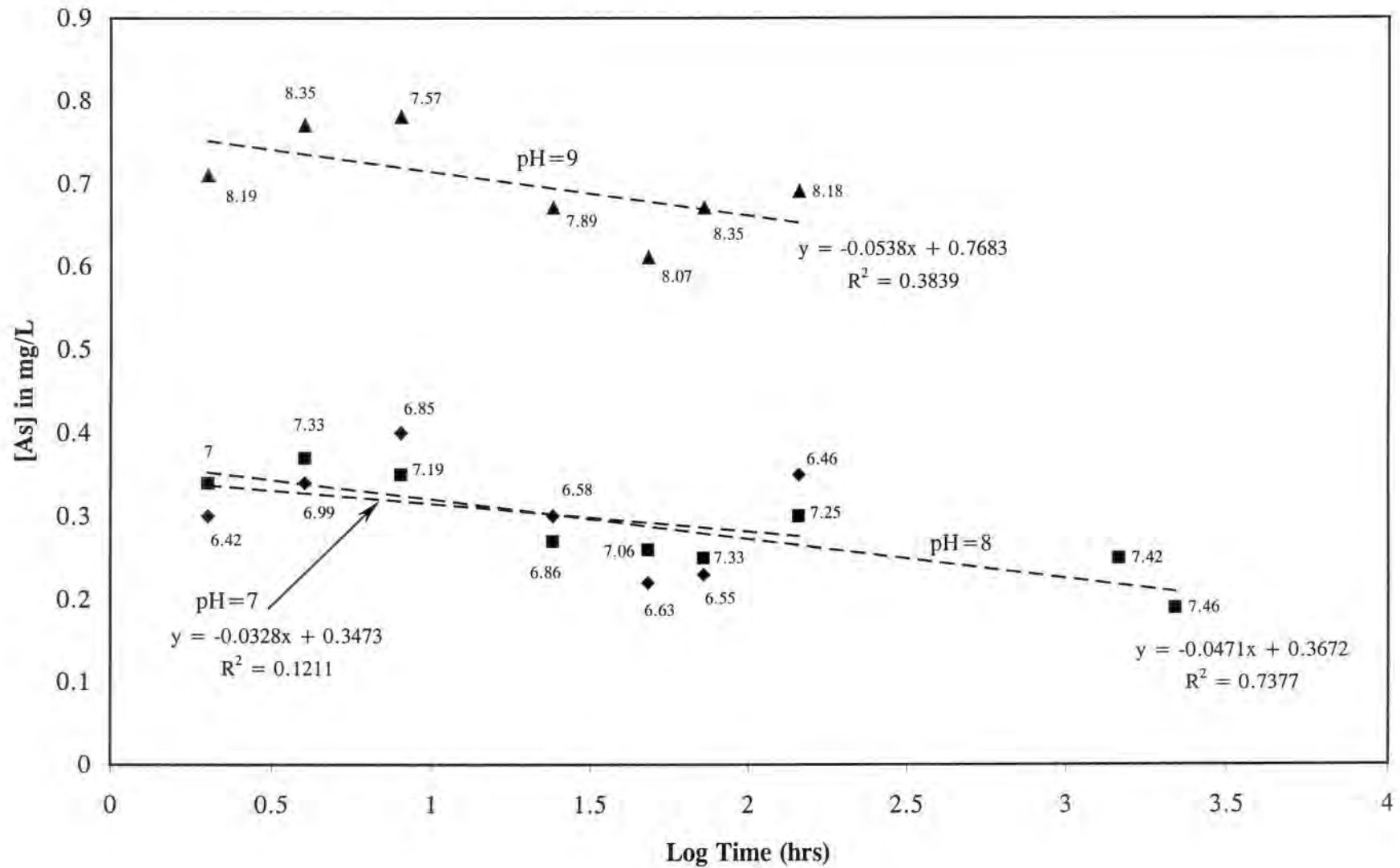
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of JEB tailings at 25°C, for molar Fe/As ratios of 2.6, 3.0, and 5.0 and nominal pH 9. ^{Note 1}



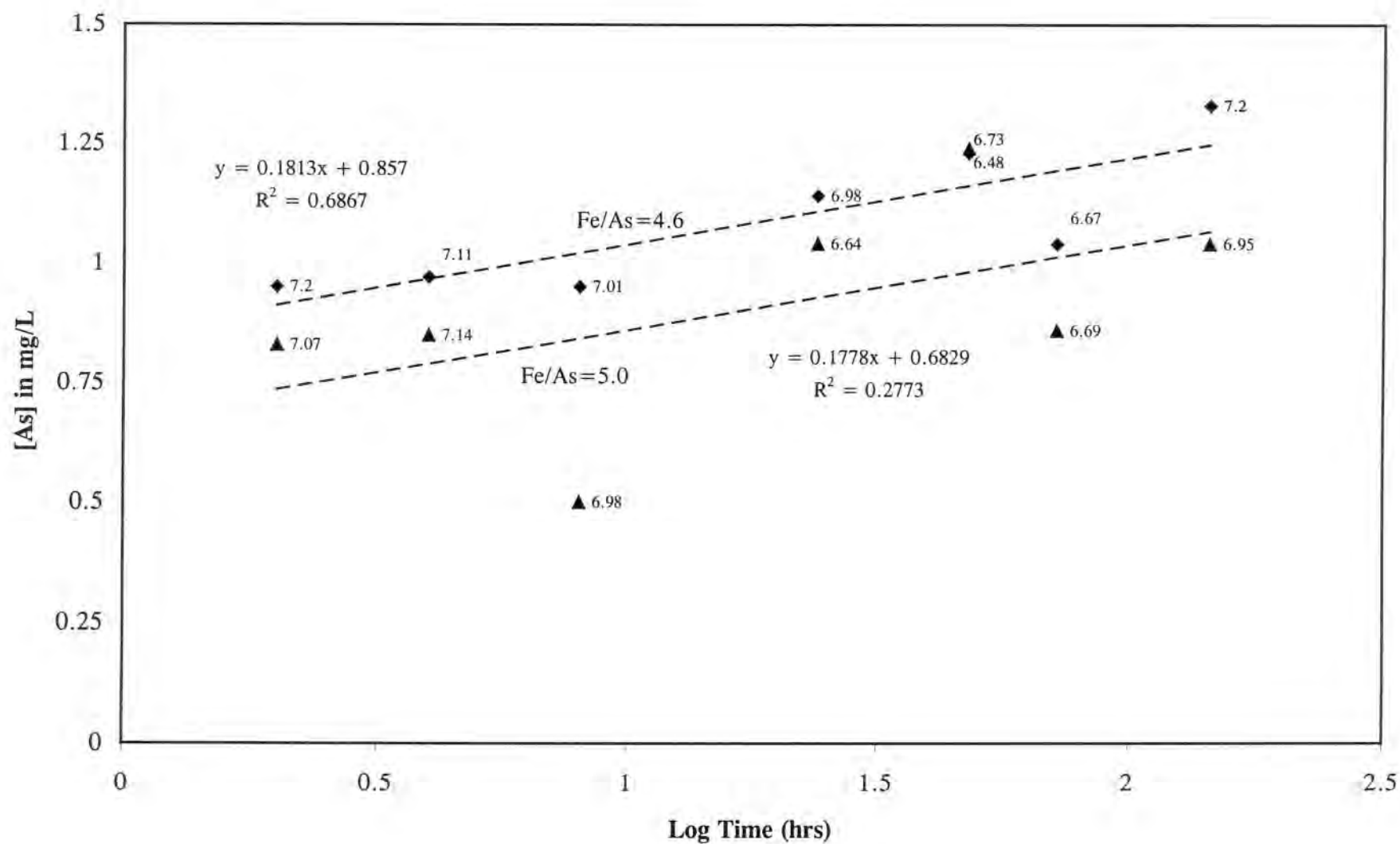
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Sue C tailings at 25°C, for molar Fe/As ratio of 7.7 and nominal pH 7, 8, and 9. ^{Note 1}



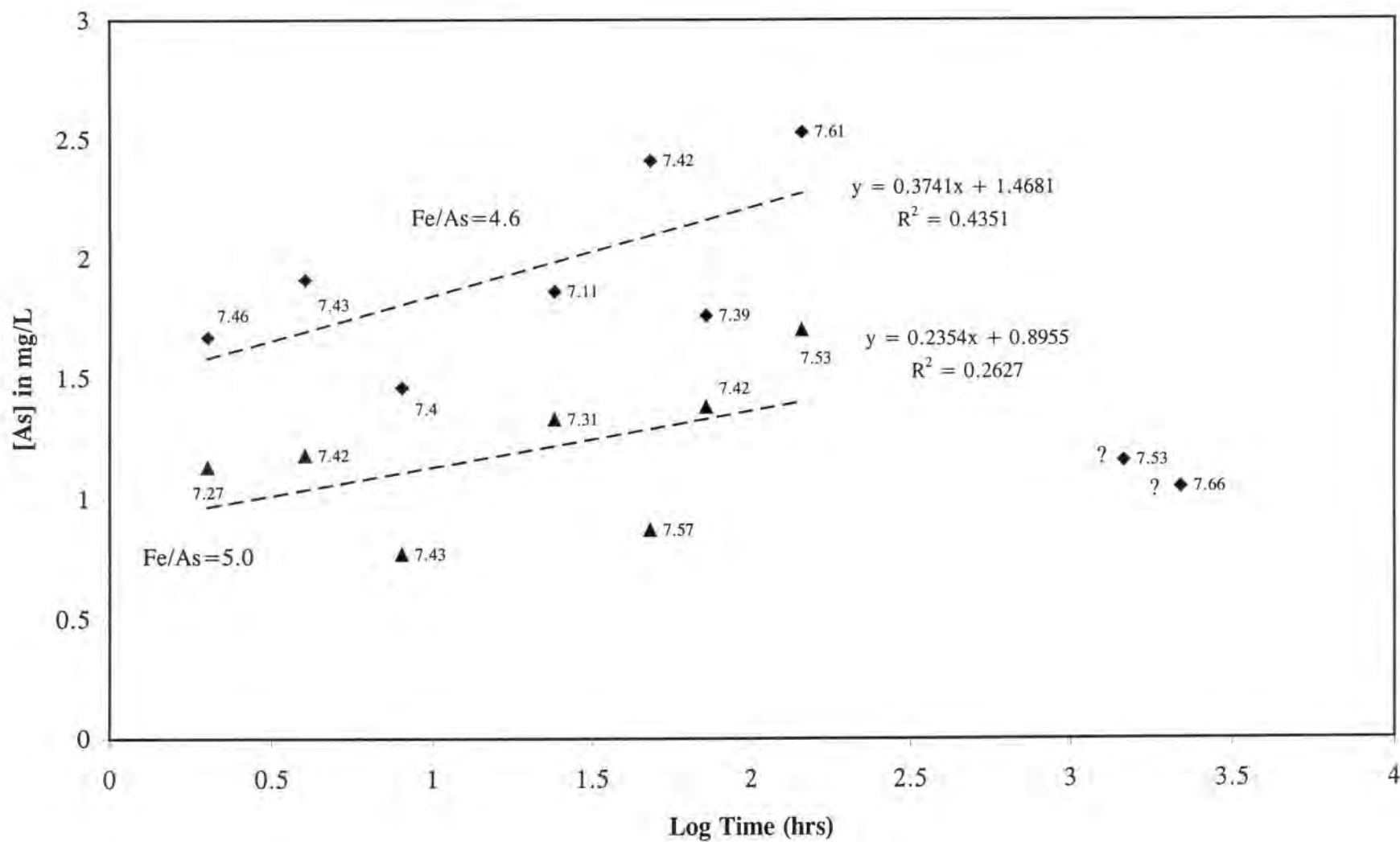
Note 1: Also shown are equations for linear regressions of the data, and measured pH value for each data point.

Arsenic concentration as a function of time during long-term tests of McClean Lake tailings at 25°C,
for molar Fe/As ratios of 4.6 and 5.0 and nominal pH 7. ^{Note 1}



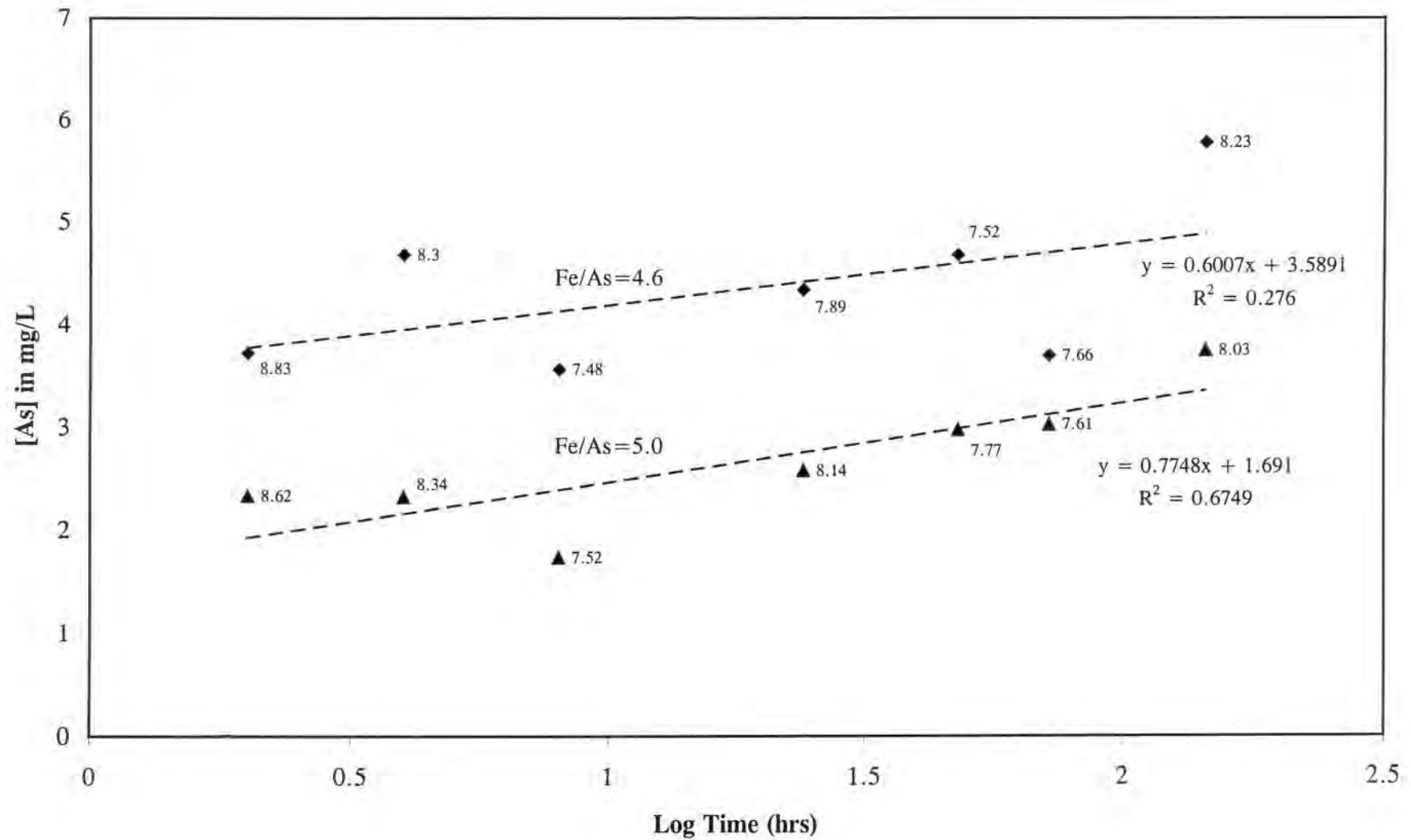
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of McClean Lake tailings at 25°C,
for molar Fe/As ratios of 4.6 and 5.0 and nominal pH 8. ^{Note 1}



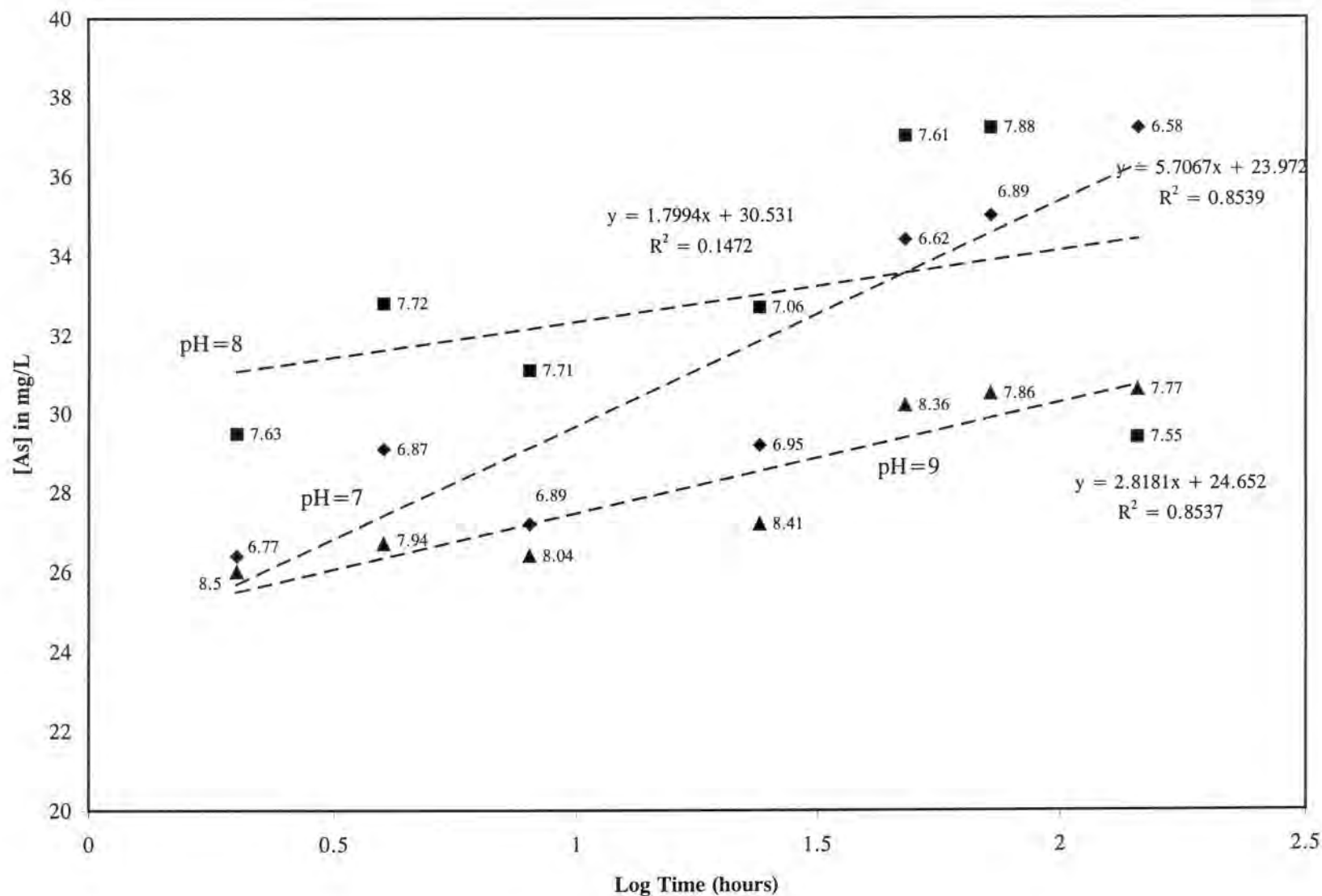
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of McClean Lake tailings at 25°C,
for molar Fe/As ratios of 4.6 and 5.0 and nominal pH 9. ^{Note 1}



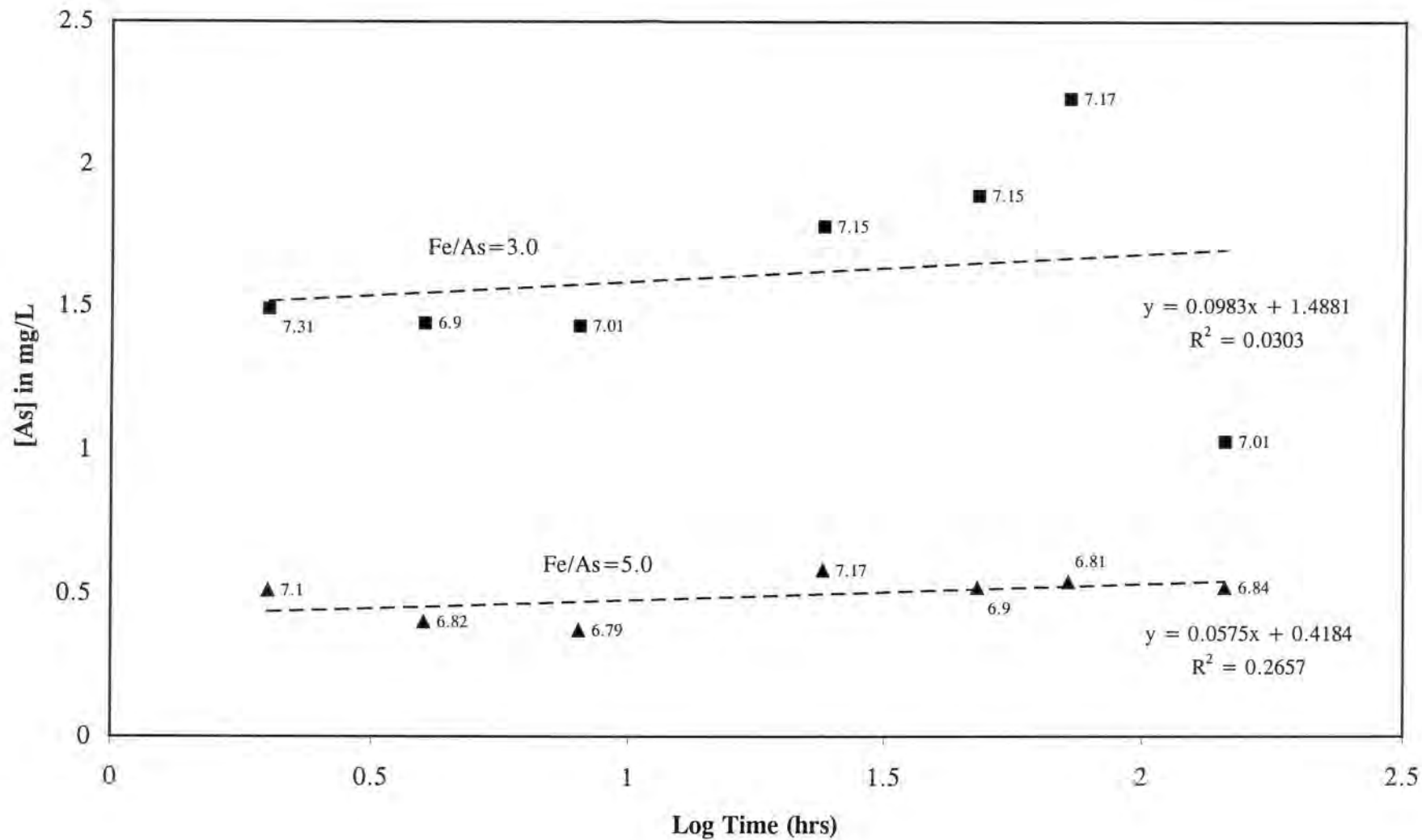
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Sue A+B tailings at 25°C, for molar Fe/As ratios of 0.6 and nominal pH 7, 8, and 9, ^{Note 1}



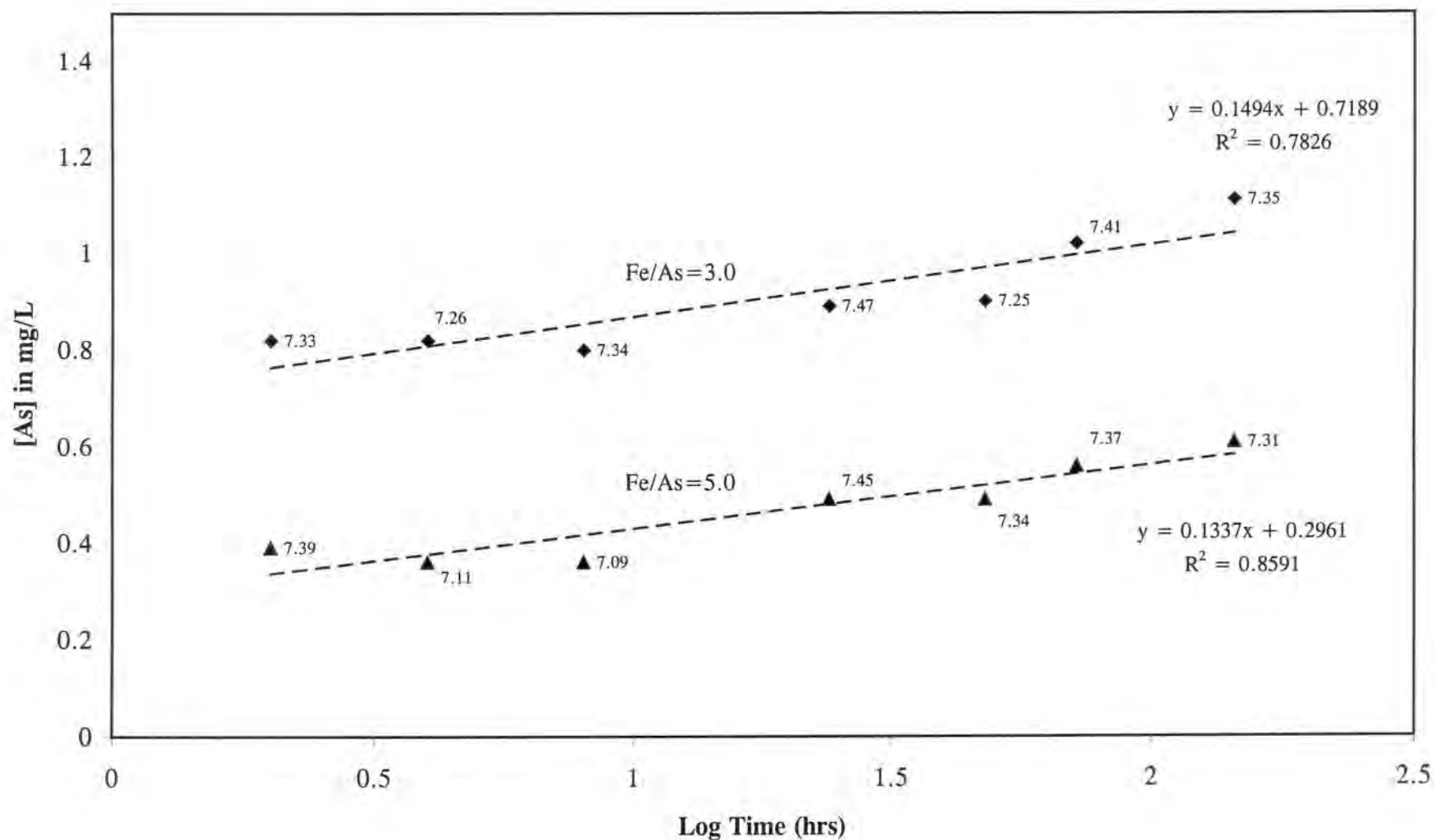
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Sue A+B tailings at 25°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 7. ^{Note 1}



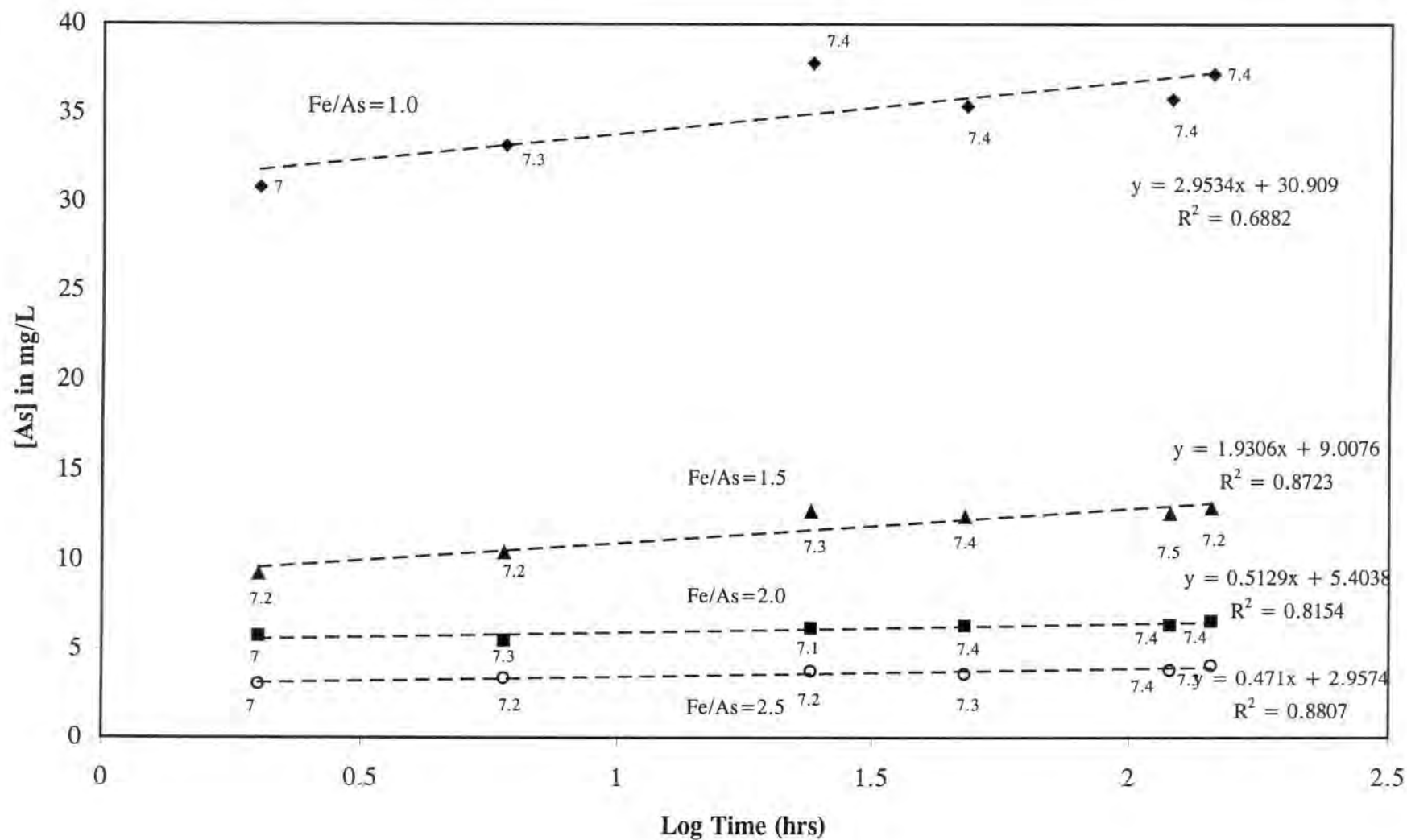
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Sue A+B tailings at 25°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 8. ^{Note 1}



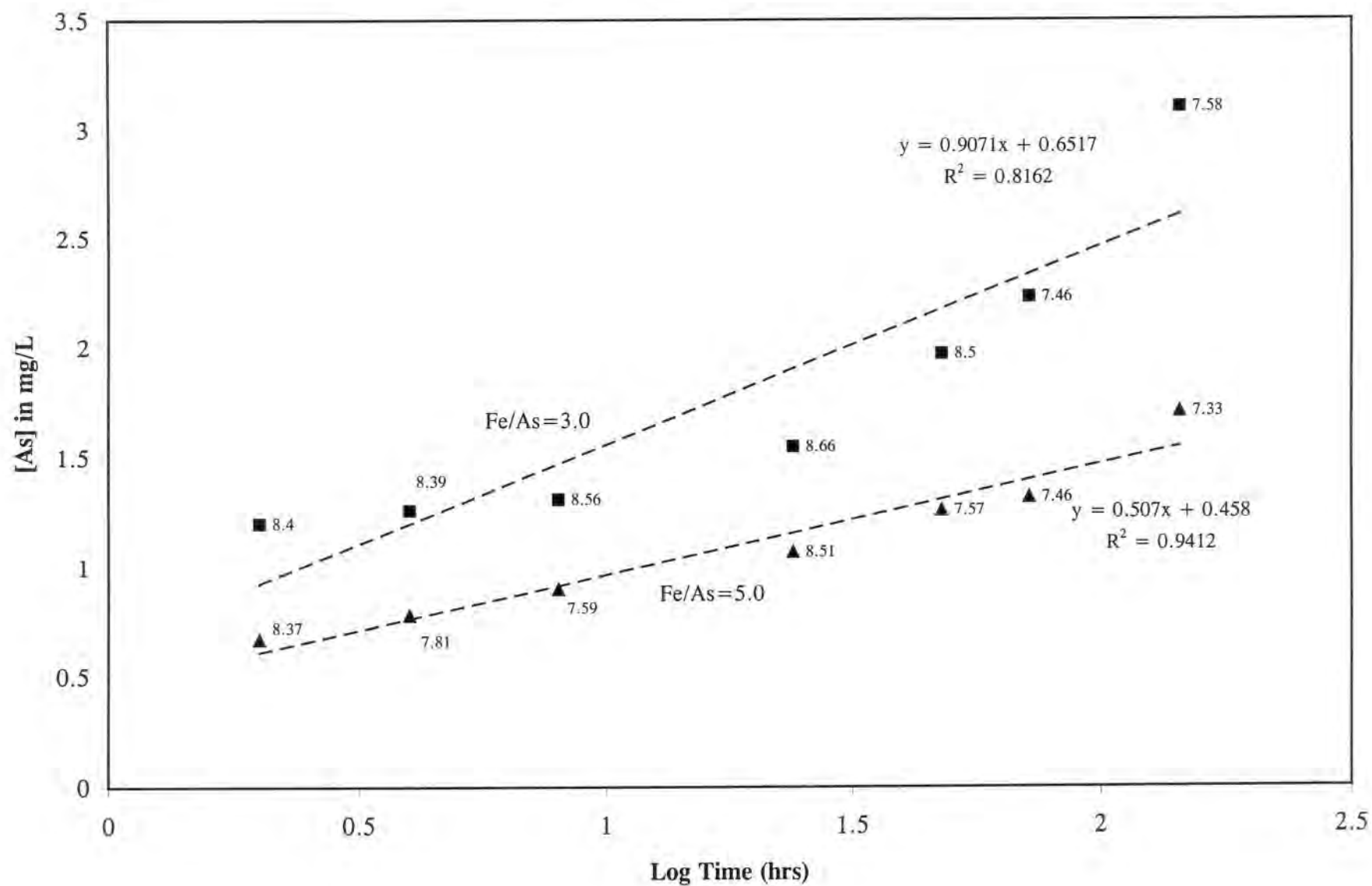
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Sue A+B tailings at 25°C, for molar Fe/As ratios of 1.0, 1.5, 2.0, and 2.5 and nominal pH 8. ^{Note 1}



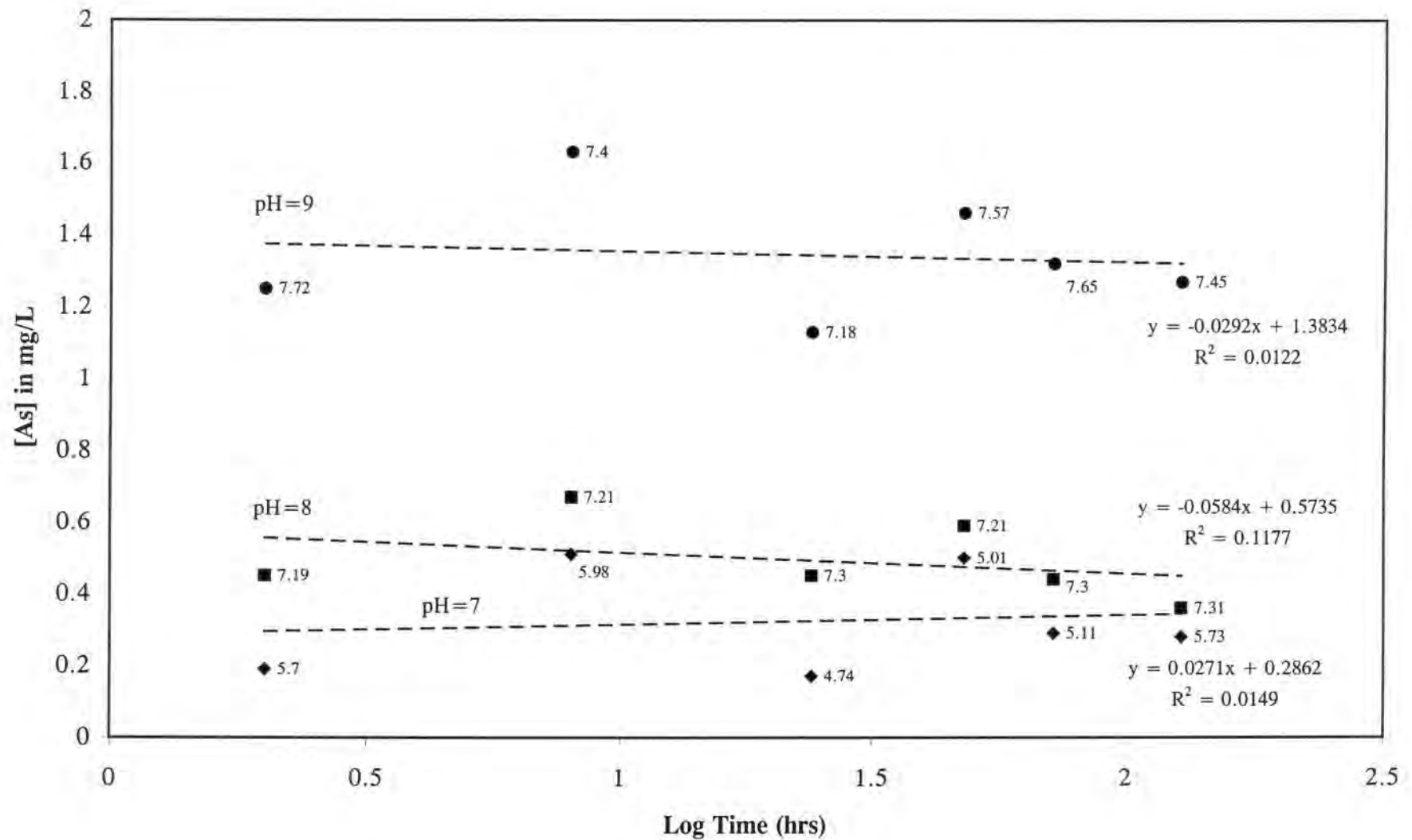
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Sue A+B tailings at 25°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 9. ^{Note 1}



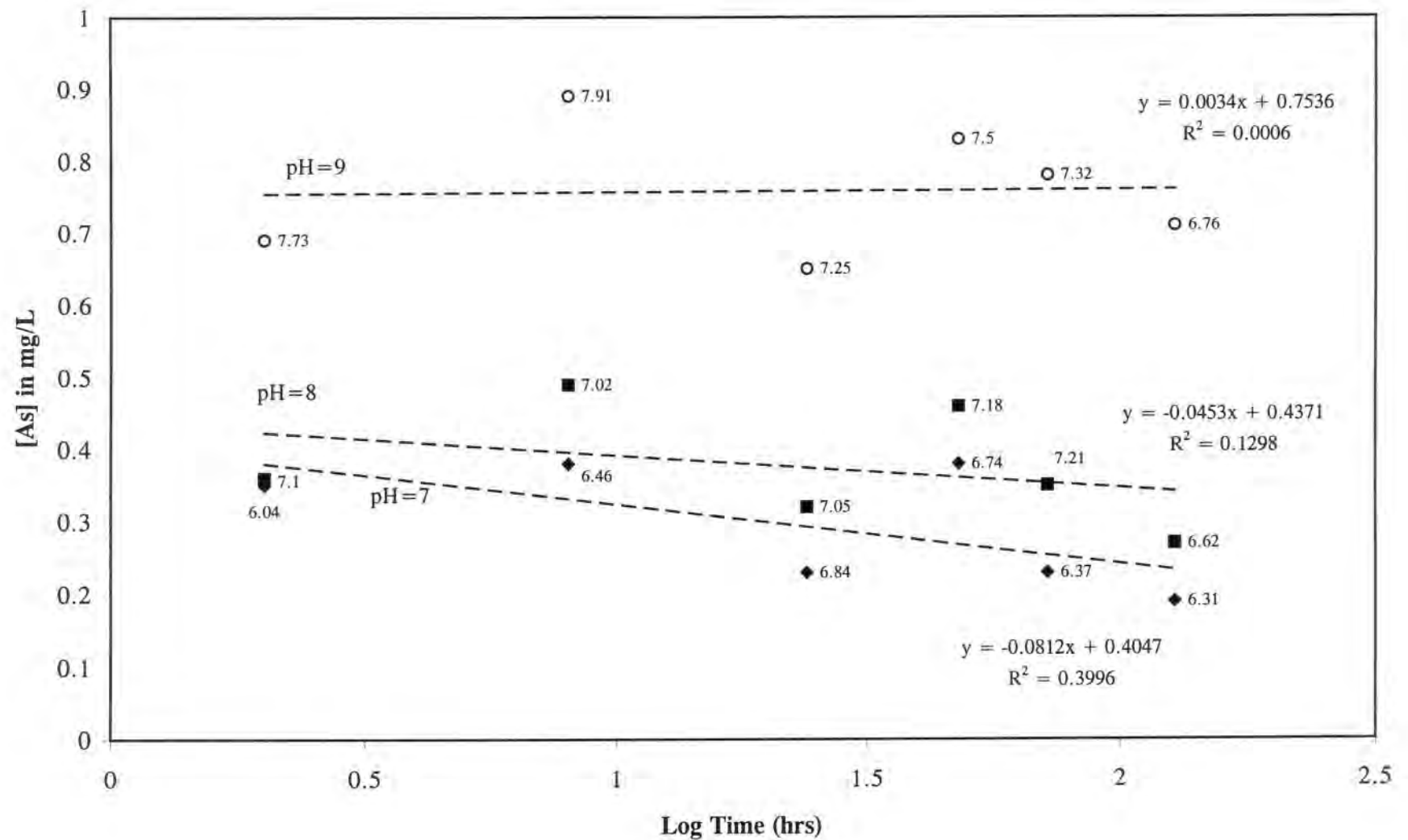
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Cigar Lake tailings at 25°C, for molar Fe/As ratio of 7.5 and nominal pH 7, 8, and 9. ^{Note 1}



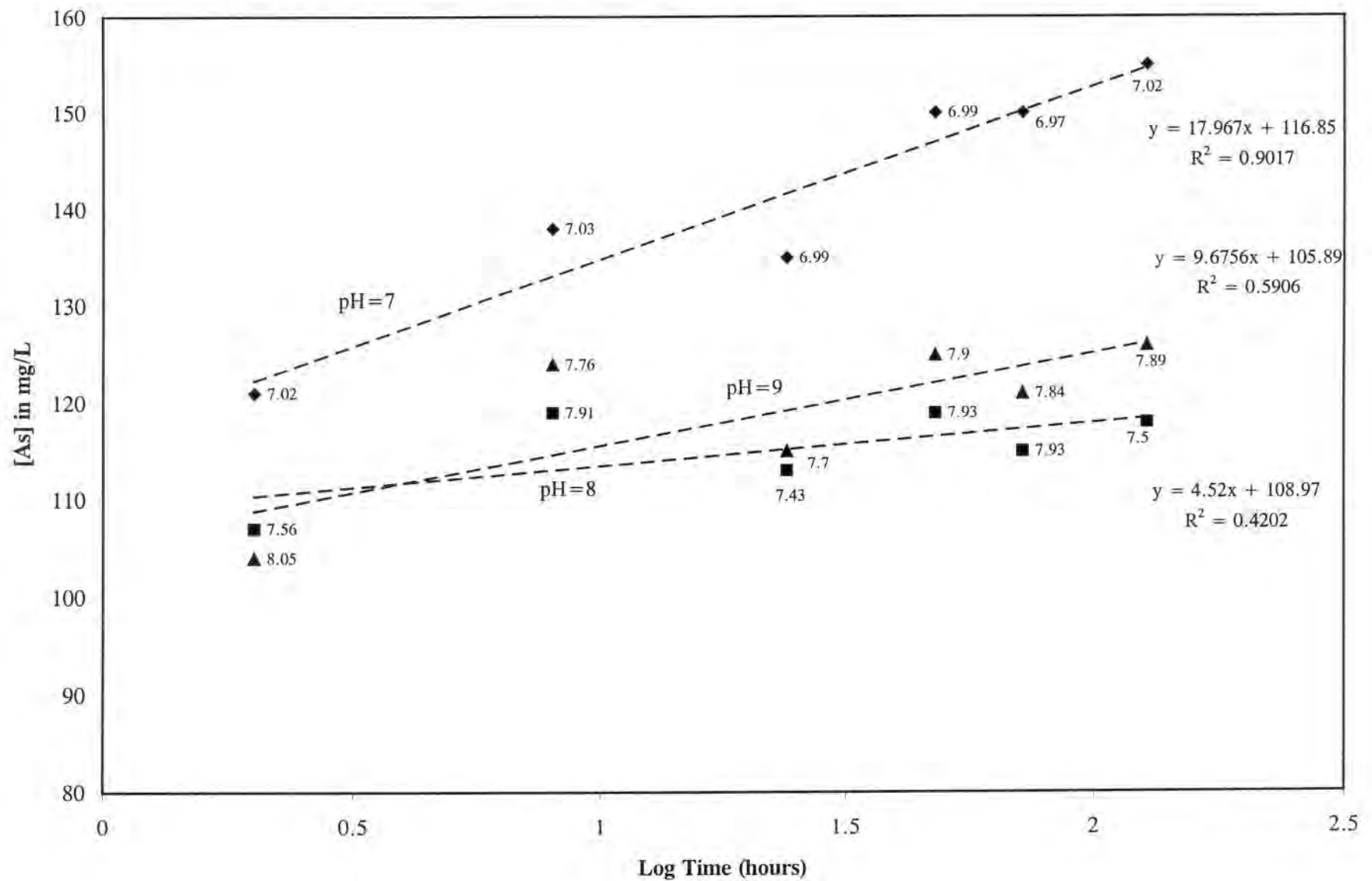
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Blend 1 (75% Sue C + 25% Cigar Lake) tailings at 25°C, for molar Fe/As ratios of 7.6 and nominal pH 7, 8, and 9. ^{Note 1}



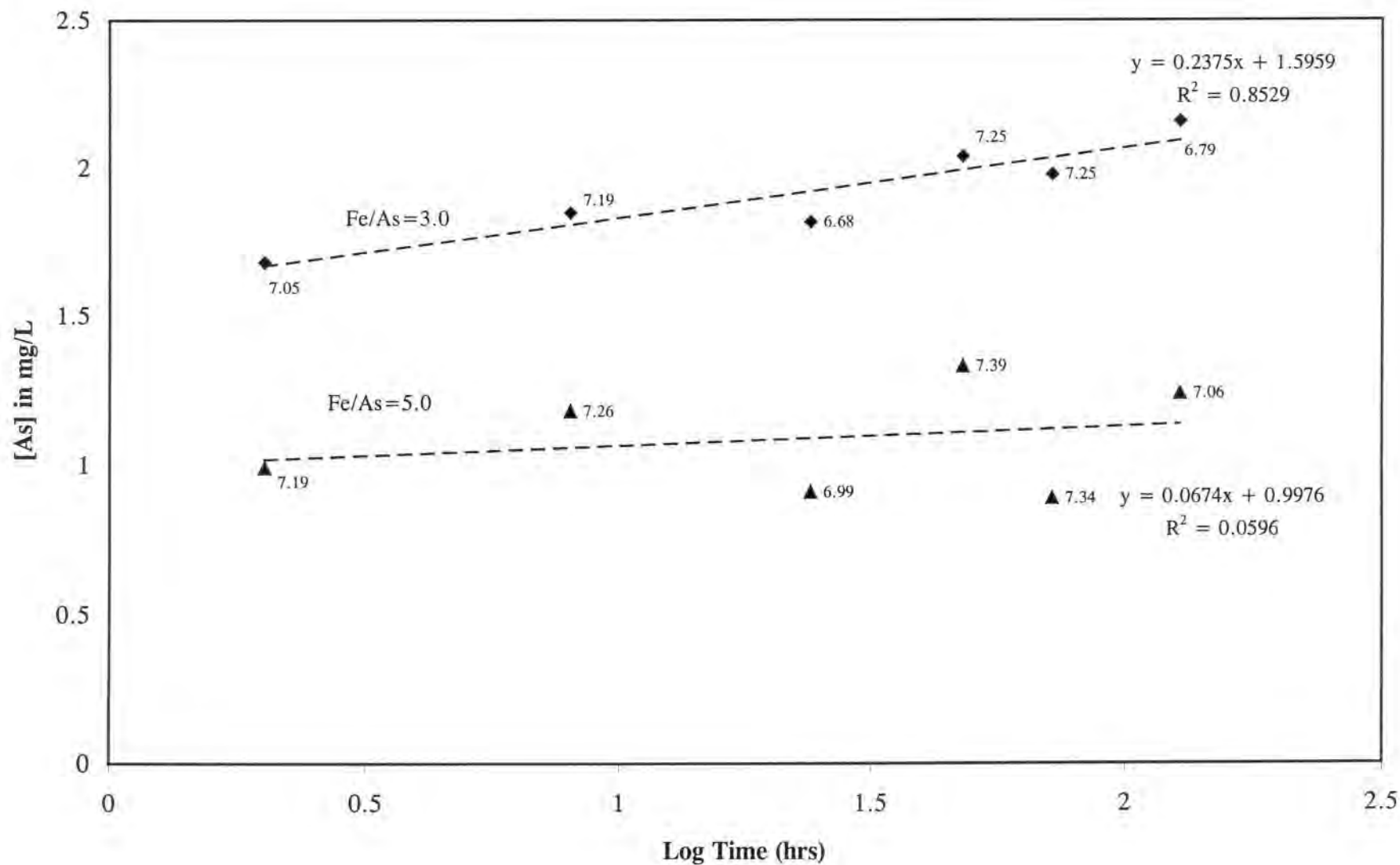
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 25°C, for molar Fe/As ratios of 0.3 and nominal pH 7, 8, and 9. ^{Note 1}



Note 1: Also shown are equations for linear regression of the data, and measured pH values for each data point.

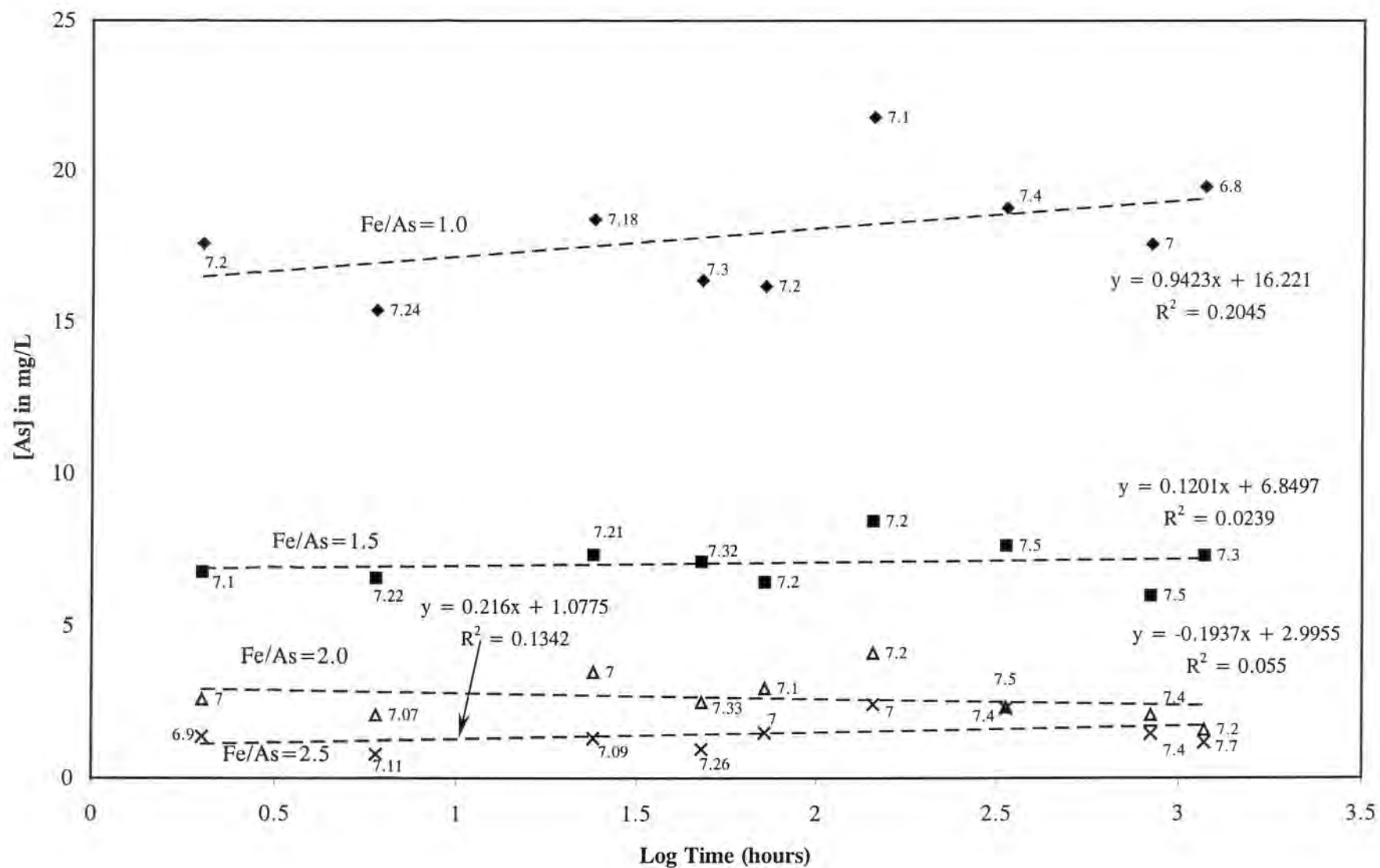
Arsenic concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 25°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 7. ^{Note 1}



Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

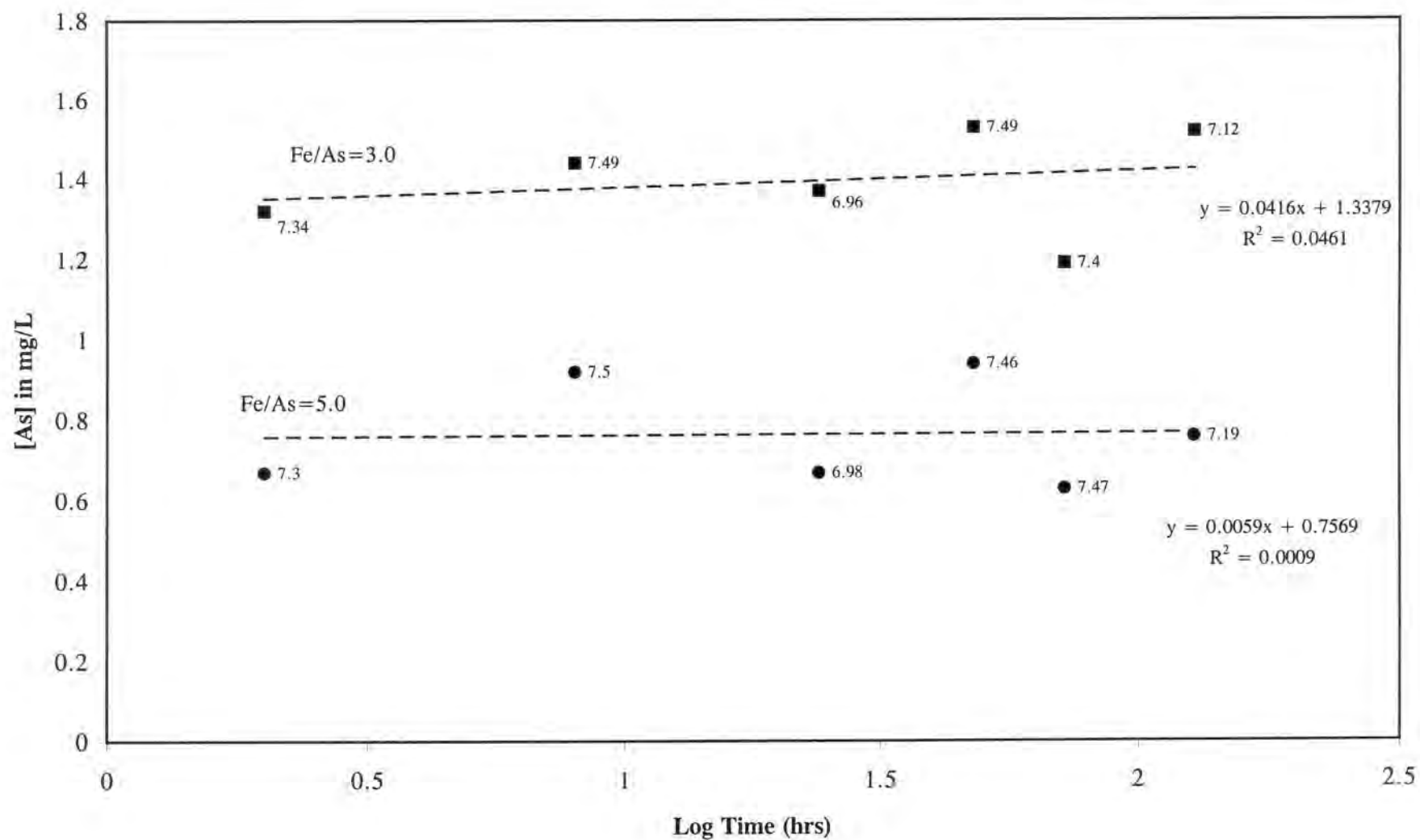
Arsenic concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A + B + 30% Cigar Lake) tailings at 25°C, for molar Fe/As ratios of 1.0, 1.5, 2.0, and 2.5 and nominal pH 8.

Note 1



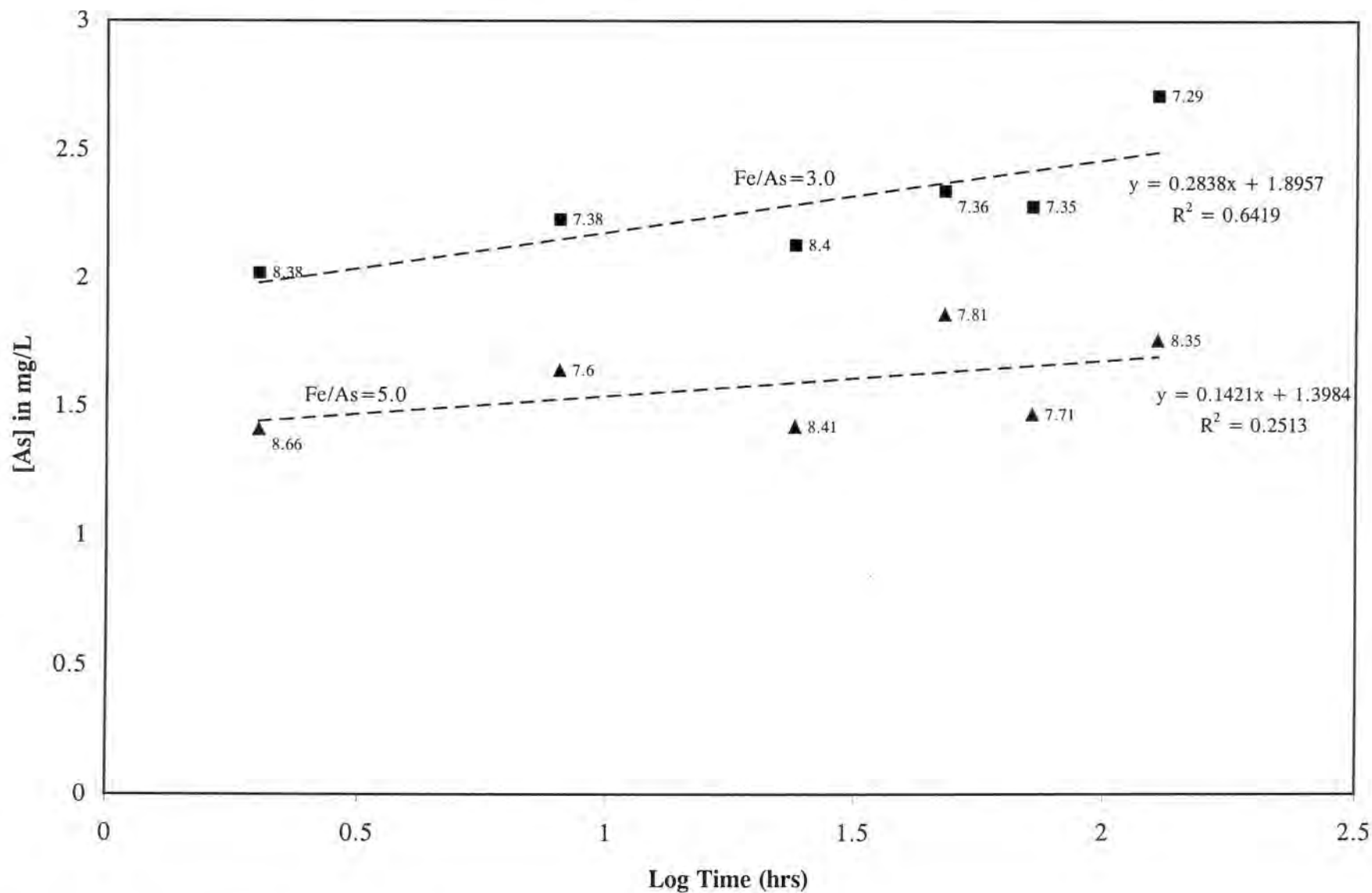
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 25°C, for molar Fe/As of 3.0 and 5.0 and nominal pH 8. ^{Note 1}



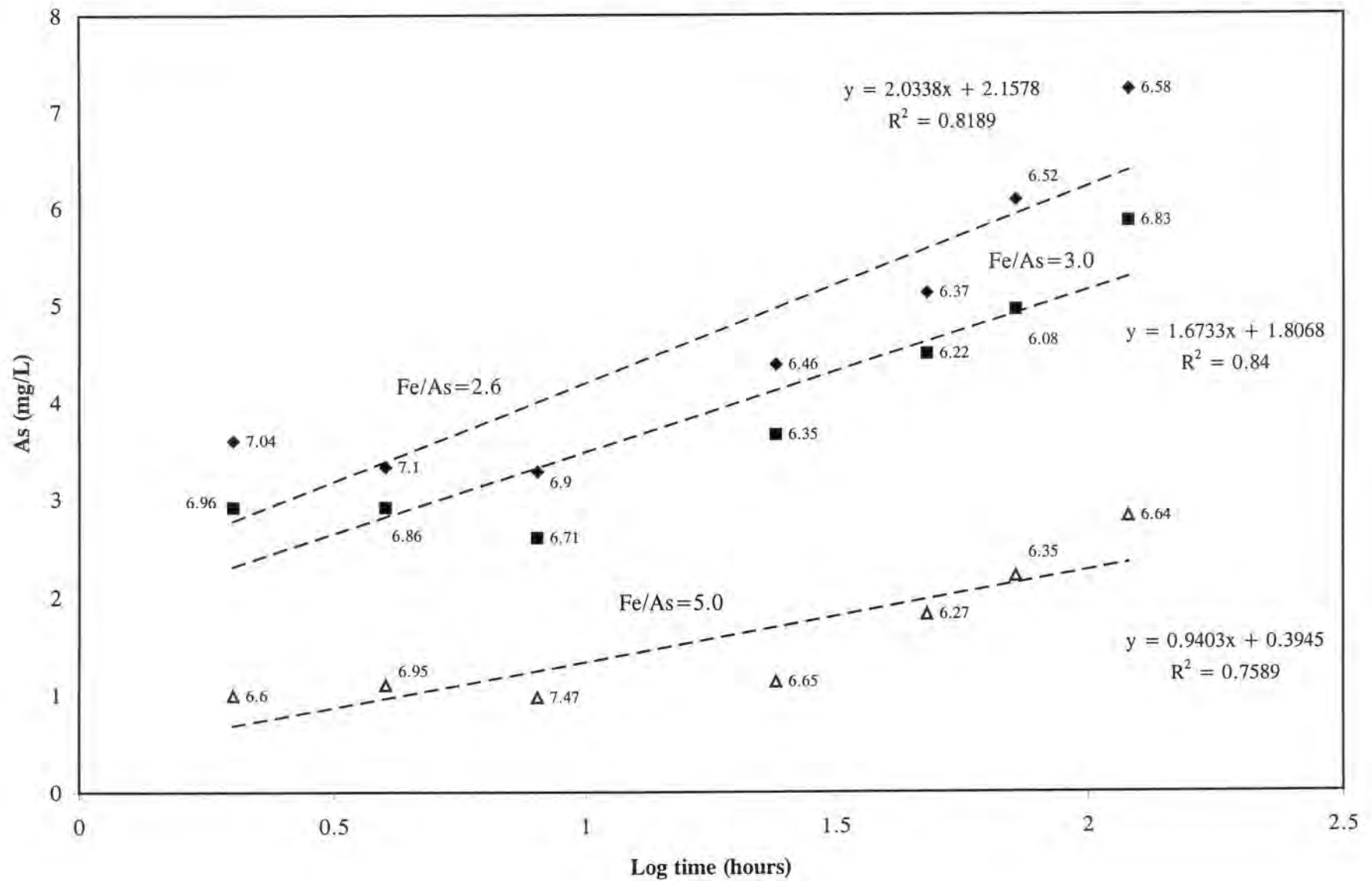
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 25°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 9. ^{Note 1}



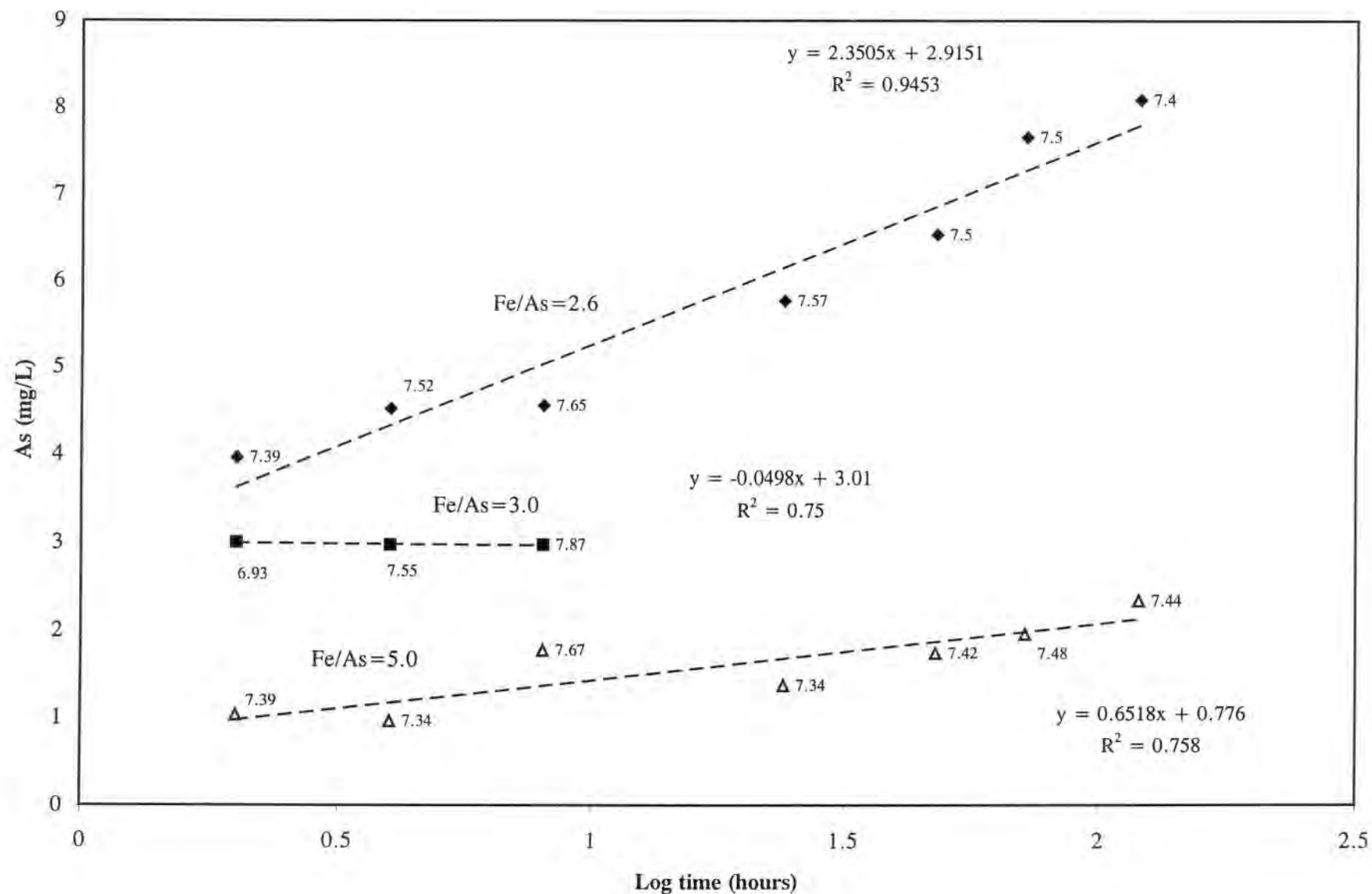
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of JEB tailings at 50°C, for molar Fe/As ratios of 2.6, 3.0 and 5.0 and nominal pH 7. ^{Note 1}



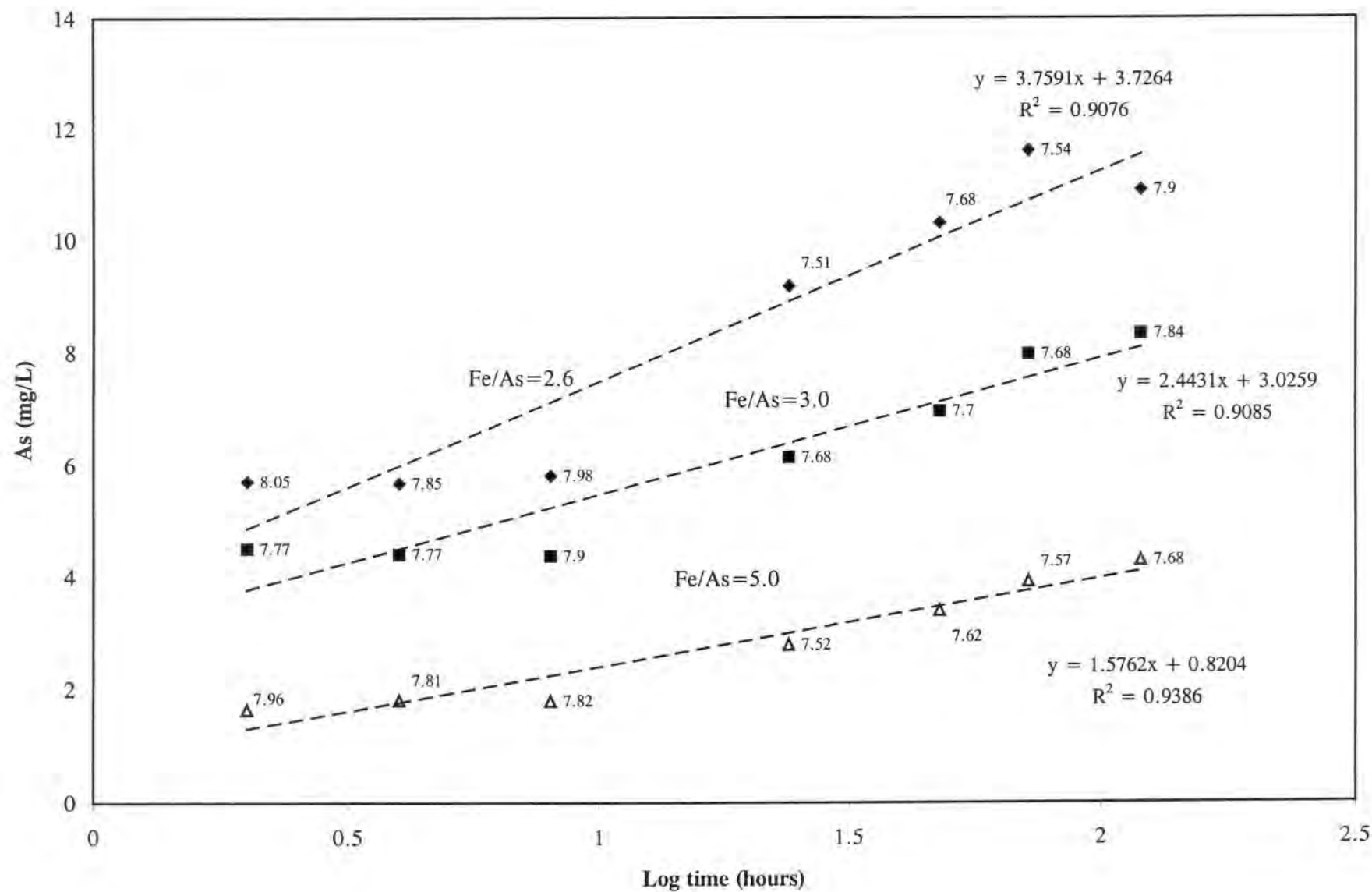
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of JEB tailings at 50°C, for molar Fe/As ratios of 2.6, 3.0, and 5.0 and nominal pH 8. ^{Note 1}



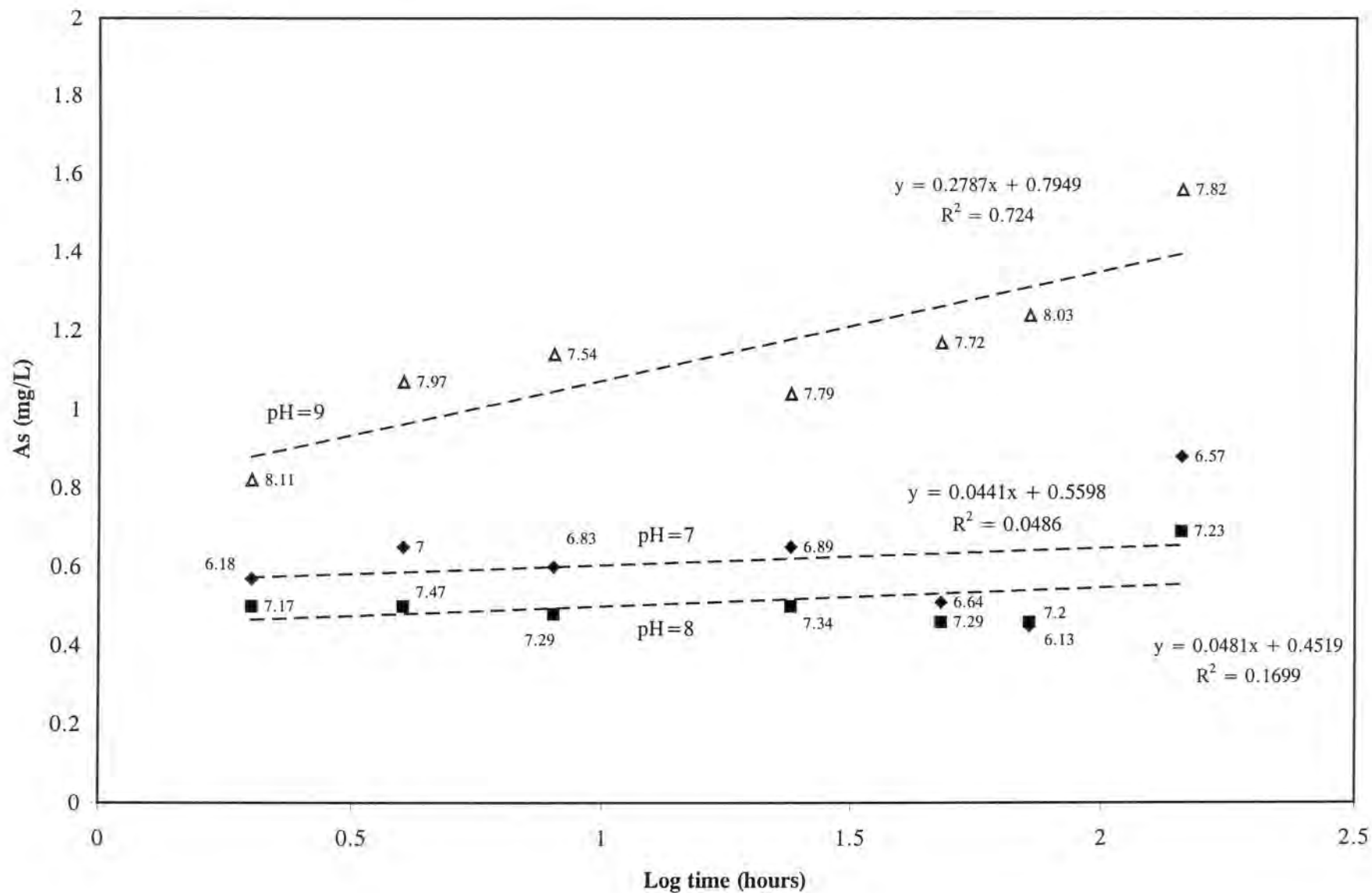
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of JEB tailings at 50°C, for molar Fe/As ratios of 2.6, 3.0, and 5.0 and nominal pH 9. ^{Note 1}



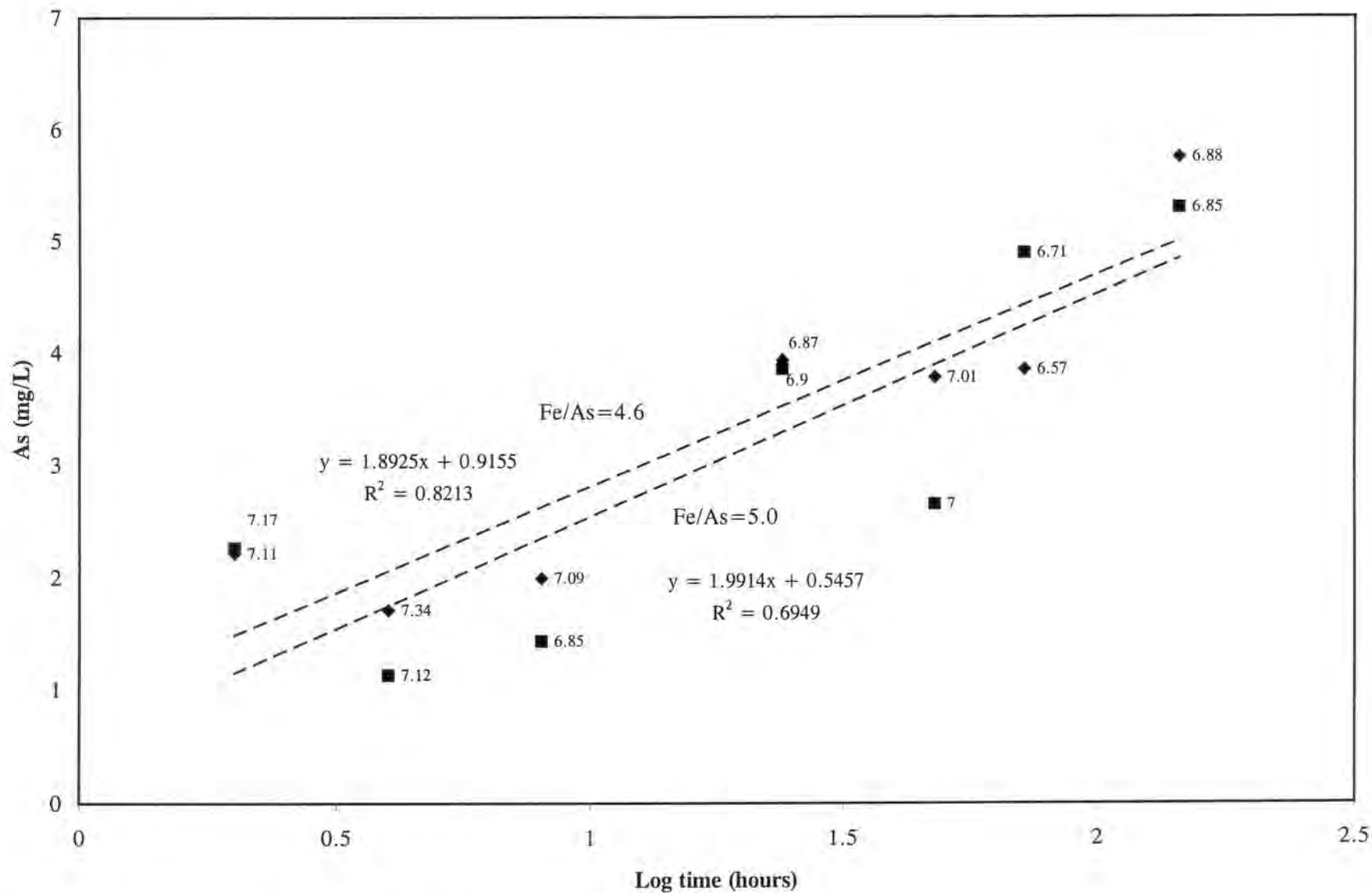
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Sue C tailings at 50°C, for molar Fe/As ratios of 7.7 and nominal pH 7, 8, and 9. ^{Note 1}



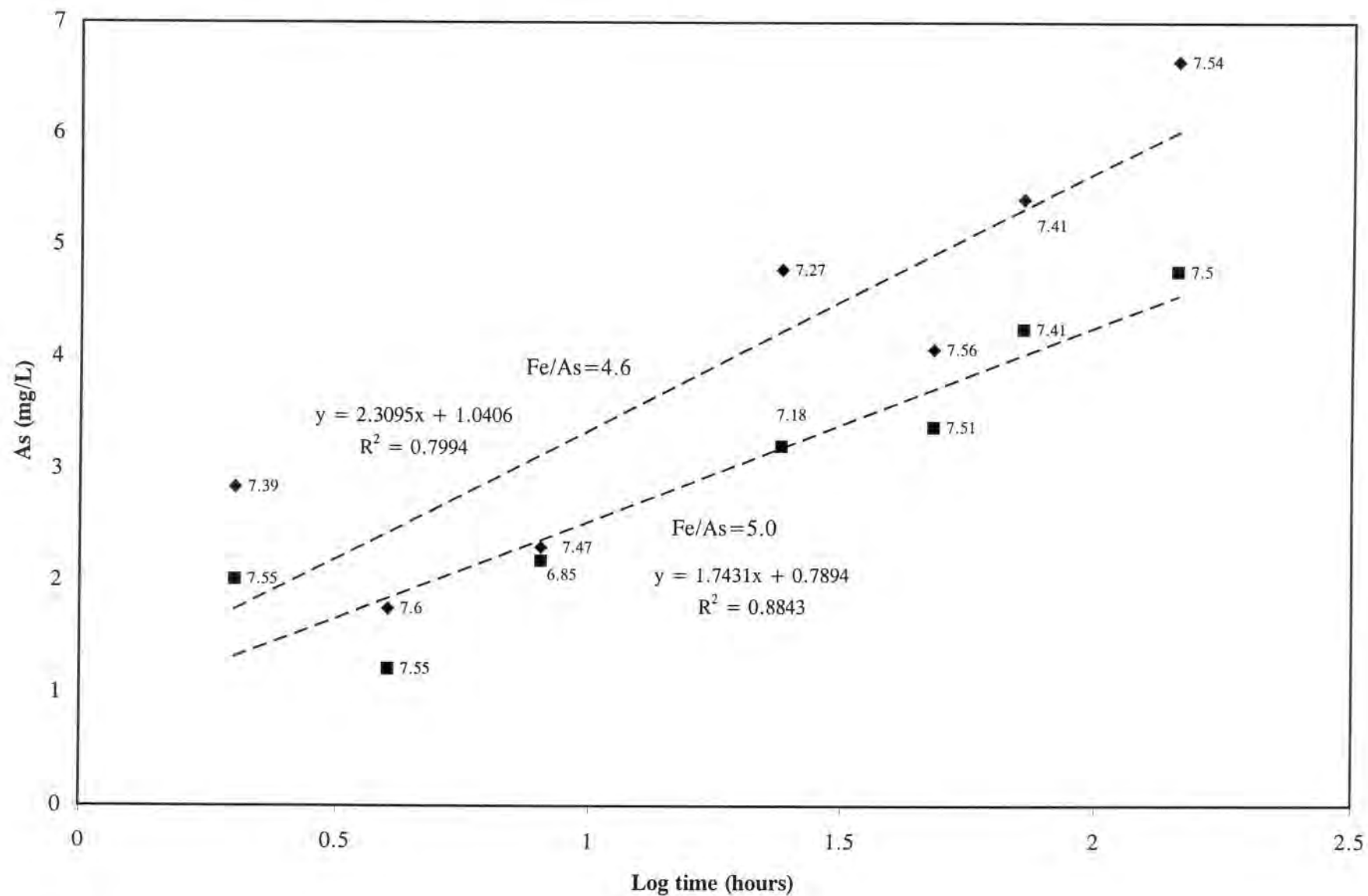
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of McClean Lake tailings at 50°C, for molar Fe/As ratios of 4.6 and 5.0 and nominal pH 7. ^{Note 1}



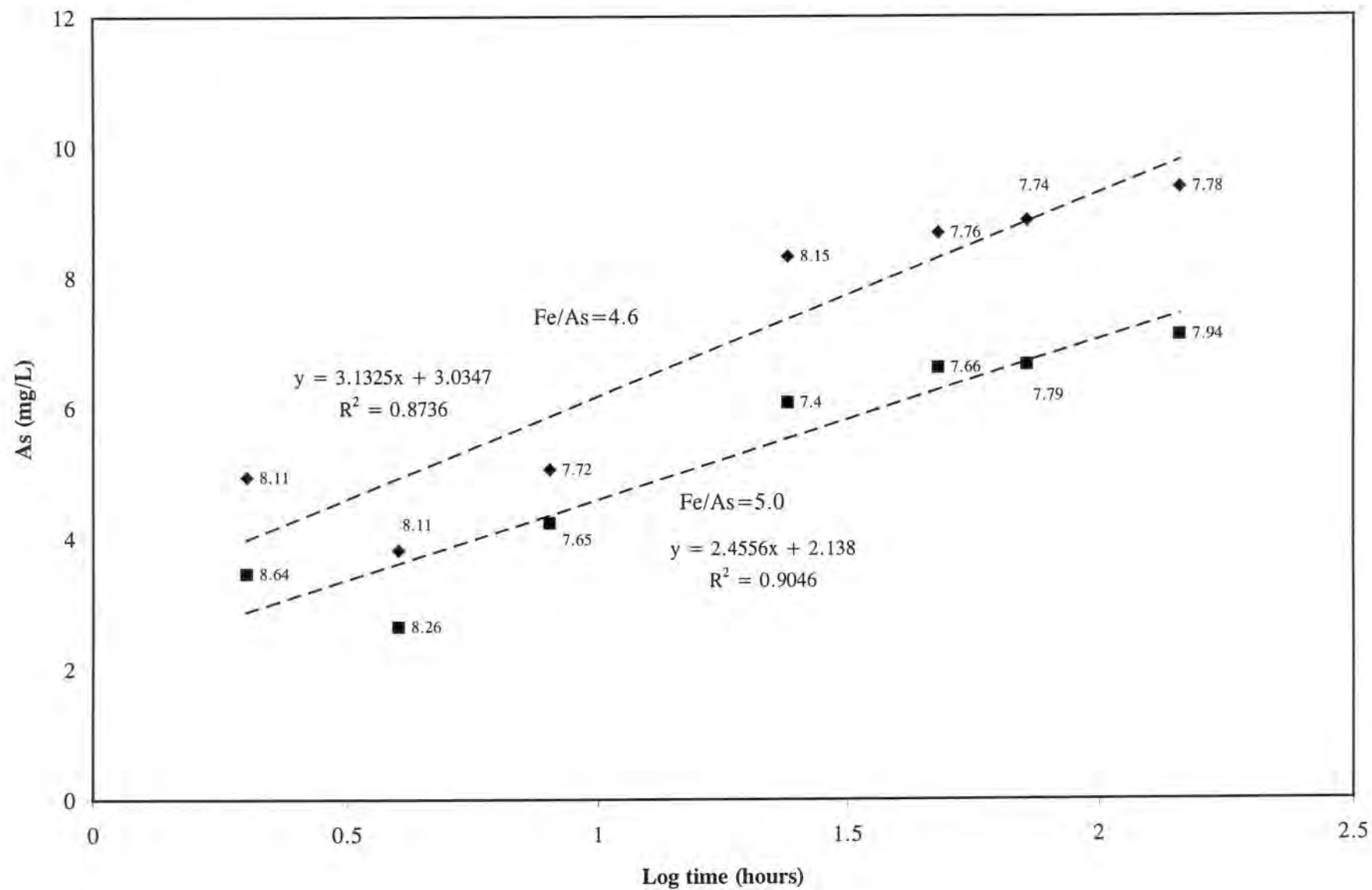
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of McClean Lake tailings at 50°C, for molar Fe/As ratios of 4.6 and 5.0 and nominal pH 8. ^{Note 1}



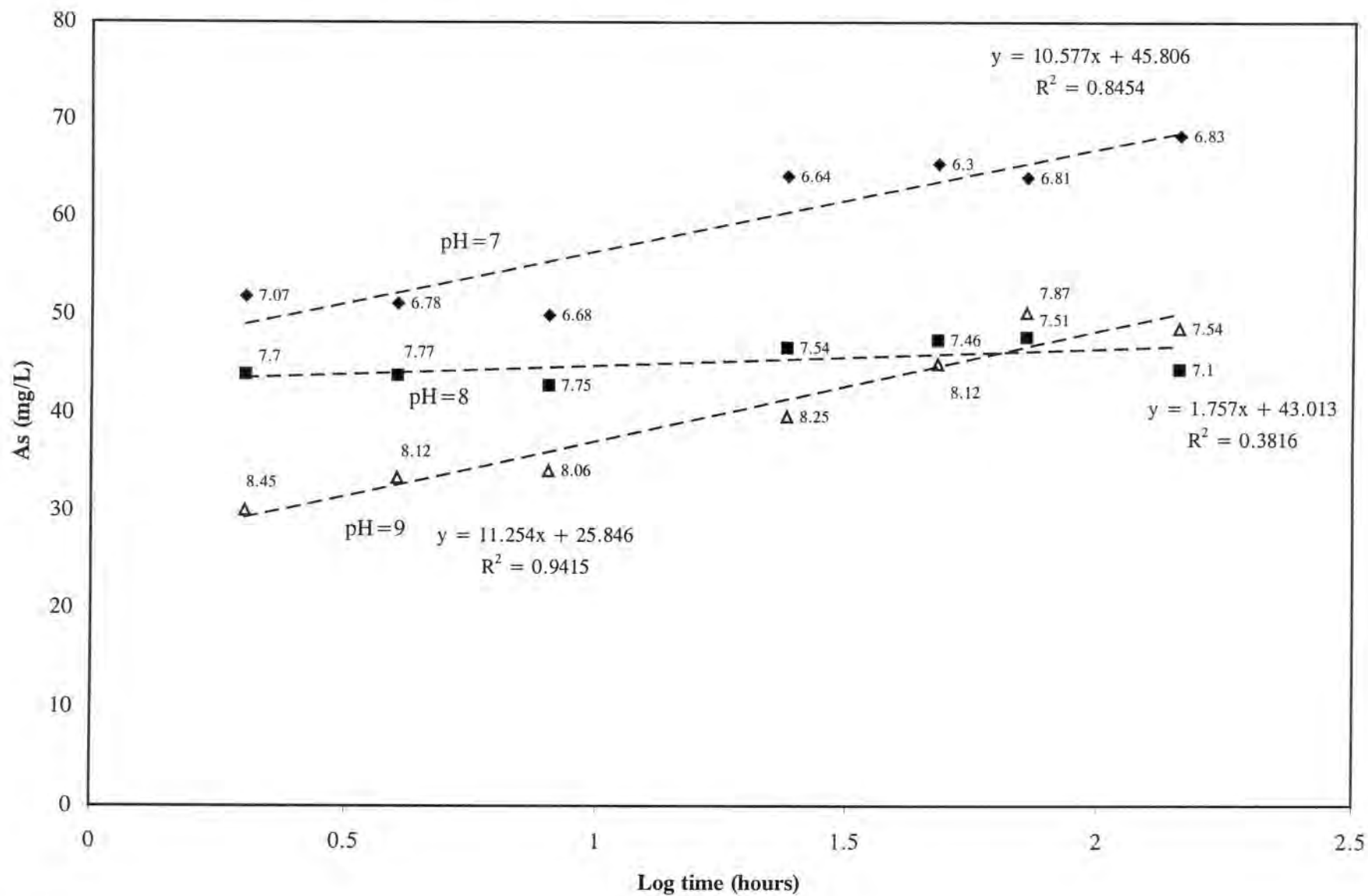
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of McClean Lake tailings at 50°C, for molar Fe/As ratios of 4.6 and 5.0 and nominal pH 9. ^{Note 1}



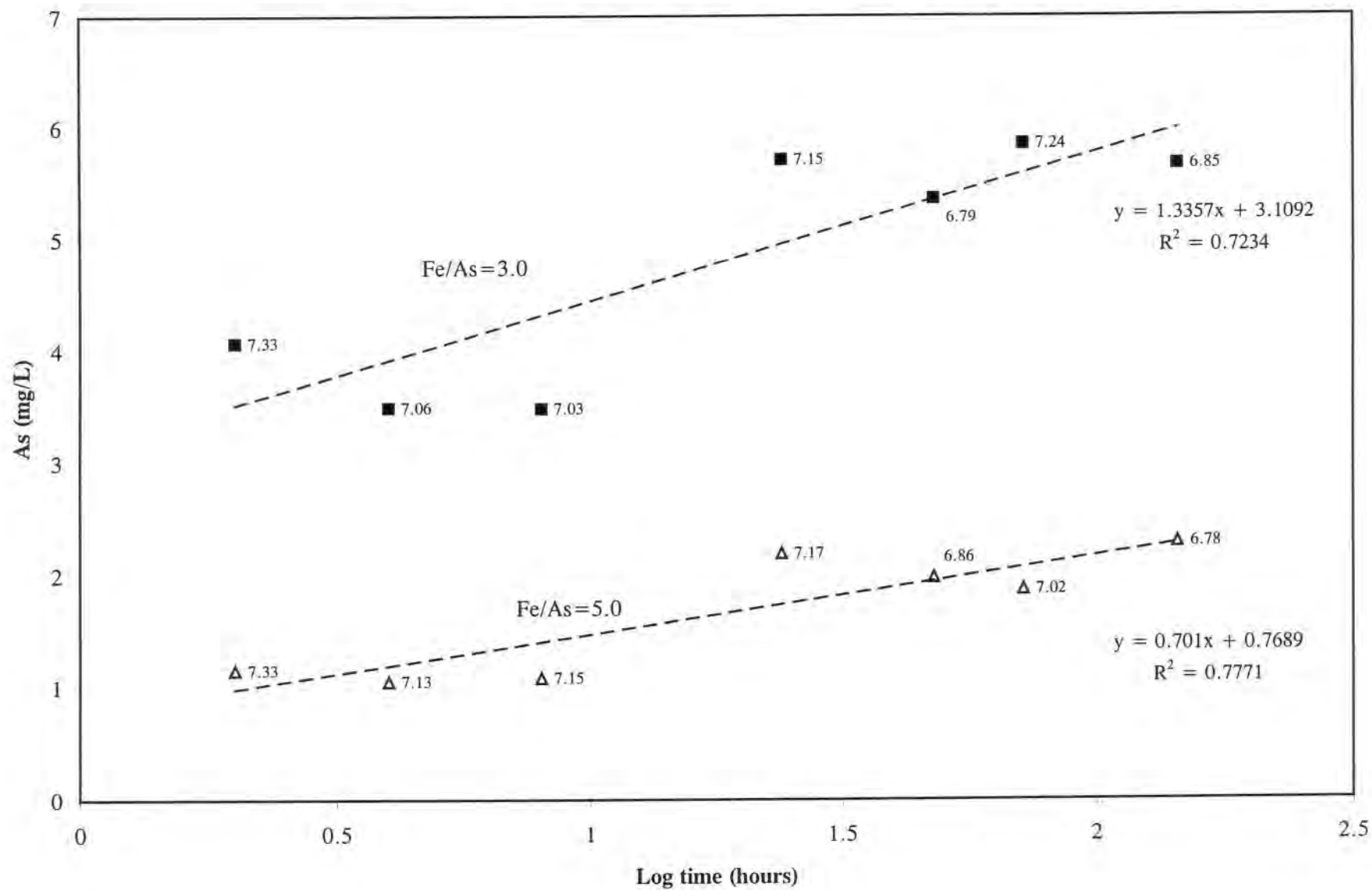
Note 1: Also shown are equation for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Sue A+B tailings at 50°C, for molar Fe/As ratios of 0.6 and nominal pH 7, 8, and 9. ^{Note 1}



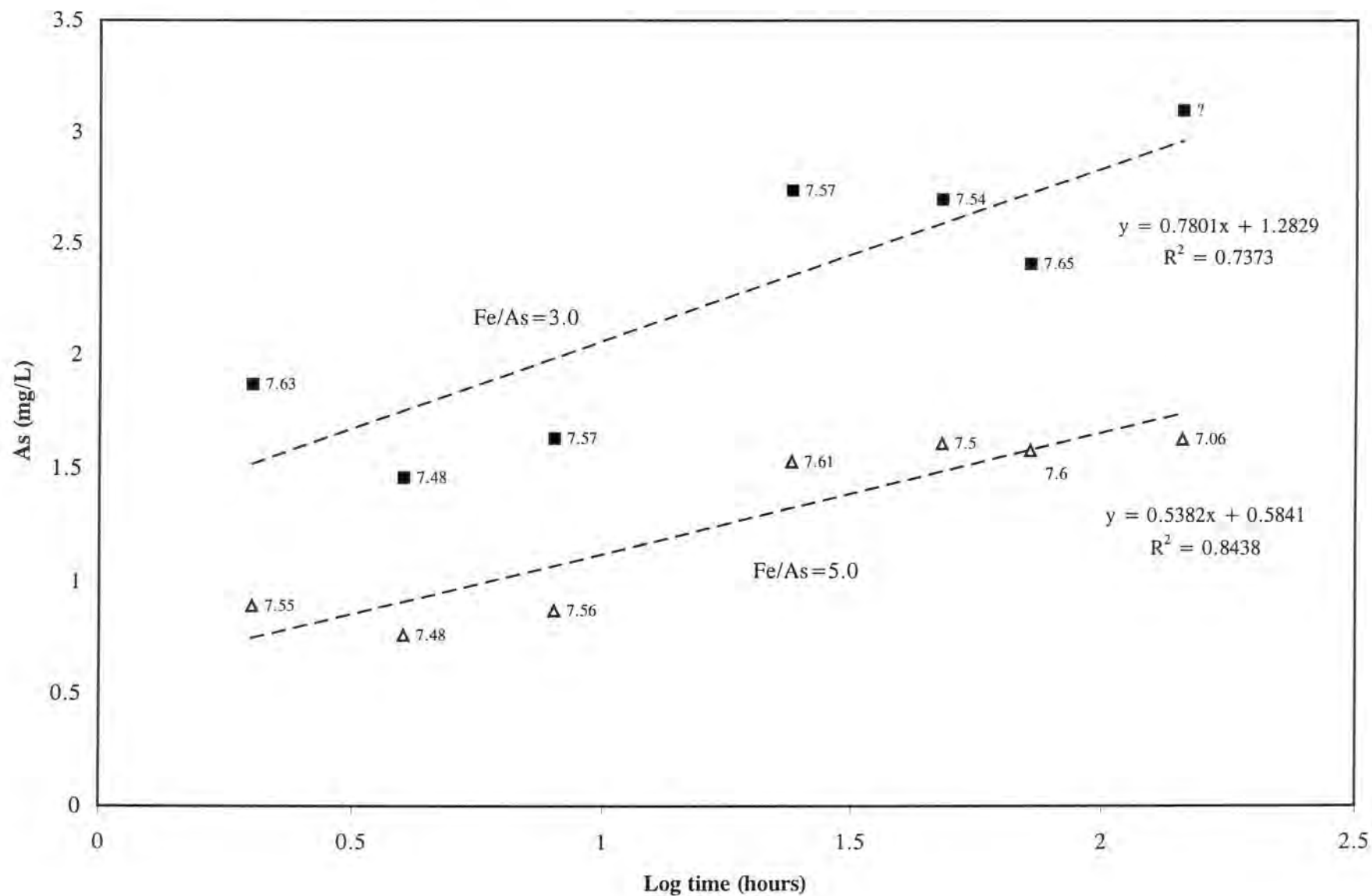
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Sue A+B tailings at 50°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 7. ^{Note 1}



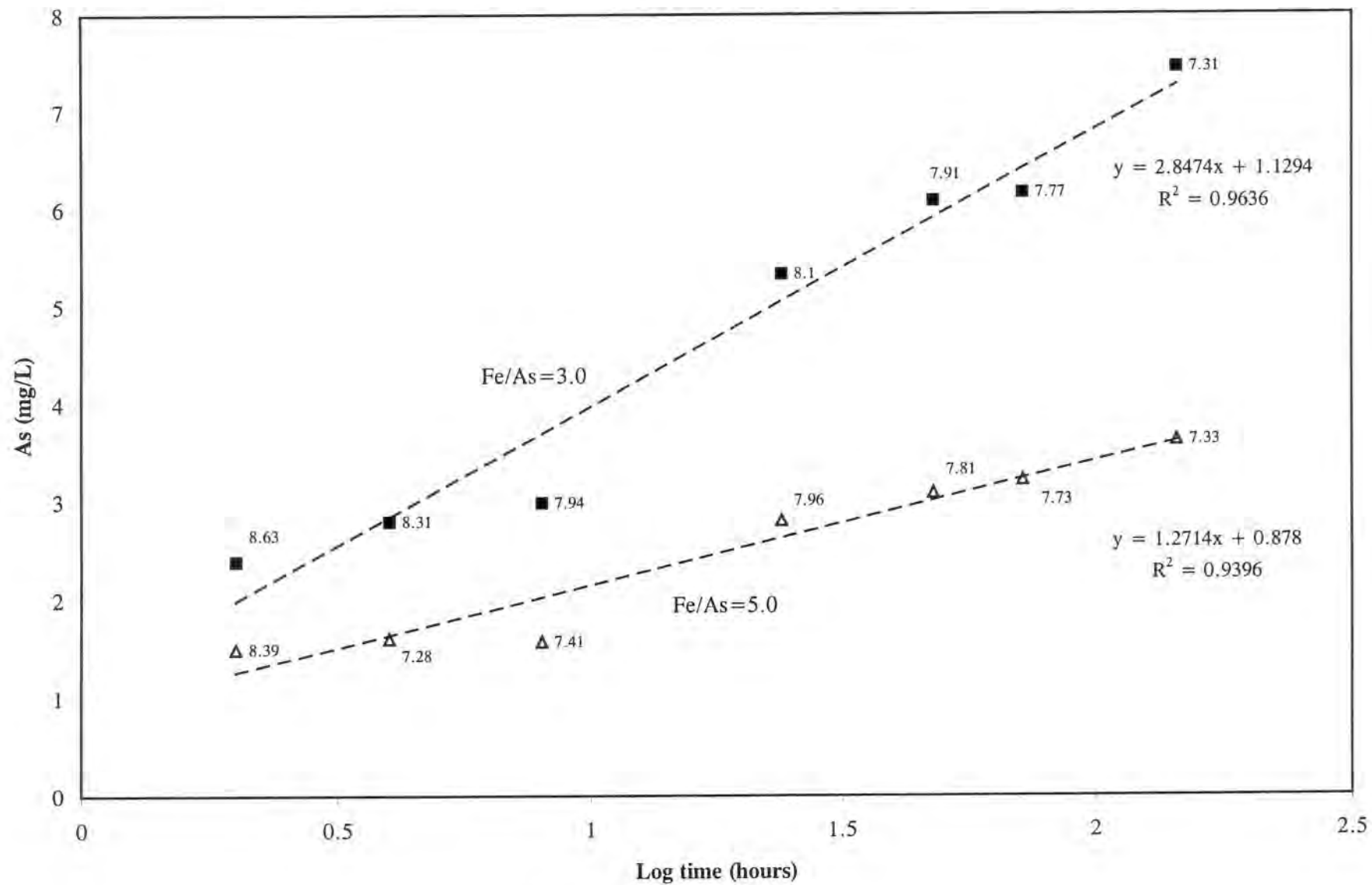
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Sue A+B tailings at 50°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 8. ^{Note 1}



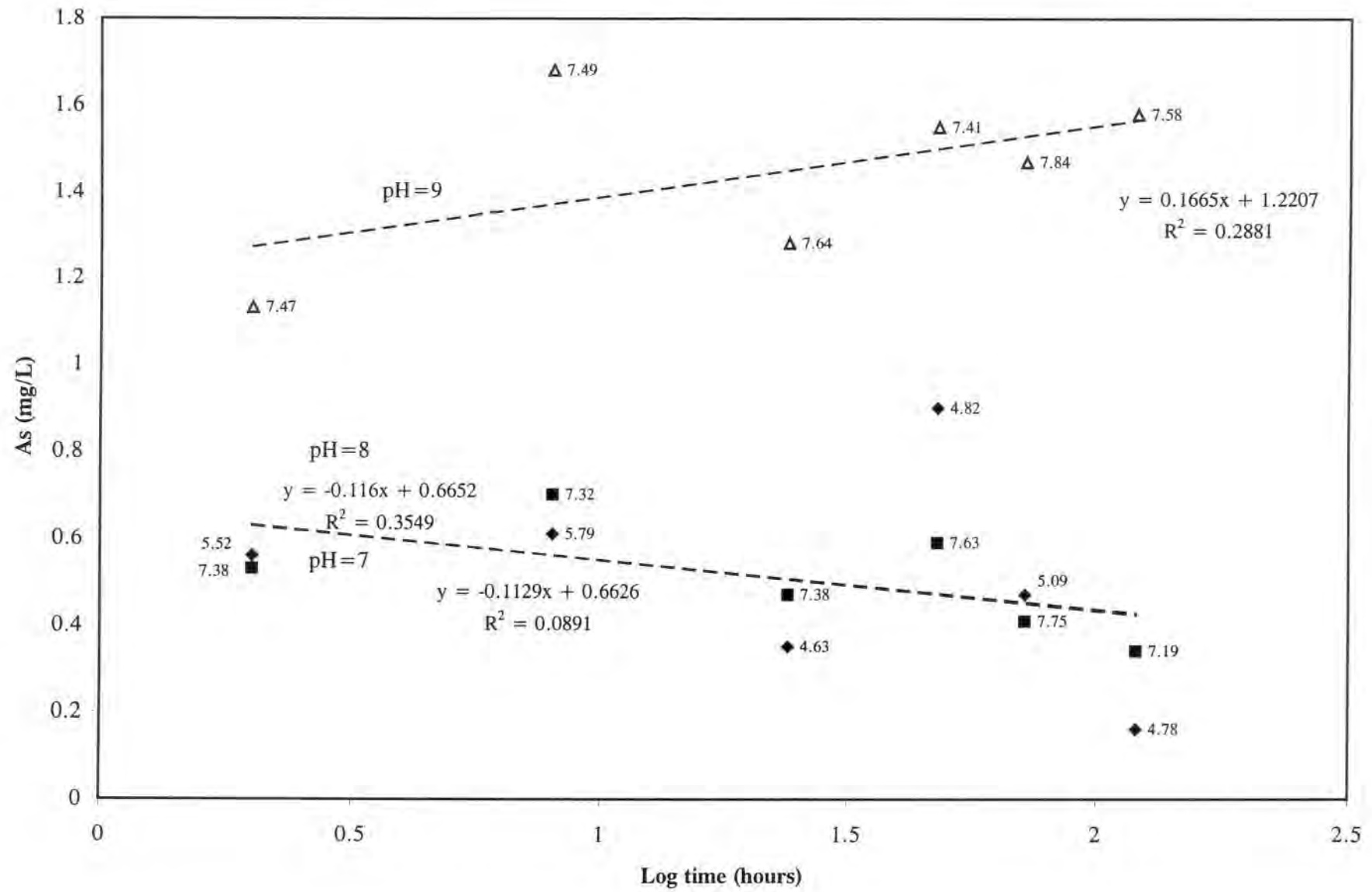
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Sue A + B tailings at 50°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 9. ^{Note 1}



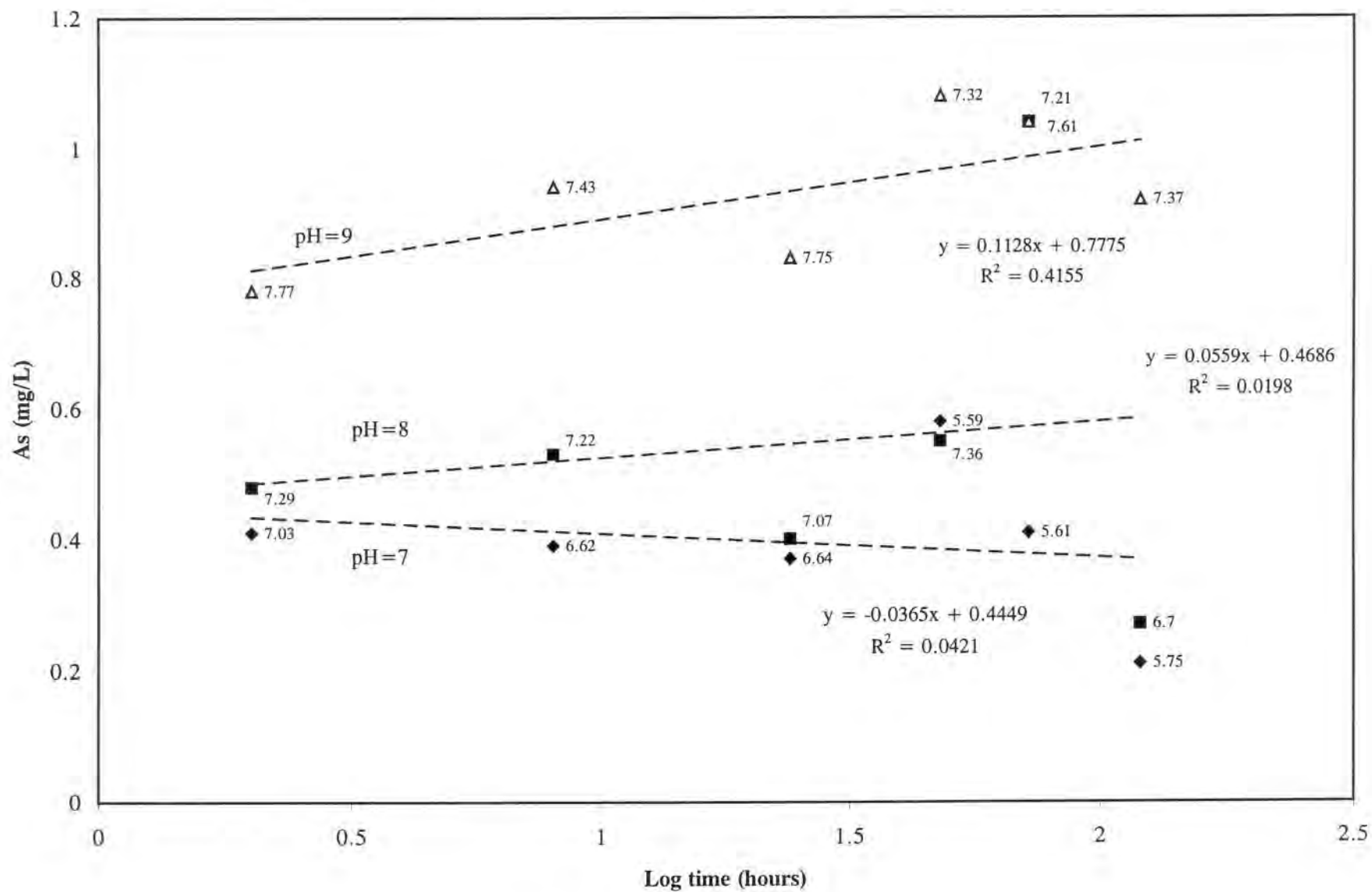
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Cigar Lake tailings at 50°C, for molar Fe/As ratios of 7.5 and nominal pH 7, 8, and 9. ^{Note 1}



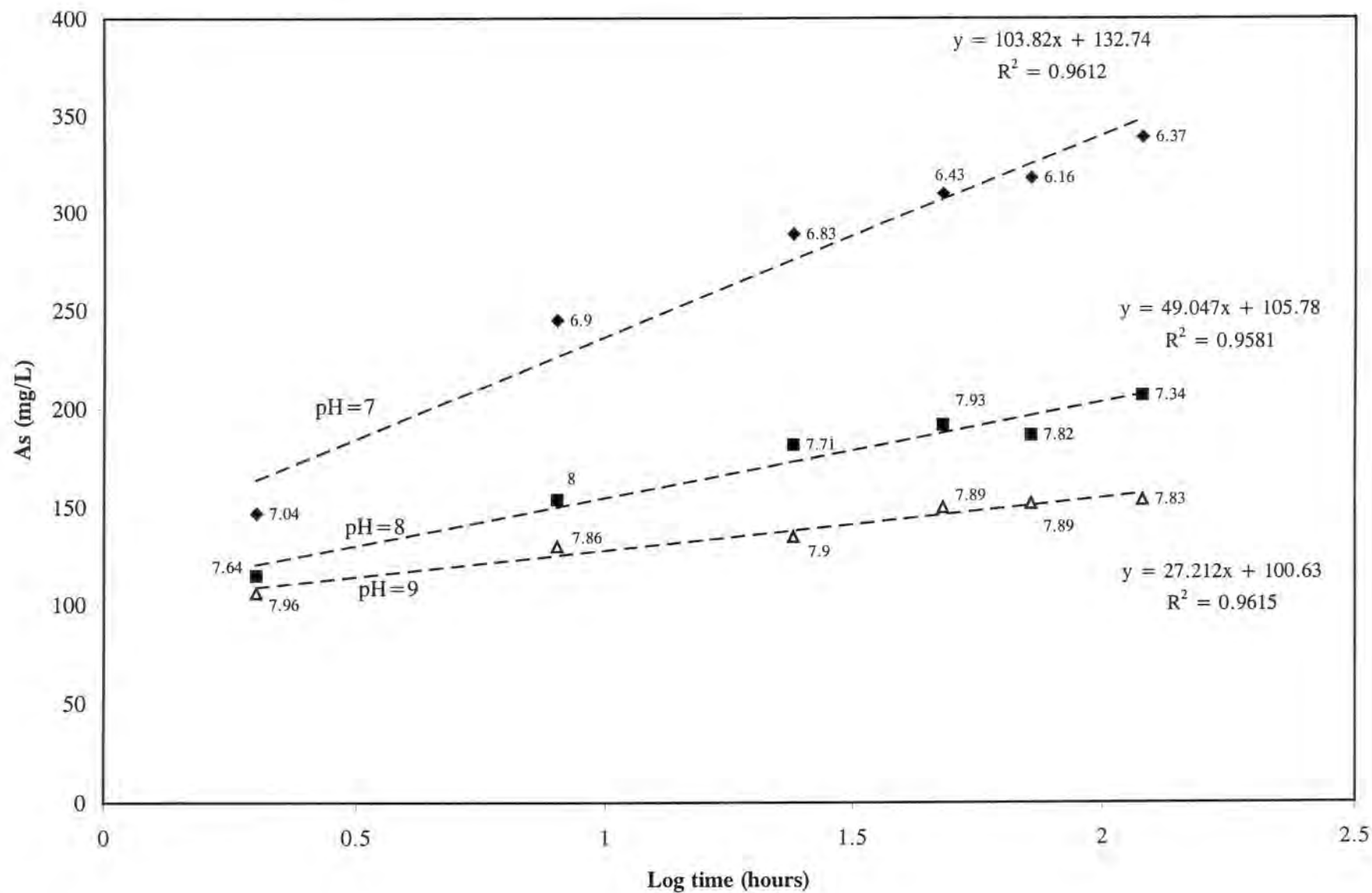
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Blend 1 (75% Sue C + 25% Cigar Lake) tailings at 50°C, for molar Fe/As ratios of 7.6 and nominal pH 7, 8, and 9. ^{Note 1}



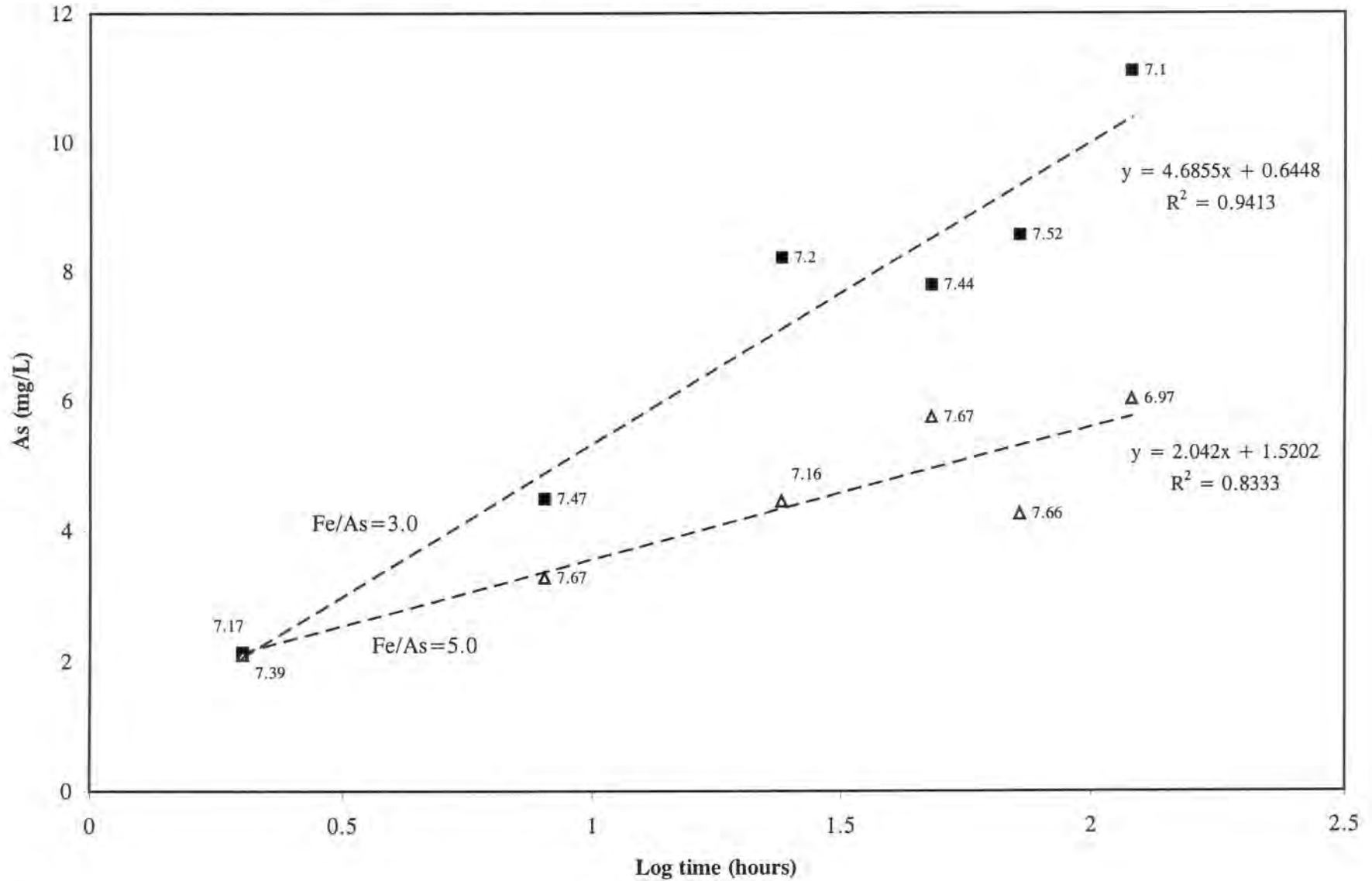
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 50°C, for molar Fe/As ratios of 0.3 and nominal pH 7, 8, and 9. ^{Note 1}



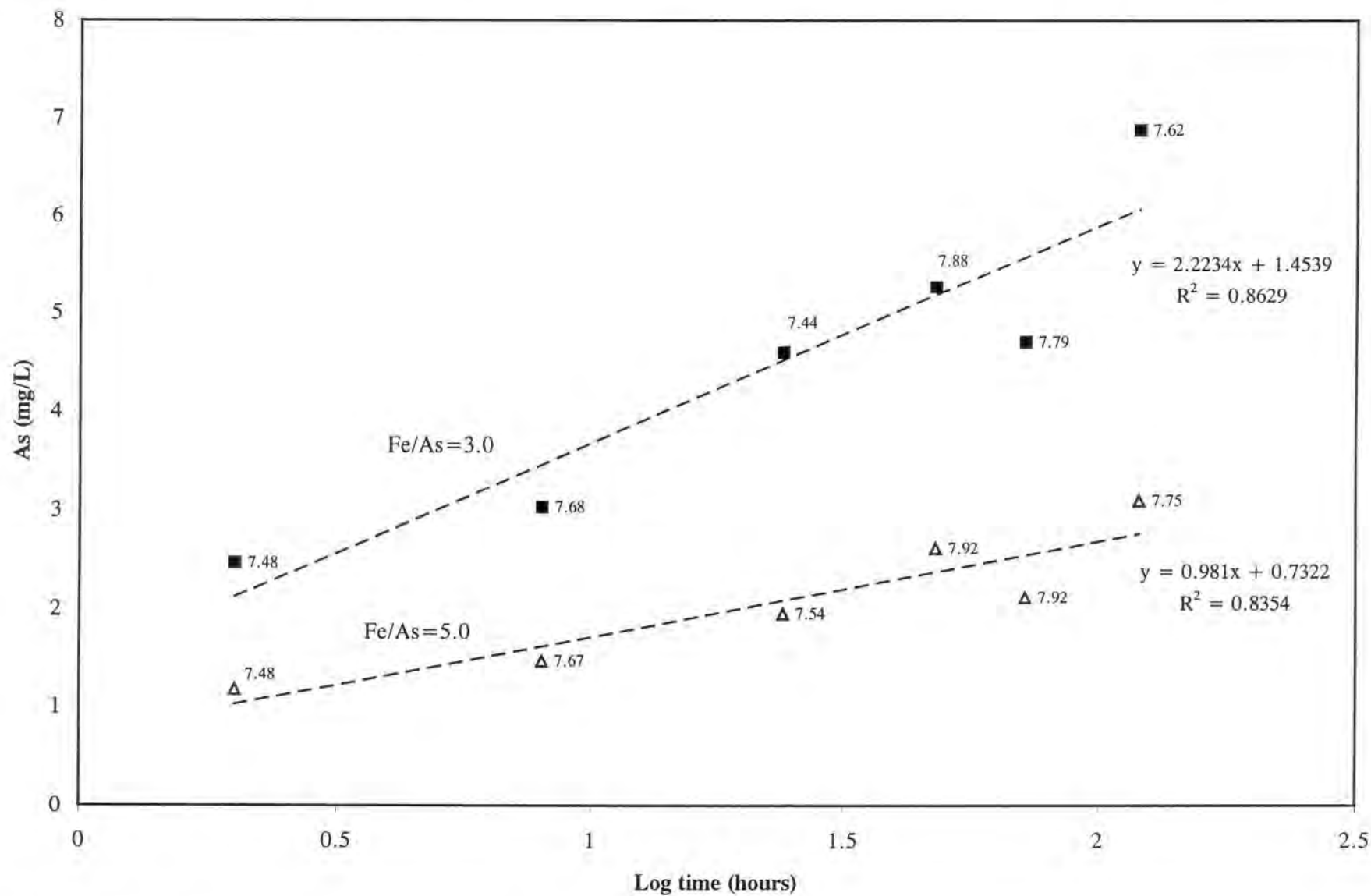
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 50°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 7. ^{Note 1}



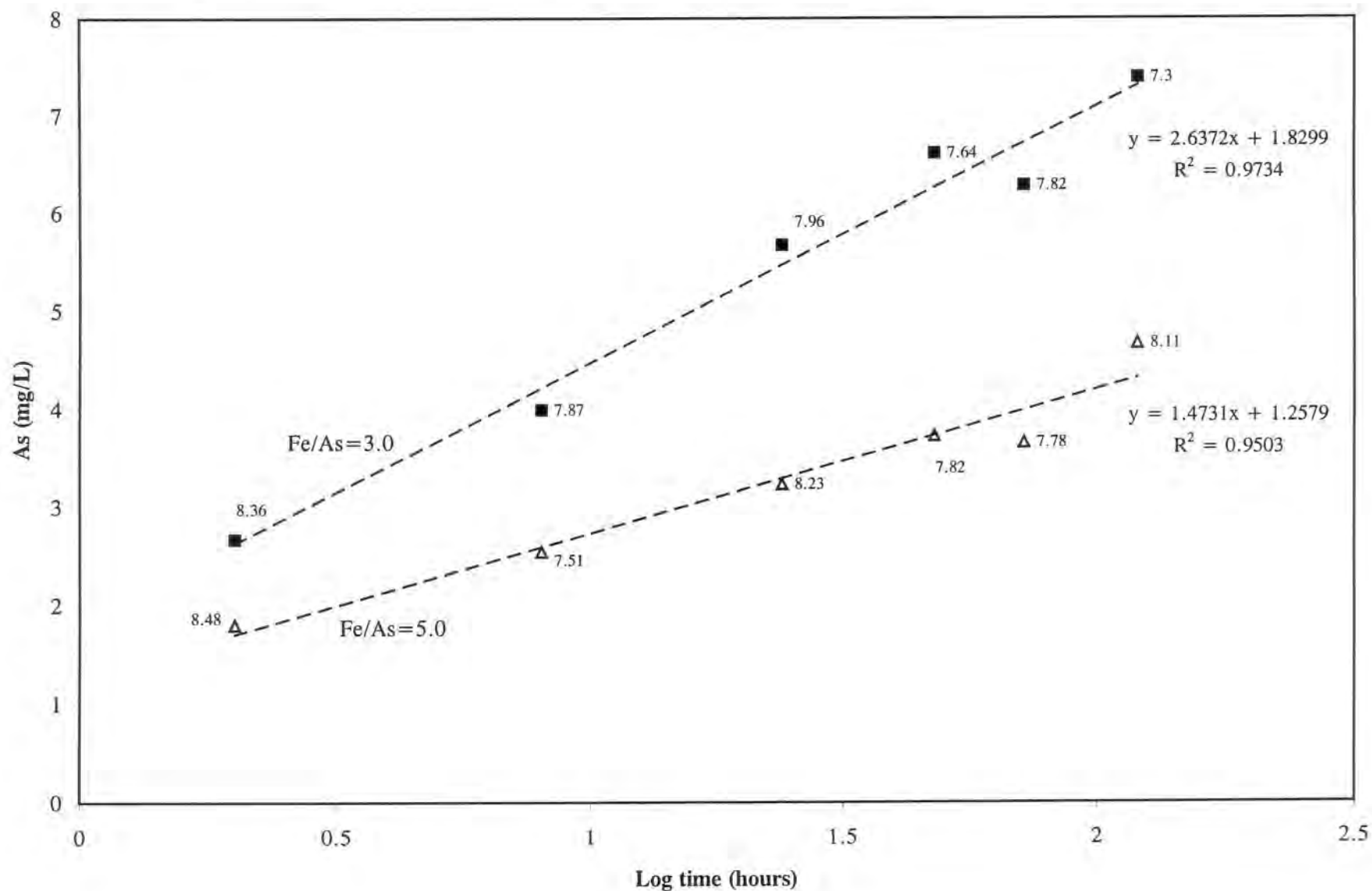
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 50°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 8. ^{Note 1}



Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Arsenic concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 50°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 9. ^{Note 1}



Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

**Nickel concentrations in tailings pore-waters and their statistical significance including *t*-test results at 4°C:
Results of the large scale laboratory tests.**

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of Trend (R^2) ^{Note} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
JEB	3.0	4	8	6.8-7.22	2.1 ± 0.4	2.11	4.3	random
JEB	5.0	4	8	7.3-7.9	0.81 ± 0.1	1.70	4.3	random
Sue C	7.7	4	8	6.27-7.95	$y = 0.0289x - 0.0046$ (0.722)	2.79	2.78	significant
Blend 2	3.0	4	8	6.65-7.44	1.4 ± 1.3	1.27	2.57	random

Note 1: Linear regression equation where $x = \log$ time (hours) and $y =$ concentration of nickel (mg/L)

Blend 1 = 75% Sue C + 25% Cigar Lake

Blend 2 = 55% Midwest + 15% Sue A+B + 30% Cigar Lake

Nickel concentrations in tailings pore-waters and their statistical significance including *t*-test results at 25°C:
Results of the large scale laboratory tests.
 (page 1 of 3)

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of Trend (R^2) ^{Note} or Average value $\pm$ 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
JEB	2.6	25	7	6.77-6.93	19 ± 0.5	1.27	4.30	random
JEB	2.6	25	8	7.35-7.58	0.69 ± 0.1	3.56	4.30	random
JEB	2.6	25	9	7.68-8.49	0.02 ± 0.01	0.12	4.30	random
JEB	3.0	25	7	6.61-6.85	29 ± 1.7	0.62	4.30	random
JEB	3.0	25	8	7.44-7.71	0.78 ± 0.1	1.68	4.30	random
JEB	3.0	25	9	7.72-8.12	0.03 ± 0.01	0.42	4.30	random
JEB	5.0	25	7	6.41-6.79	20 ± 1.3	1.87	4.30	random
JEB	5.0	25	8	7.16-7.32	0.57 ± 0.04	0.81	4.30	random
JEB	5.0	25	9	7.98	0.02 (one point)	na	na	na
Sue C	7.7	25	7	6.42-6.58	21 ± 2.1	4.08	4.30	random
Sue C	7.7	25	8	6.86-7.46	1.1 ± 0.7	1.29	4.30	random
Sue C	7.7	25	9	7.89-8.19	0.01 ± 0.01	1.41	4.30	random
McClean Lake	4.6	25	7	6.98-7.2	6.4 ± 0.4	0.06	4.30	random
McClean Lake	4.6	25	8	7.11-7.66	0.35 ± 0.2	0.09	4.30	random
McClean Lake	4.6	25	9	7.89-8.83	$0.02 \pm 3.3E-10$	0.00	4.30	random
McClean Lake	5.0	25	7	6.64-7.07	11 ± 0.4	0.56	4.30	random
McClean Lake	5.0	25	8	7.27-7.53	0.18 ± 0.02	0.46	4.30	random
McClean Lake	5.0	25	9	8.03-8.62	0.02 ± 0.01	2.18	4.30	random
Sue A + B	0.6	25	7	6.58-6.95	144 ± 25	3.16	4.30	random
Sue A + B	0.6	25	8	7.06-7.63	3.1 ± 0.7	0.50	4.30	random
Sue A + B	0.6	25	9	7.77-8.5	0.38 ± 0.6	0.16	4.30	random
Sue A + B	1.0	25	8	7.0-7.4	$y = 3.5789x + 11.086$ (0.993)	11.70	4.30	significant
Sue A + B	1.5	25	8	7.2-7.3	7.4 ± 1.8	3.79	4.30	random
Sue A + B	2.0	25	8	7.0-7.4	3.4 ± 0.5	3.84	4.30	random

Note 1: Linear regression equation where $x = \log$ time (hours) and $y =$ concentration of nickel (mg/L)

Blend 1 = 75% Sue C + 25% Cigar Lake

Blend 2 = 55% Midwest + 15% Sue A + B + 30% Cigar Lake

Nickel concentrations in tailings pore-waters and their statistical significance including *t*-test results at 25°C:
Results of the large scale laboratory tests.
 (page 2 of 3)

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of Trend (R^2) ^{Note} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
Sue A+B	2.5	25	8	7.0-7.3	$y=0.3817x+2.0782$ (0.982)	7.43	4.30	significant
Sue A+B	3.0	25	7	7.01-7.31	$y=6.3673x+31.151$ (0.999)	40.80	4.30	significant
Sue A+B	3.0	25	8	7.33-7.47	1.1 ± 0.6	0.37	4.30	random
Sue A+B	3.0	25	9	7.58-8.66	0.36 ± 0.6	0.14	4.30	random
Sue A+B	5.0	25	7	6.84-7.17	$y=6.9818x+24.098$ (0.965)	5.22	4.30	significant
Sue A+B	5.0	25	8	7.31-7.45	0.94 ± 0.7	0.41	4.30	random
Sue A+B	5.0	25	9	7.33-8.51	0.36 ± 0.6	0.14	4.30	random
Cigar Lake	7.5	25	7	4.74-5.73	7.6 ± 1.7	1.91	4.30	random
Cigar Lake	7.5	25	8	7.19-7.31	$y=0.051x+0.259$ (0.961)	4.98	4.30	significant
Cigar Lake	7.5	25	9	7.18-7.72	0.04 ± 0.03	3.83	4.30	random
Blend 1	7.6	25	7	6.04-6.84	7.2 ± 1.7	3.08	4.30	random
Blend 1	7.6	25	8	6.62-7.1	0.23 ± 0.02	0.11	4.30	random
Blend 1	7.6	25	9	6.76-7.73	0.03 ± 0.01	2.29	4.30	random
Blend 2	0.3	25	7	6.99-7.02	529 ± 59	3.70	4.30	random
Blend 2	0.3	25	8	7.43-7.56	11 ± 1.2	2.62	4.30	random
Blend 2	0.3	25	9	7.7-8.05	0.32 ± 0.04	2.70	4.30	random
Blend 2	1.0	25	8	6.8-7.4	20 ± 15	2.49	2.57	random
Blend 2	1.5	25	8	7.1-7.7	$y=3.7184x+1.8263$ (0.834)	4.49	2.57	significant
Blend 2	2.0	25	8	7.0-7.8	$y=2.5279x-1.0411$ (0.806)	4.08	2.57	significant

Note 1: Linear regression equation where $x = \log$ time (hours) and $y =$ concentration of nickel (mg/L)

Blend 1 = 75% Sue C + 25% Cigar Lake

Blend 2 = 55% Midwest + 15% Sue A+B + 30% Cigar Lake

Nickel concentrations in tailings pore-waters and their statistical significance including *t*-test results at 25°C:
Results of the large scale laboratory tests.
 (page 3 of 3)

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of Trend (R^2) ^{Note} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
Blend 2	2.5	25	8	6.9-7.8	$y=2.0376x-0.8927$ (0.898)	5.94	2.57	significant
Blend 2	3.0	25	7	6.68-7.05	53 ± 6.6	3.18	4.30	random
Blend 2	3.0	25	8	6.96-7.34	1.3 ± 0.08	0.92	4.30	random
Blend 2	3.0	25	9	7.29-8.4	0.05 ± 0.01	0.11	4.30	random
Blend 2	5.0	25	7	6.99-7.19	26 ± 3.6	1.85	4.30	random
Blend 2	5.0	25	8	6.98-7.3	0.53 ± 0.03	0.11	4.30	random
Blend 2	5.0	25	9	8.35-8.66	0.02 ± 0.01	0.11	4.30	random

Note 1: Linear regression equation where $x = \log$ time (hours) and $y =$ concentration of nickel (mg/L)

Blend 1 = 75% Sue C + 25% Cigar Lake

Blend 2 = 55% Midwest + 15% Sue A+B + 30% Cigar Lake

Nickel concentrations in tailings pore-waters and their statistical significance including *t*-test results at 50°C:
Results of the large scale laboratory tests.
 (page 1 of 3)

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of Trend (R^2) ^{Note} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
JEB	2.6	50	7	6.46-7.04	14 ± 2.7 $y = -0.1587x + 0.7222$ (0.952)	2.95	4.3	random
JEB	2.6	50	8	7.39-7.57	0.04 ± 0.006	4.43	4.3	significant
JEB	2.6	50	9	7.51-8.05	23 ± 3.9	1.33	4.3	random
JEB	3.0	50	7	6.35-6.96	1.4 (one point)	2.27	4.3	random
JEB	3.0	50	8	6.93	0.1 ± 0.14	na	na	na
JEB	3.0	50	9	7.68-7.84	19 ± 0.67	2.36	4.3	random
JEB	5.0	50	7	6.6-6.65	$y = -0.1151x + 0.6743$ (0.959)	0.18	4.3	random
JEB	5.0	50	8	7.34-7.44	0.04 ± 0.006	4.81	4.3	significant
JEB	5.0	50	9	7.52-7.96	16 ± 3.3	2.36	4.3	random
Sue C	7.7	50	7	6.18-6.89	$y = -0.1748x + 0.6904$ (0.976)	1.86	4.3	random
Sue C	7.7	50	8	7.17-7.34	0.02 ± 0.006	6.43	4.3	significant
Sue C	7.7	50	9	7.79-8.11	5.8 ± 0.37	1.41	4.3	random
McClean Lake	4.6	50	7	6.87-7.11	$y = 0.0219x + 0.2153$ (0.965)	1.15	4.3	random
McClean Lake	4.6	50	8	7.27-7.54	$y = 0.0107x + 0.0263$ (0.991)	5.27	4.3	significant
McClean Lake	4.6	50	9	7.78-8.15	$y = 1.6358x + 10.106$ (0.982)	10.67	4.3	significant
McClean Lake	5.0	50	7	6.85-7.17	0.2 ± 0.03	7.43	4.3	significant
McClean Lake	5.0	50	8	7.18-7.55	$y = 0.0107x + 0.0263$ (0.991)	1.41	4.3	random
McClean Lake	5.0	50	9	7.4-8.64		10.67	4.3	significant

Note 1: Linear regression equation where x = log time (hours) and y = concentration of nickel (mg/L)
 Blend 1 = 75% Sue C + 25% Cigar Lake
 Blend 2 = 55% Midwest + 15% Sue A+B + 30% Cigar Lake

Nickel concentrations in tailings pore-waters and their statistical significance including *t*-test results at 50°C:
Results of the large scale laboratory tests.
 (page 2 of 3)

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of Trend (R^2) ^{Note} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
Sue A + B	0.6	50	7	6.64-7.07	$y = 18.046x + 129.9$ (0.974)	6.07	4.3	significant
Sue A + B	0.6	50	8	7.1-7.7	2.9 ± 0.51	0.08	4.3	random
Sue A + B	0.6	50	9	7.54-8.45	0.4 ± 0.6	0.23	4.3	random
Sue A + B	3.0	50	7	6.85-7.33	58 ± 24	2.53	4.3	random
Sue A + B	3.0	50	8	7.57-7.63	1.6 ± 0.7	1.47	4.3	random
Sue A + B	3.0	50	9	7.31-8.63	0.5 ± 0.5	0.37	4.3	random
Sue A + B	5.0	50	7	6.78-7.33	75 ± 50	2.97	4.3	random
Sue A + B	5.0	50	8	7.06-7.61	1.7 ± 0.95	3.18	4.3	random
Sue A + B	5.0	50	9	7.33-8.39	0.4 ± 0.6	0.18	4.3	random
Cigar Lake	7.5	50	7	4.63-5.52	$y = 5.0069x + 6.1539$ (0.993)	11.8	4.3	significant
Cigar Lake	7.5	50	8	7.19-7.38	0.5 ± 0.1	0.62	4.3	random
Cigar Lake	7.5	50	9	7.47-7.64	0.05 ± 0.02	1.33	4.3	random
Blend 1	7.6	50	7	5.75-7.03	$y = 4.0675x + 4.3949$ (0.991)	10.2	4.3	significant
Blend 1	7.6	50	8	6.7-7.29	$y = -0.1139x + 0.4395$ (0.989)	9.57	4.3	significant
Blend 1	7.6	50	9	7.37-7.77	$y = -0.0578x + 0.1224$ (0.956)	4.68	4.3	significant
Blend 2	0.3	50	7	6.37-7.04	$y = 84.395x + 453.88$ (0.998)	19.97	4.3	significant
Blend 2	0.3	50	8	7.34-7.71	10 ± 0.2	0.87	4.3	random
Blend 2	0.3	50	9	7.83-7.96	0.3 ± 0.02	2.34	4.3	random

Note 1: Linear regression equation where $x = \log$ time (hours) and $y =$ concentration of nickel (mg/L)

Blend 1 = 75% Sue C + 25% Cigar Lake

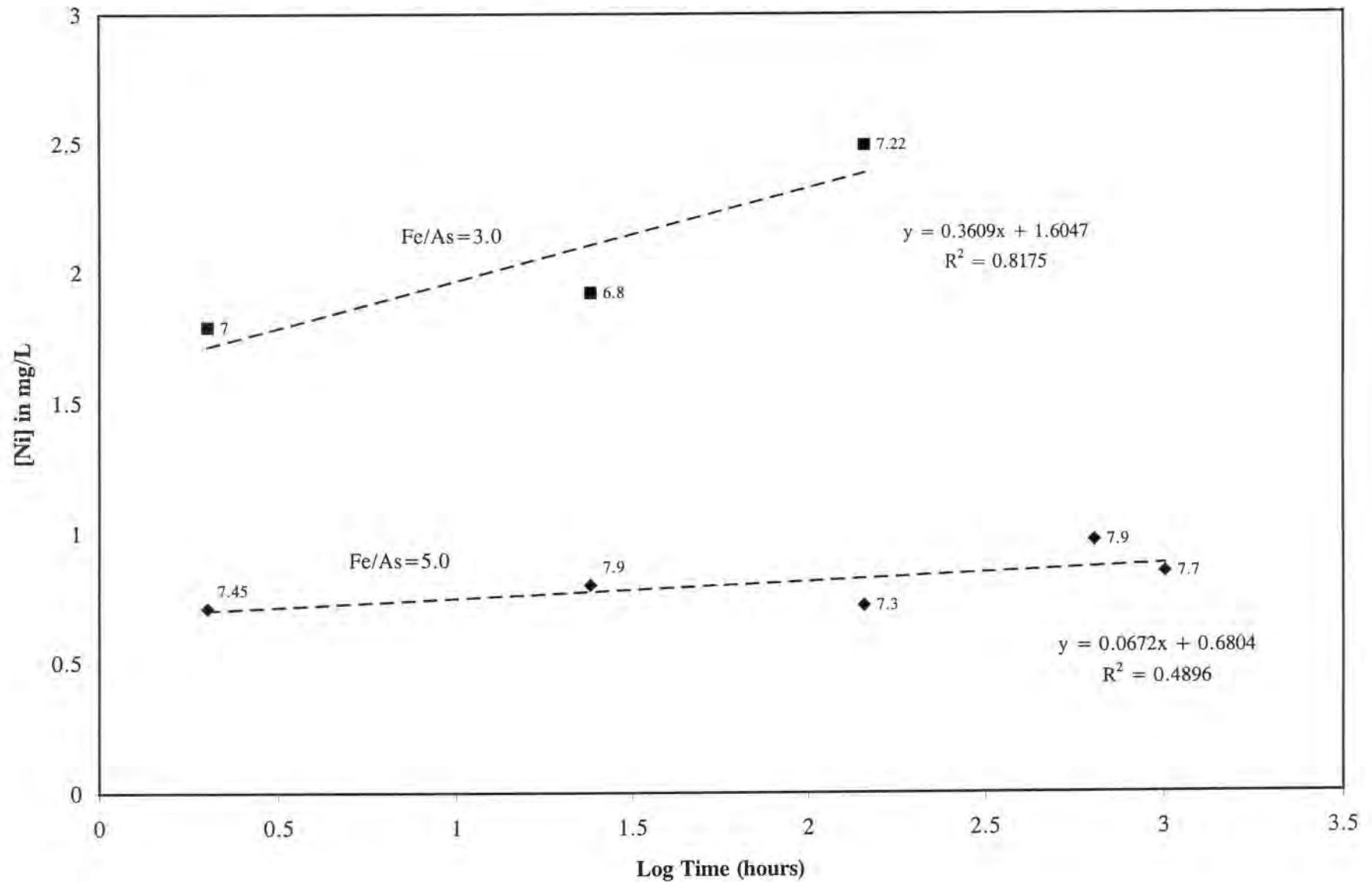
Blend 2 = 55% Midwest + 15% Sue A + B + 30% Cigar Lake

Nickel concentrations in tailings pore-waters and their statistical significance including *t*-test results at 50°C:
Results of the large scale laboratory tests.
 (page 3 of 3)

Tailings	Fe/As (molar)	T (°C)	Nominal pH	Measured pH range	Equation of Trend (R^2) ^{Note} or Average value +/- 1 standard deviation	<i>t</i> -test statistic	Value of <i>t</i> for a confidence interval of 95% (1 degree of freedom)	Data are random or have a significant trend:
Blend 2	3.0	50	7	7.1-7.2	$y = 24.867x + 37.996$ (0.997)	19.22	4.3	significant
Blend 2	3.0	50	8	7.44-7.62	1.9 ± 0.5	2.54	4.3	random
Blend 2	3.0	50	9	7.3-8.36	0.1 ± 0.02	1.33	4.3	random
Blend 2	5.0	50	7	6.97-7.39	$y = 14.205x + 20.395$ (0.988)	9.11	4.3	significant
Blend 2	5.0	50	8	7.48-7.75	0.9 ± 0.2	3.67	4.3	random
Blend 2	5.0	50	9	8.11-8.48	0.3 ± 0.3	2.1	4.3	random

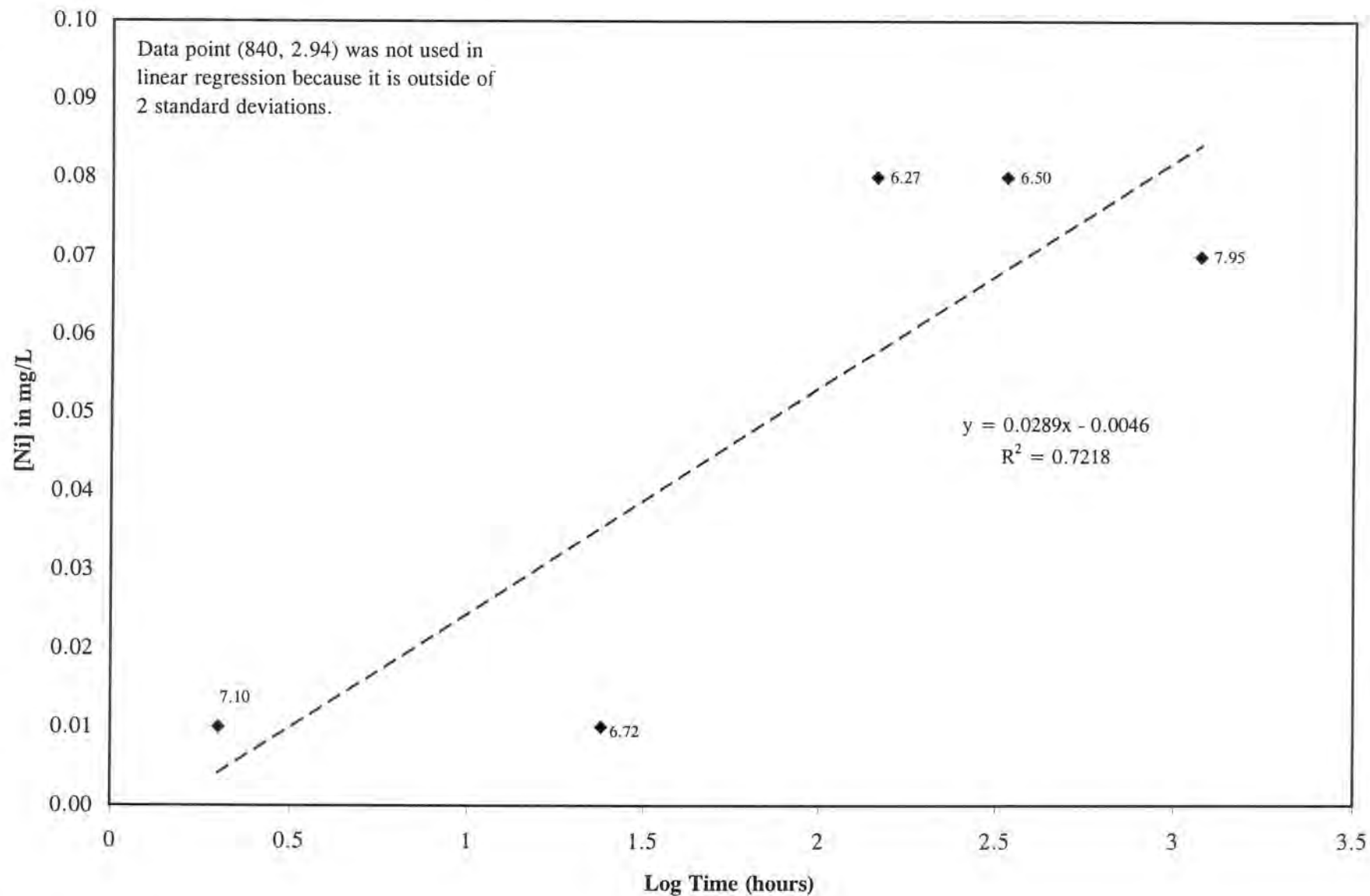
Note 1: Linear regression equation where $x = \log$ time (hours) and $y =$ concentration of nickel (mg/L)
 Blend 1 = 75% Sue C + 25% Cigar Lake
 Blend 2 = 55% Midwest + 15% Sue A+B + 30% Cigar Lake

Nickel concentration as a function of time during long-term tests of JEB tailings at 4°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 8. ^{Note 1}



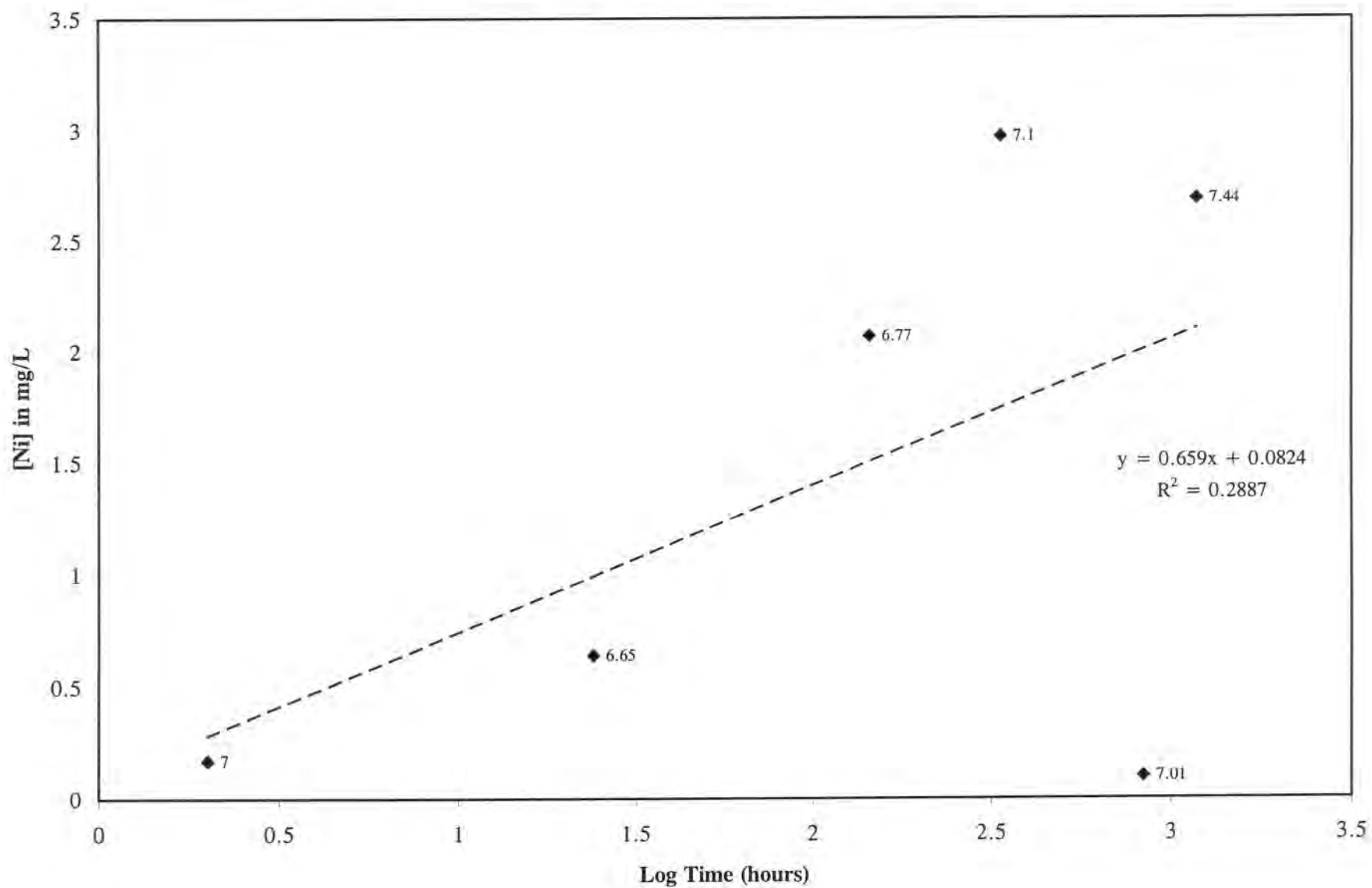
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Sue C tailings at 4°C, for molar Fe/As ratio of 7.7 and nominal pH 8. ^{Note 1}



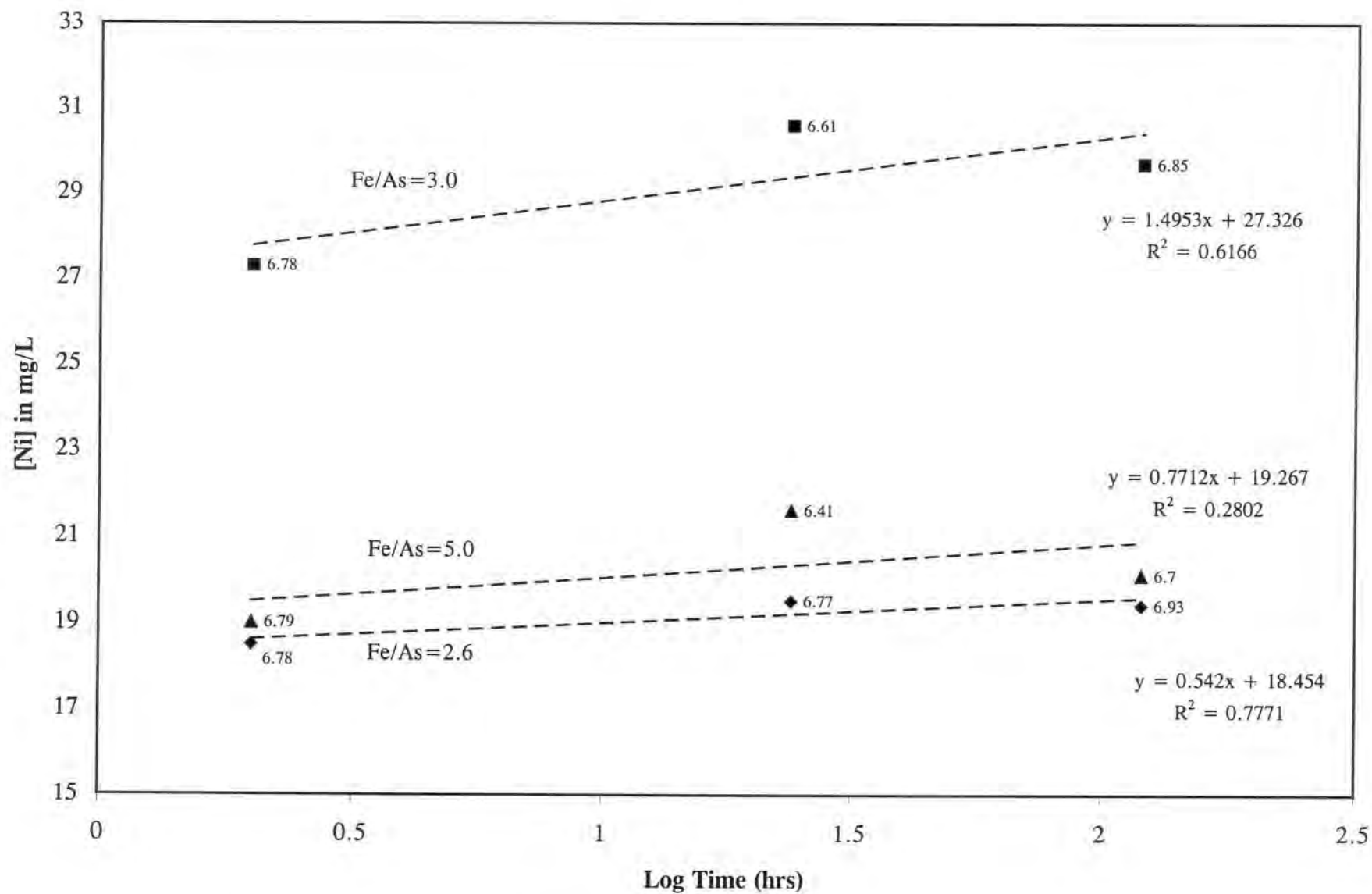
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point

Nickel concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 4°C, for molar Fe/As ratio of 3.0 and nominal pH 8. ^{Note 1}



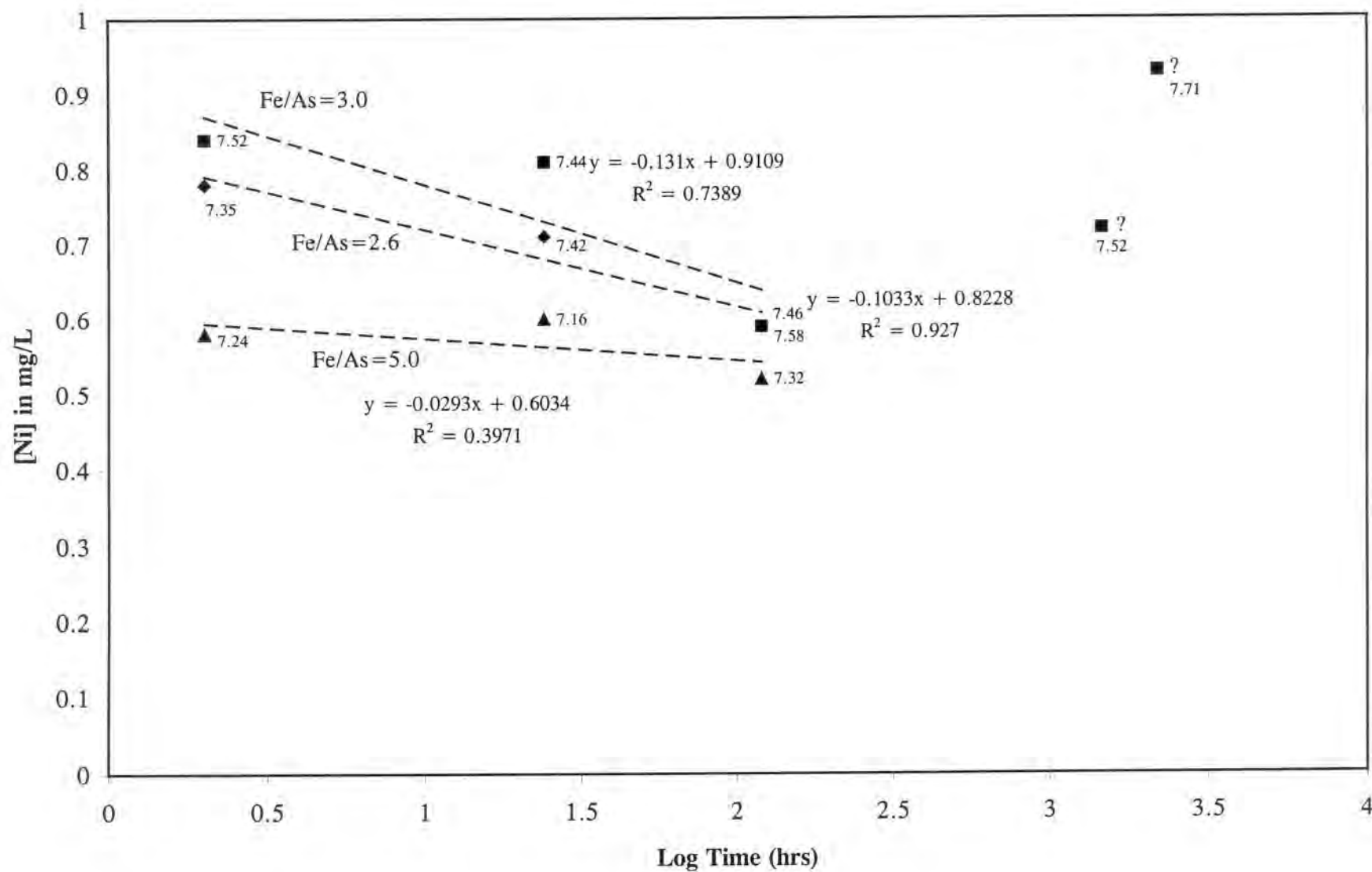
Note 1. The equations shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of JEB tailings at 25°C, for molar Fe/As ratios of 2.6, 3.0, and 5.0 and nominal pH 7. ^{Note 1}



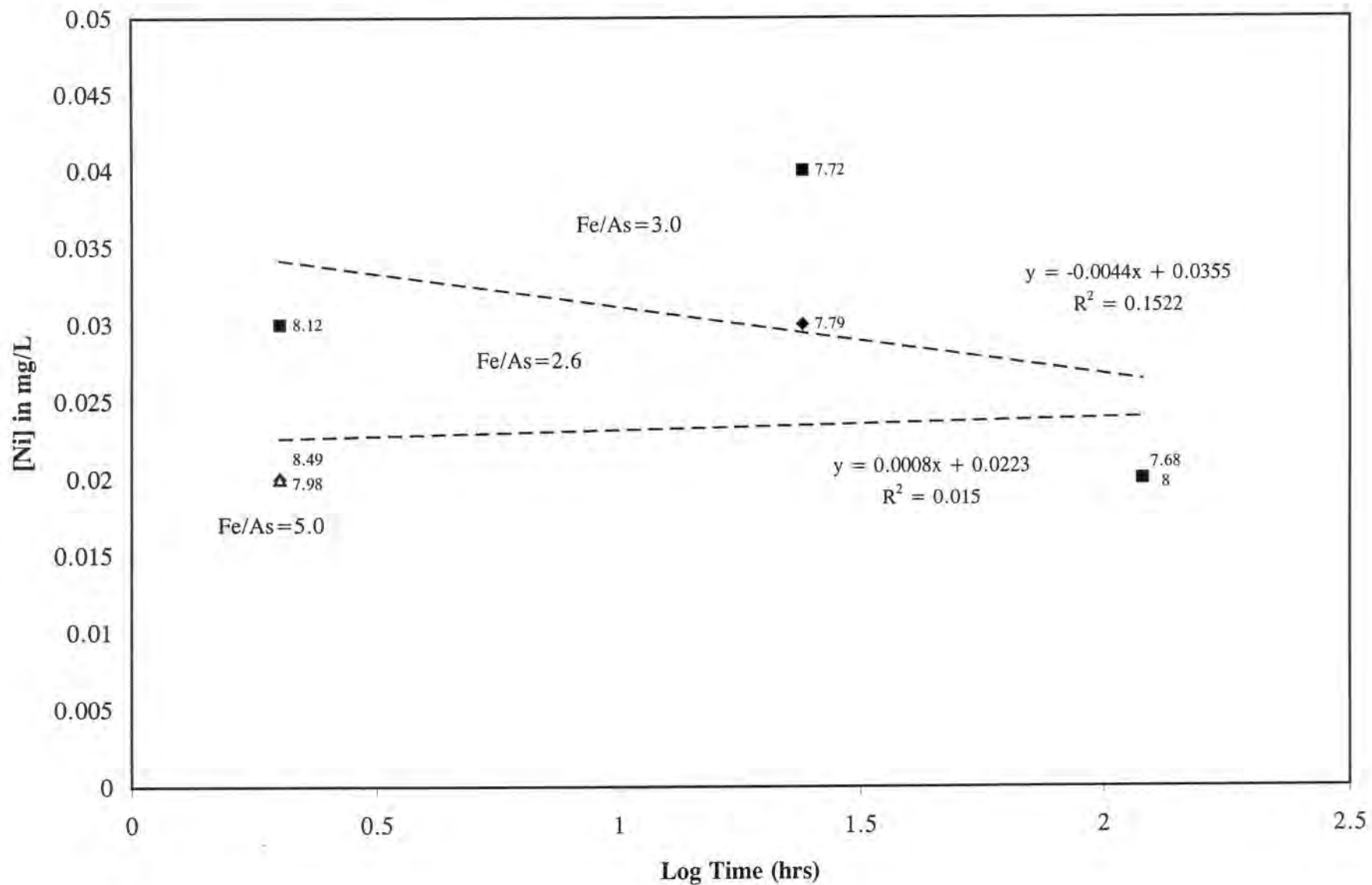
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of JEB tailings at 25°C, for molar Fe/As ratios of 2.6, 3.0, and 5.0 and nominal pH 8. ^{Note 1}



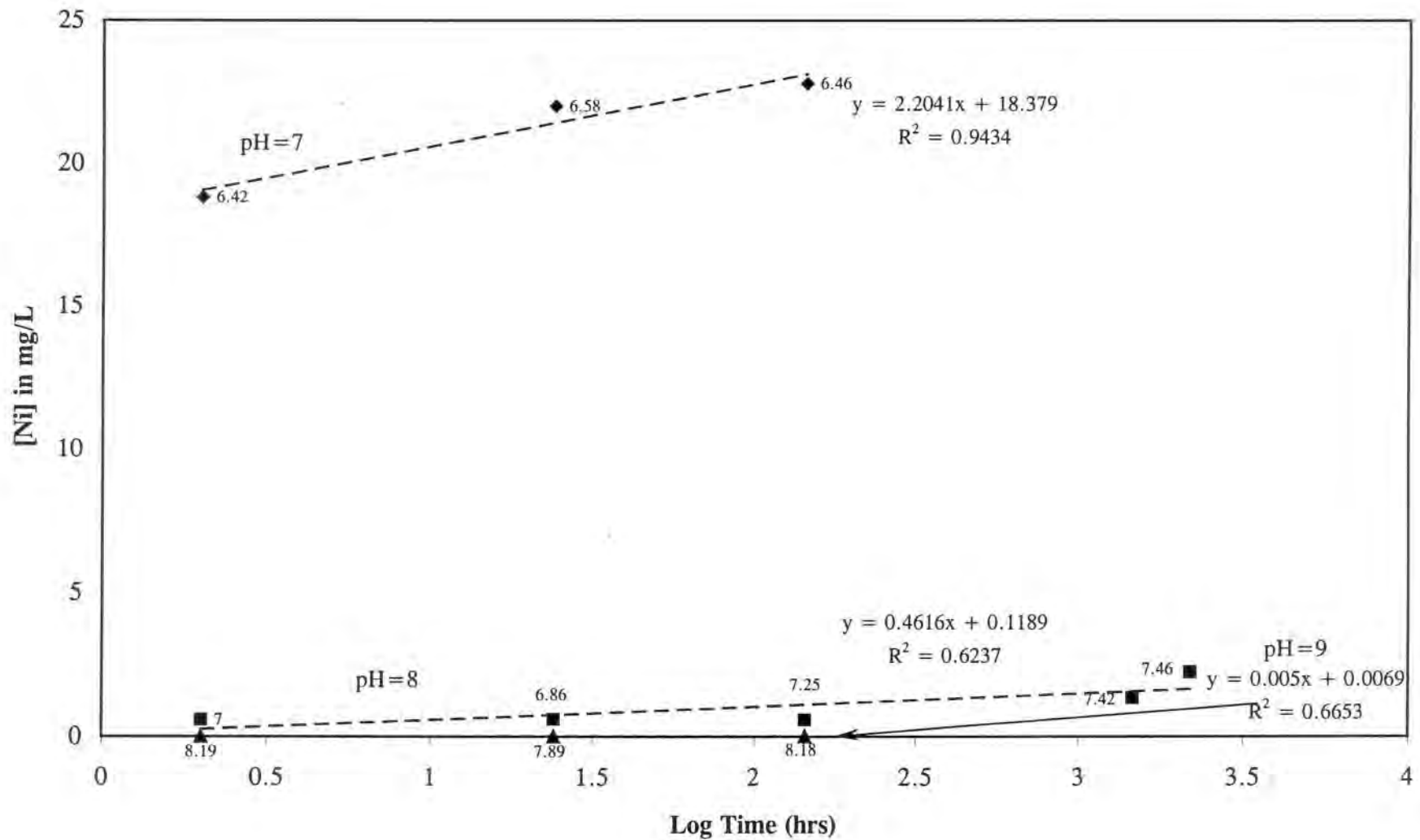
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of JEB tailings at 25°C, for molar Fe/As ratios of 2.6, 3.0, and 5.0 and nominal pH 9. ^{Note 1}



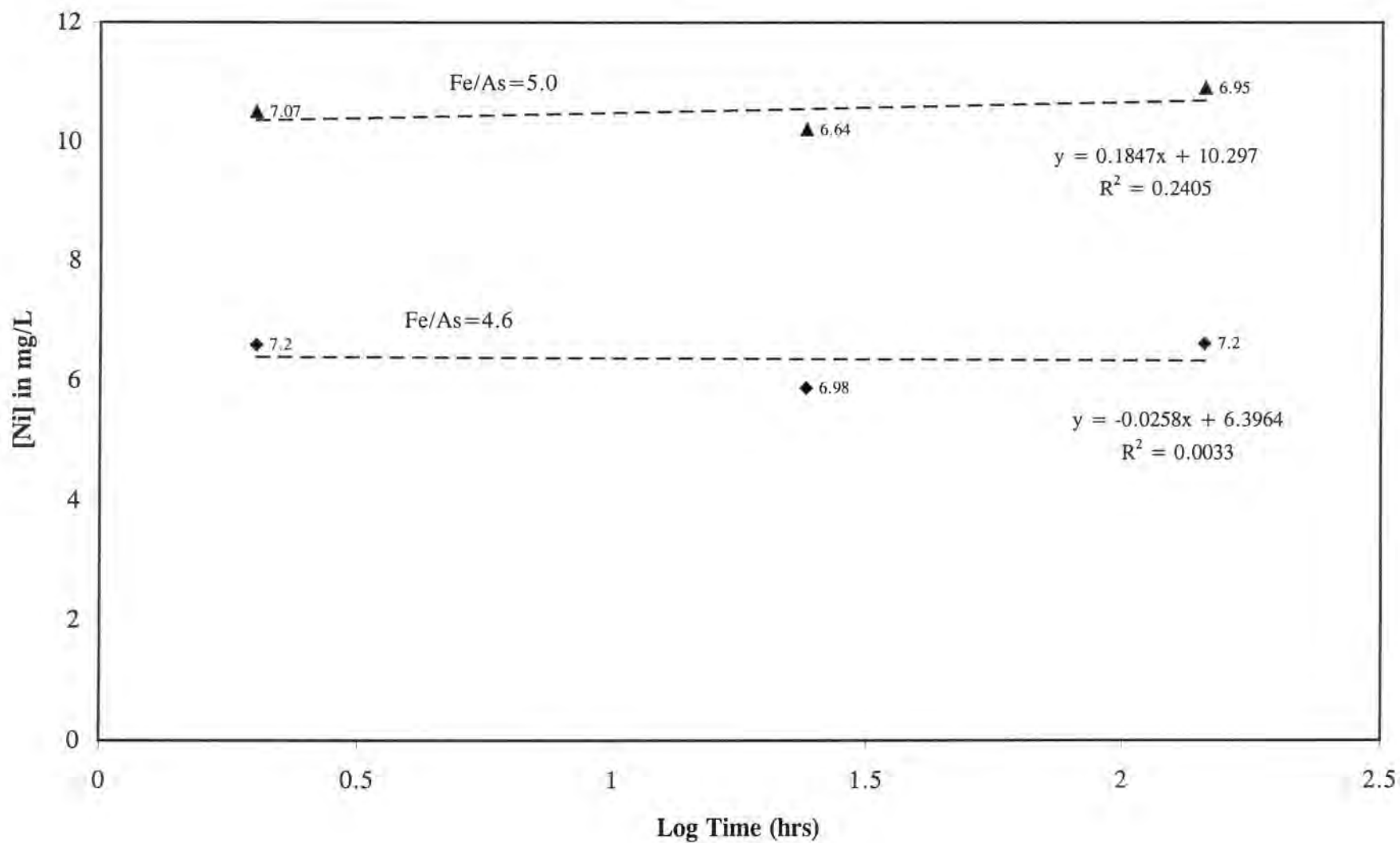
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Sue C tailings at 25°C, for molar Fe/As ratio of 7.7 and nominal pH 7, 8, and 9. ^{Note 1}



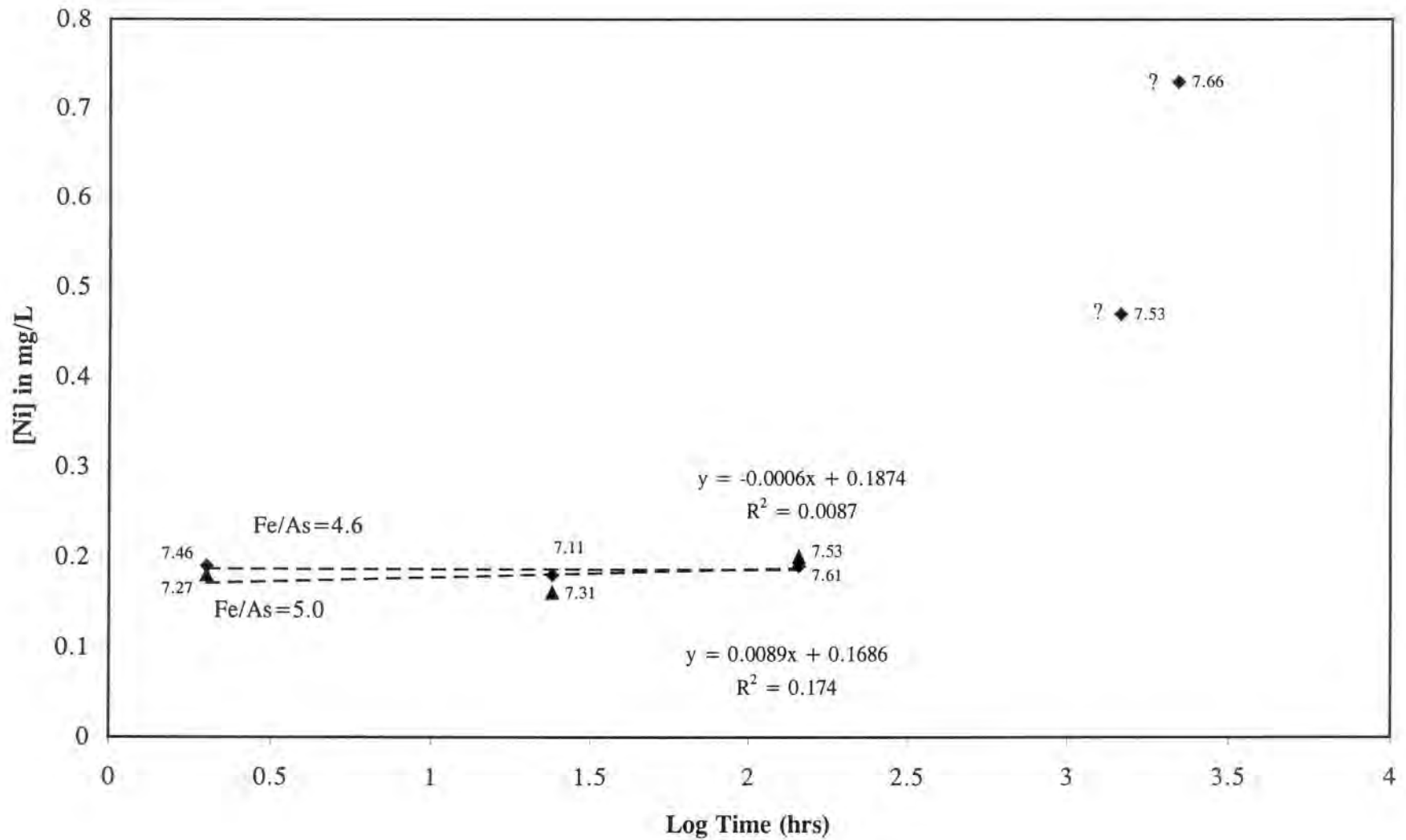
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of McClean Lake tailings at 25°C, for molar Fe/As ratios of 4.6 and 5.0 and nominal pH 7. ^{Note 1}



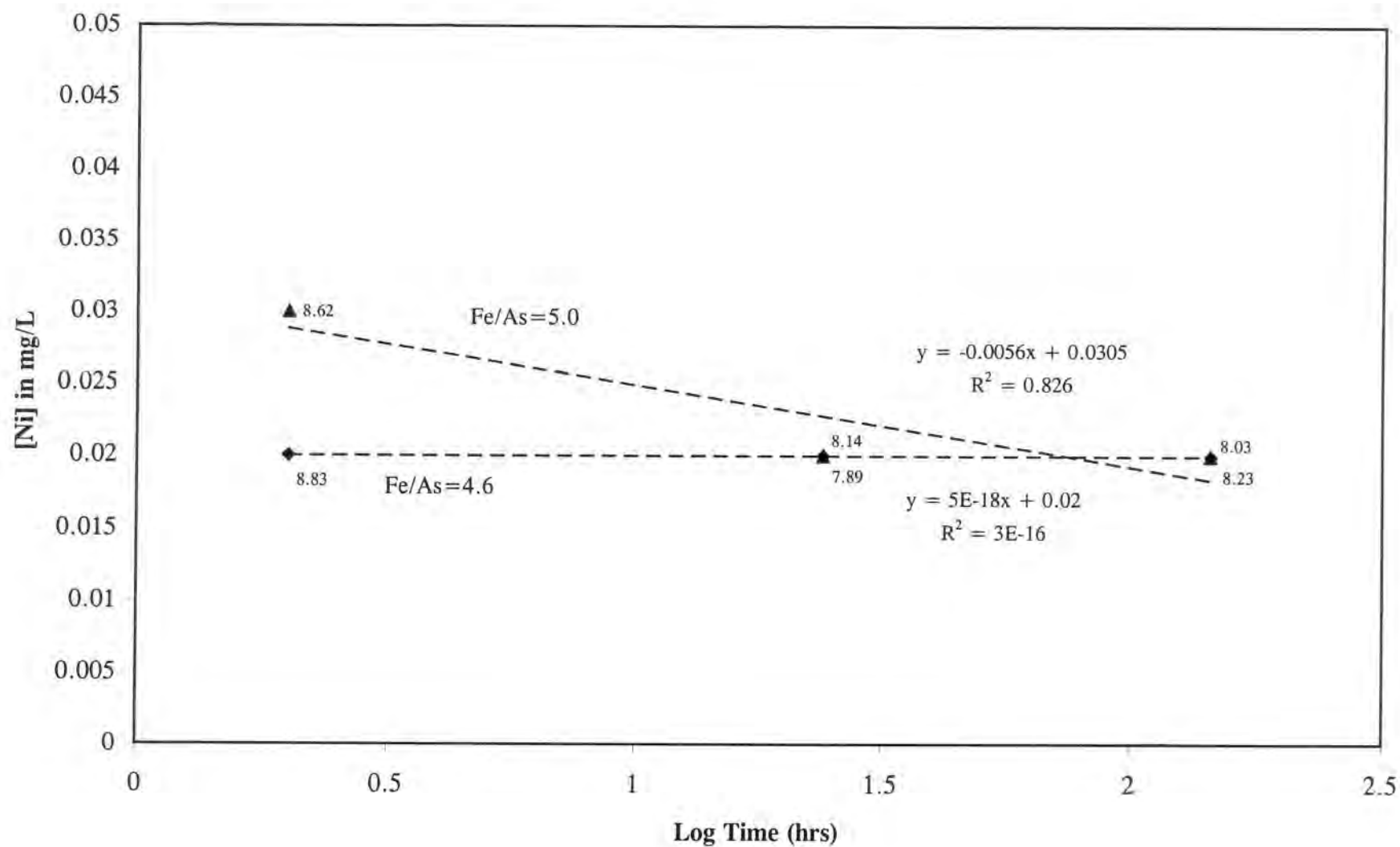
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of McClean Lake tailings at 25°C, for molar Fe/As ratios of 4.6 and 5.0 and nominal pH 8. ^{Note 1}



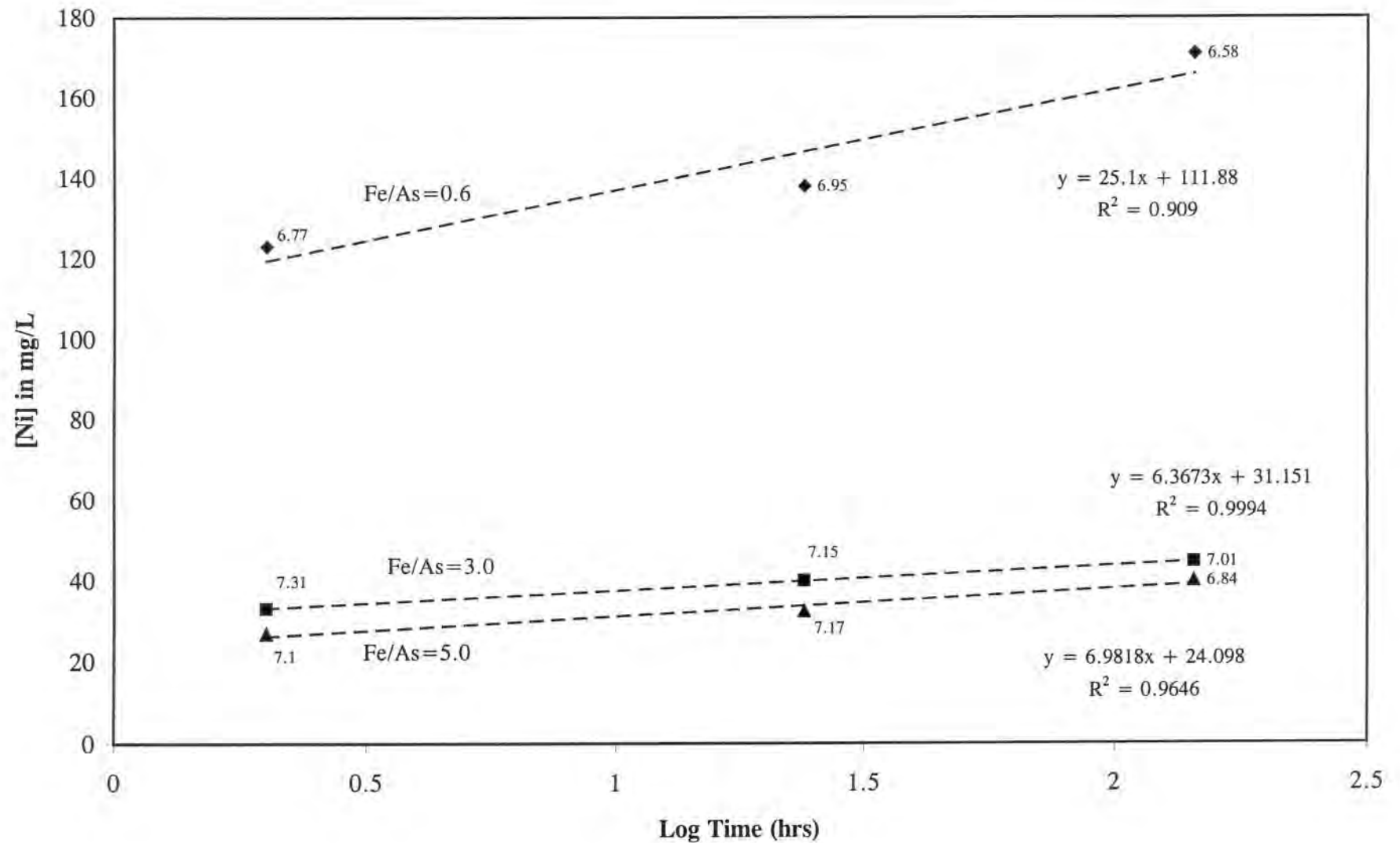
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of McClean Lake tailings at 25°C, for molar Fe/As ratios of 4.6 and 5.0 and nominal pH 9. ^{Note 1}



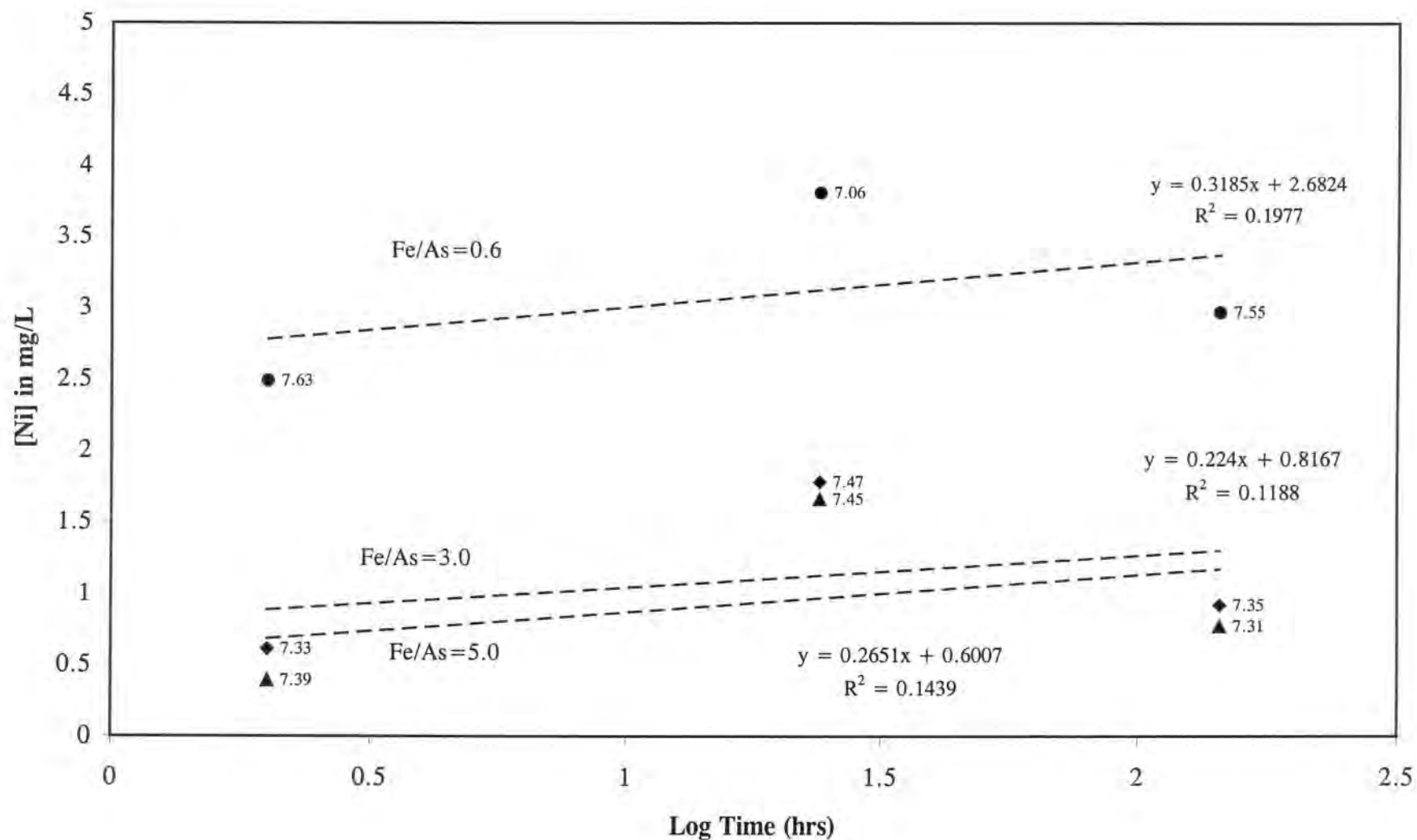
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Sue A+B tailings at 25°C, for molar Fe/As ratios of 0.6, 3.0, and 5.0 and nominal pH 7. ^{Note 1}



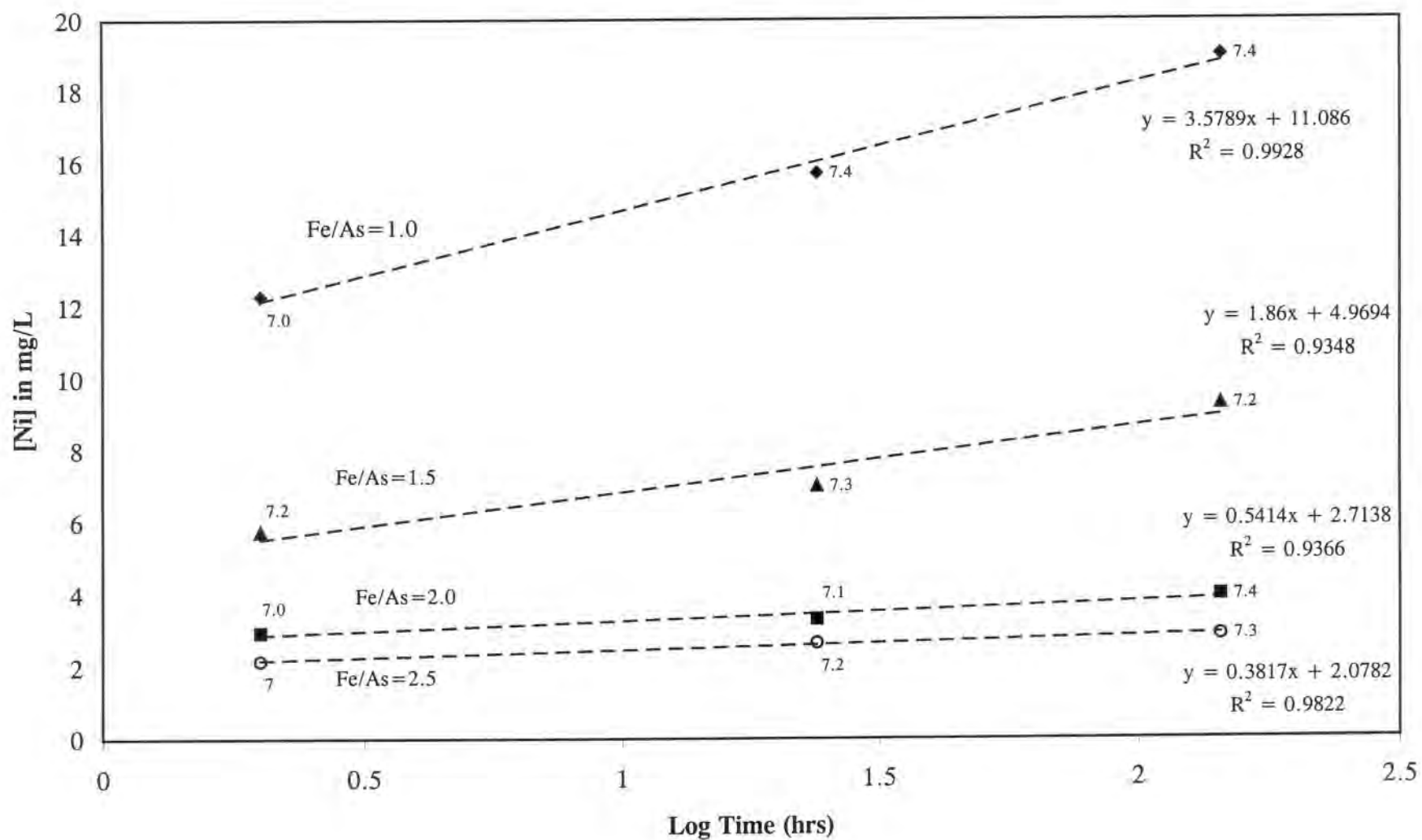
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Sue A+B tailings at 25°C, for molar Fe/As ratios of 0.6, 3.0, and 5.0 and nominal pH 8. ^{Note 1}



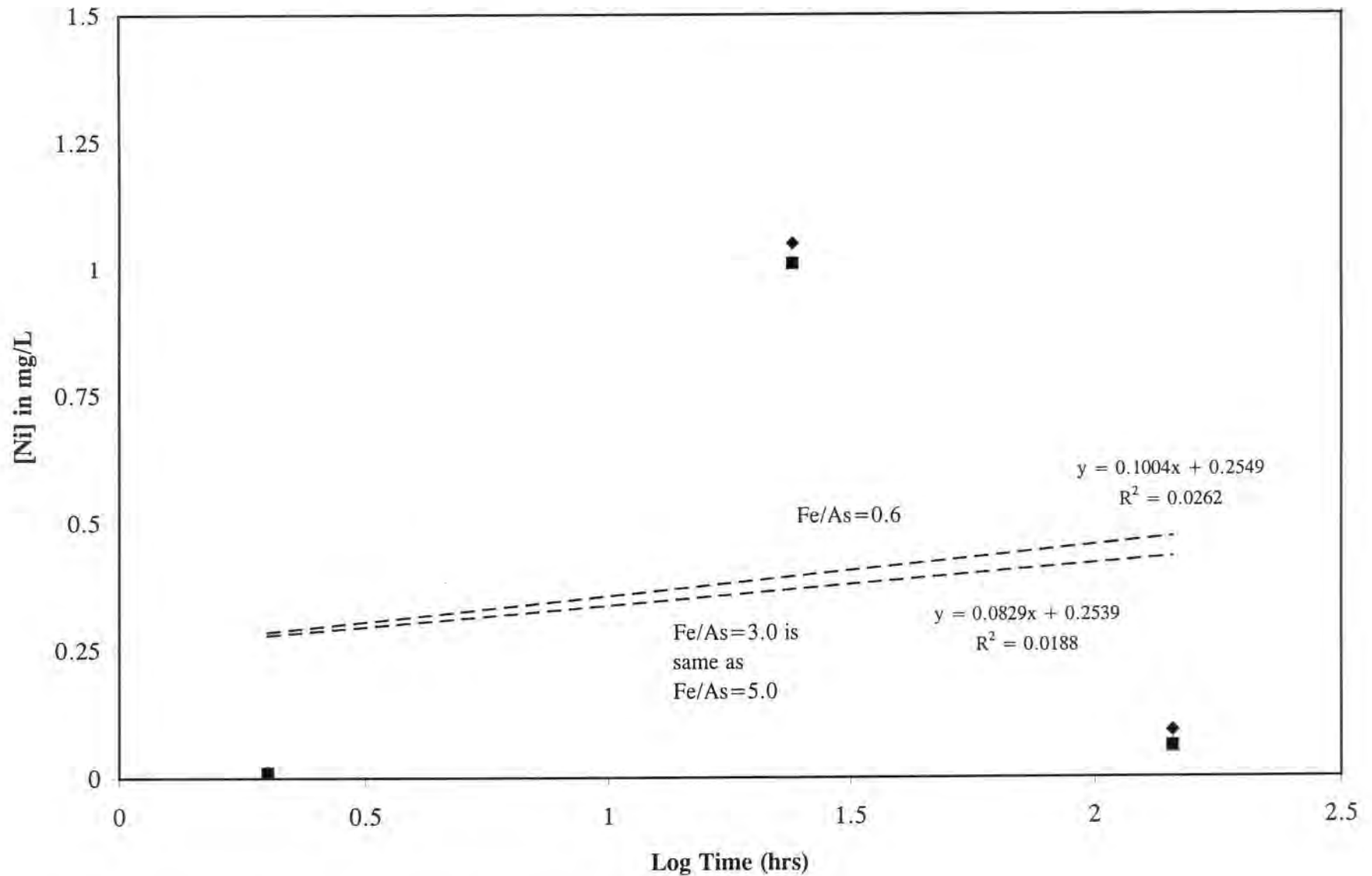
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Sue A+B tailings at 25°C, for molar Fe/As ratios of 1.0, 1.5, 2.0, and 2.5 and nominal pH 8. ^{Note 1}



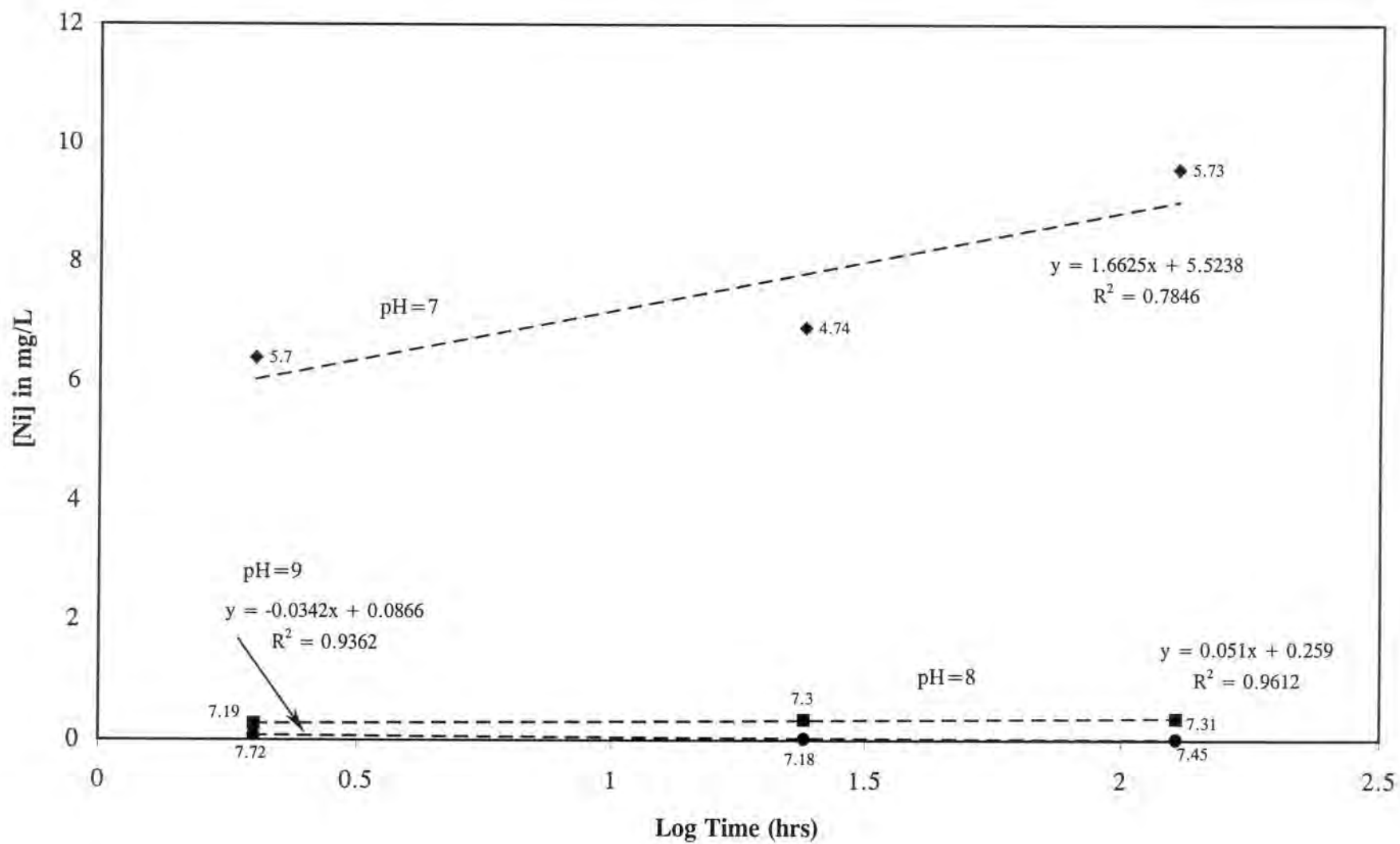
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Sue A+B tailings at 25°C, for molar Fe/As ratios of 0.6, 3.0, and 5.0 and nominal pH 9. ^{Note 1}



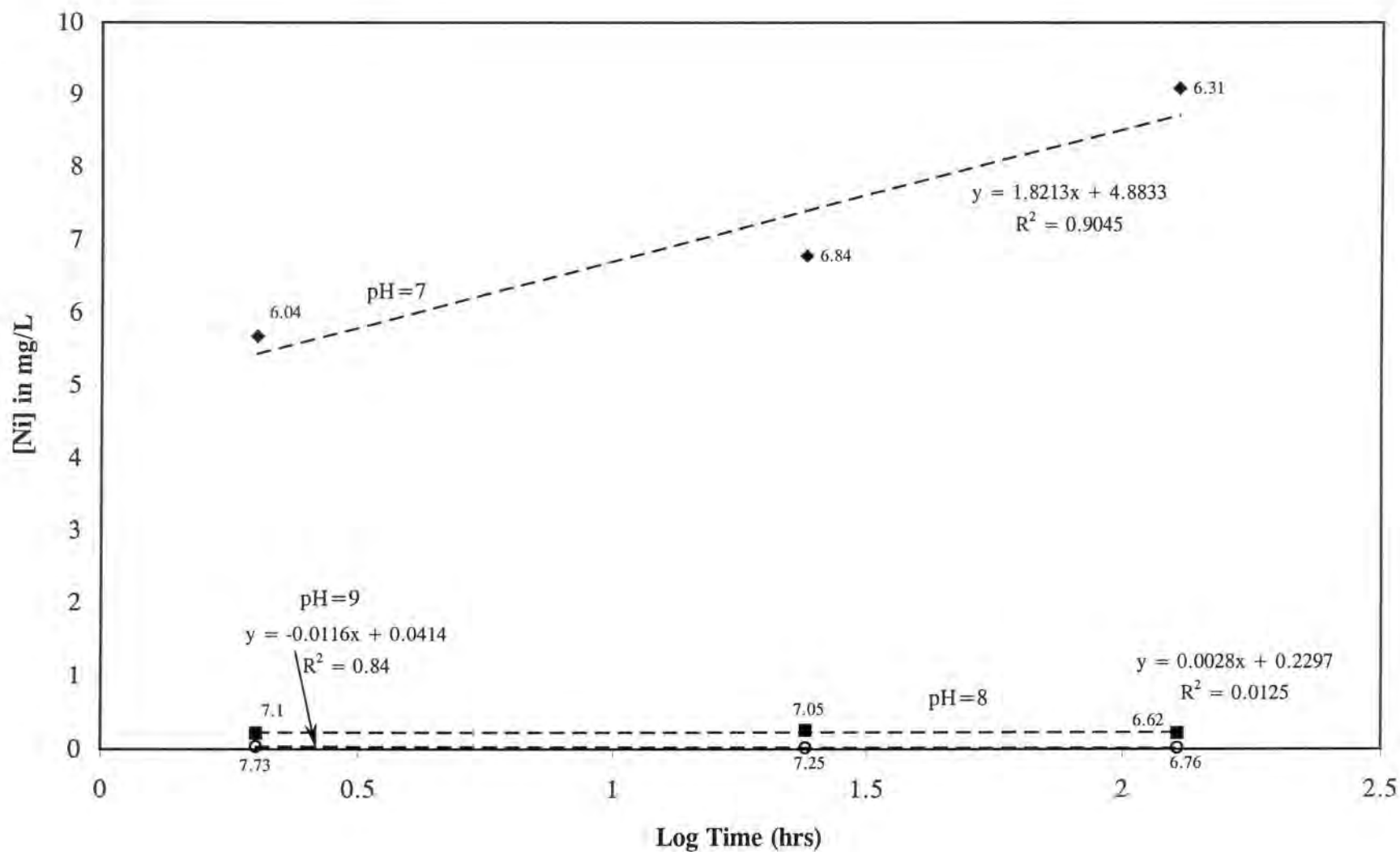
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Cigar Lake tailings at 25°C, for molar Fe/As ratios of 7.5 and nominal pH 7, 8, and 9. ^{Note 1}



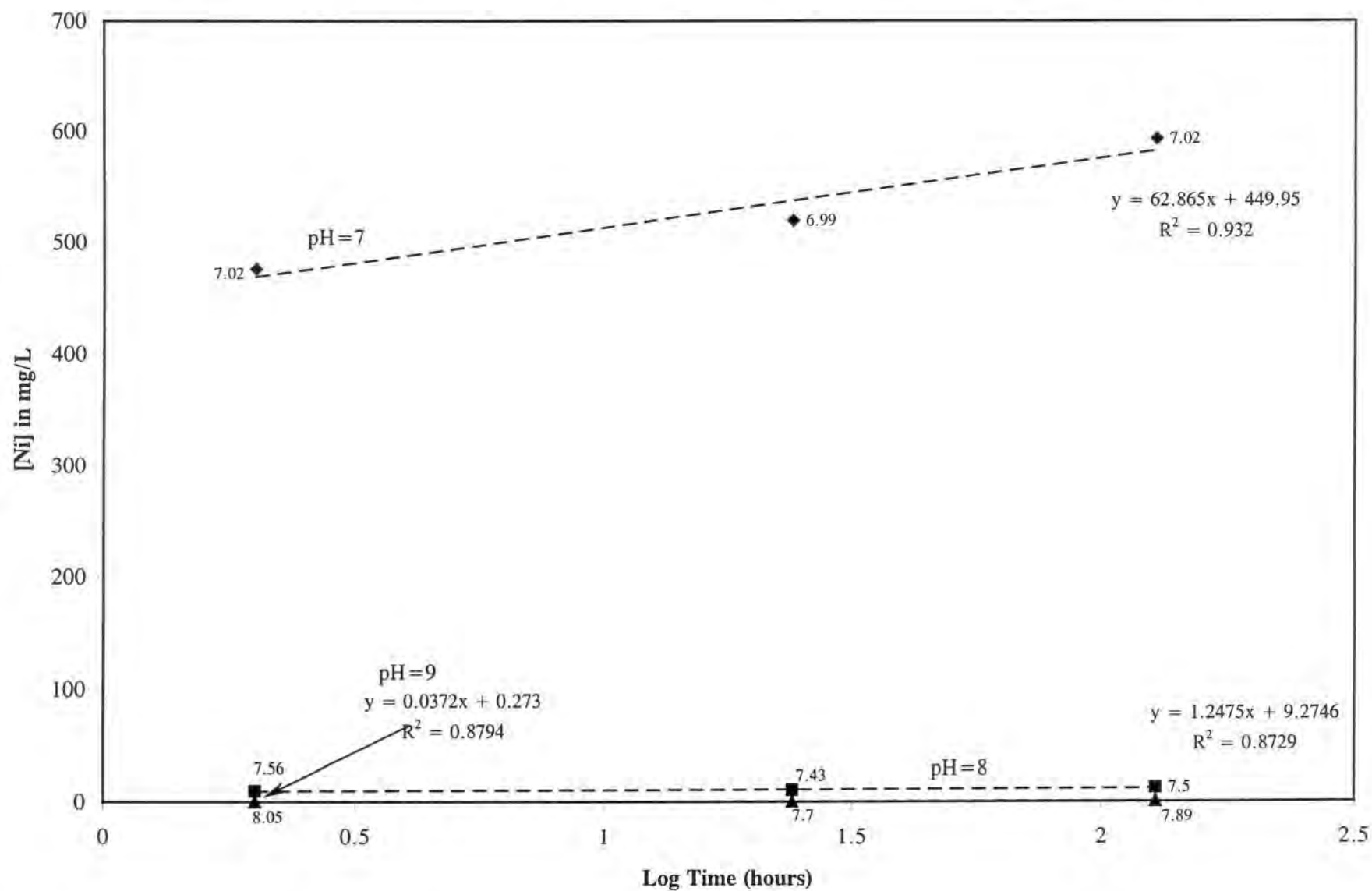
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Blend 1 (75% Sue C + 25% Cigar Lake) tailings at 25°C, for molar Fe/As ratios of 7.6 and nominal pH 7, 8, and 9. ^{Note 1}



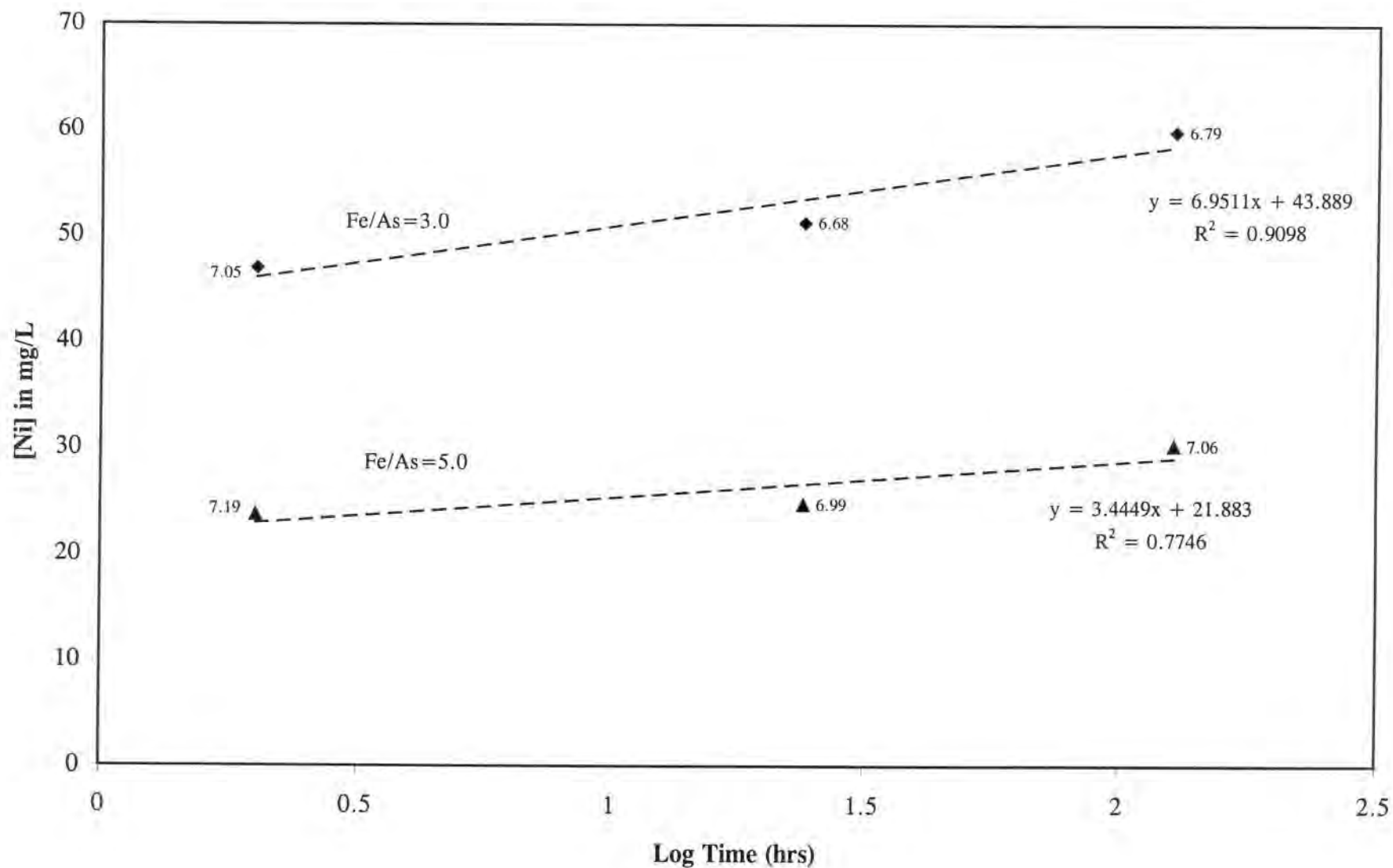
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 25°C, for molar Fe/As ratios of 0.3 and nominal pH 7, 8, and 9. ^{Note 1}



Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

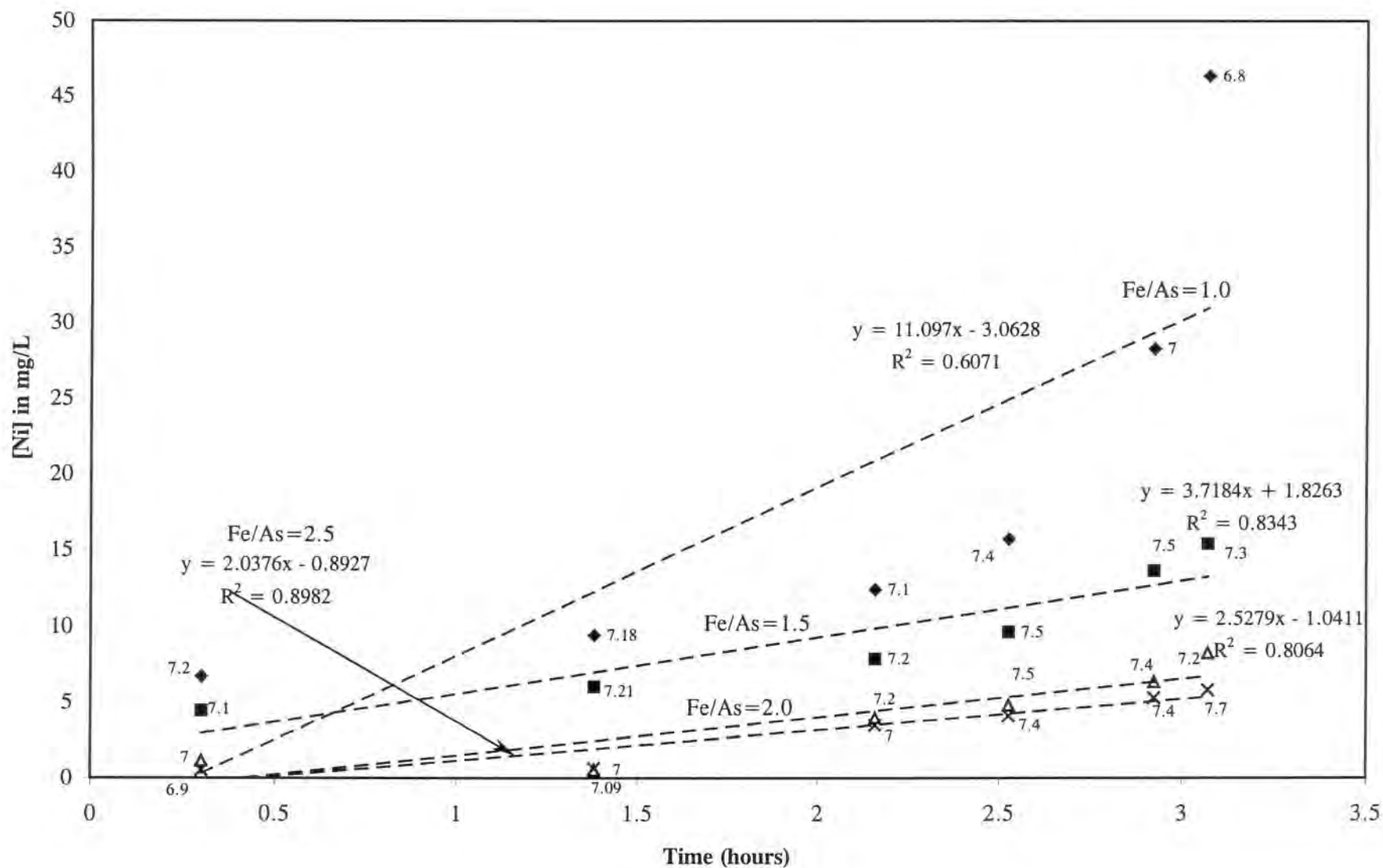
Nickel concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 25°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 7. ^{Note 1}



Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

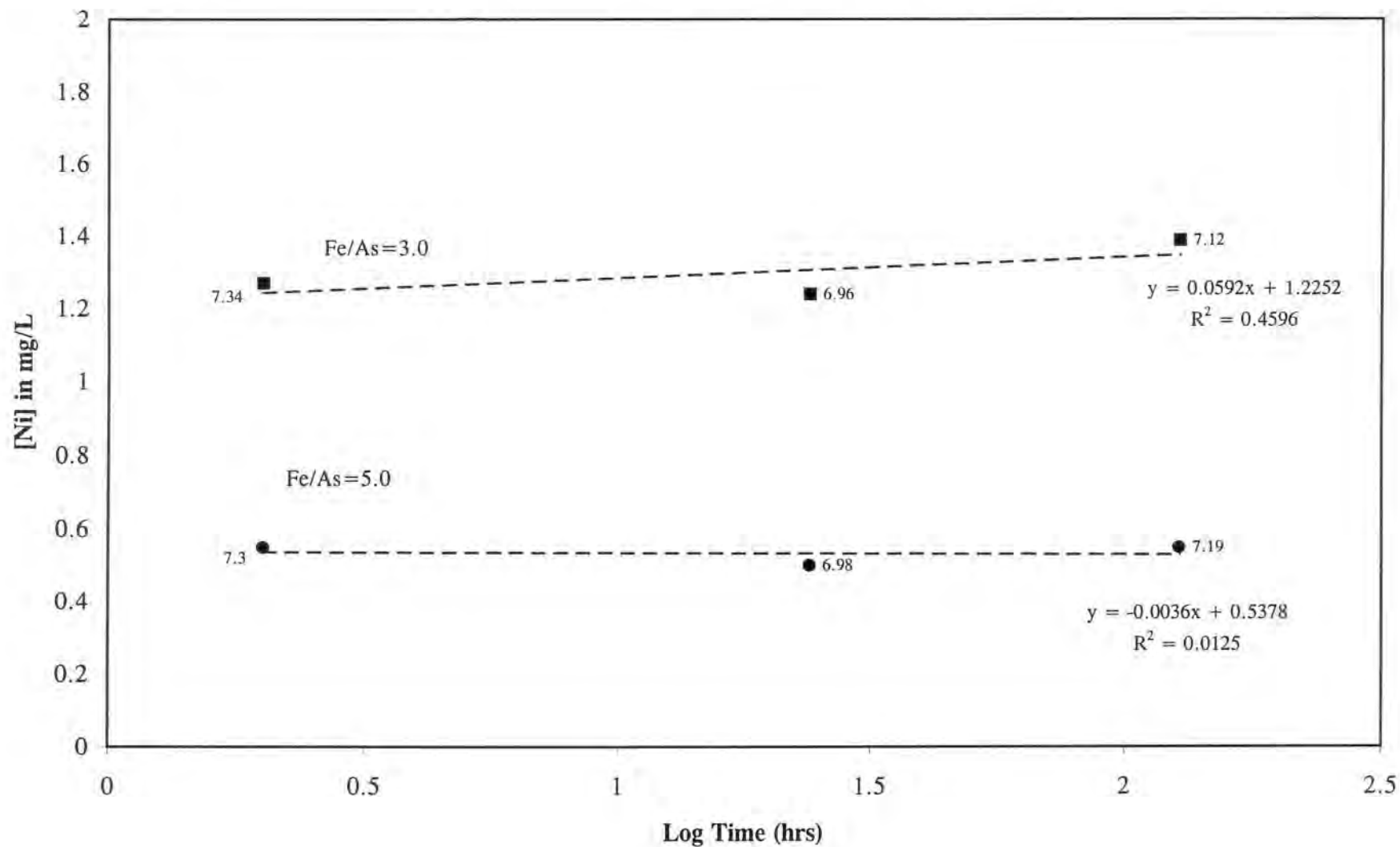
Nickel concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 25°C, for molar Fe/As ratios of 1.0, 1.5, 2.0, and 2.5 and nominal pH 8.

Note 1



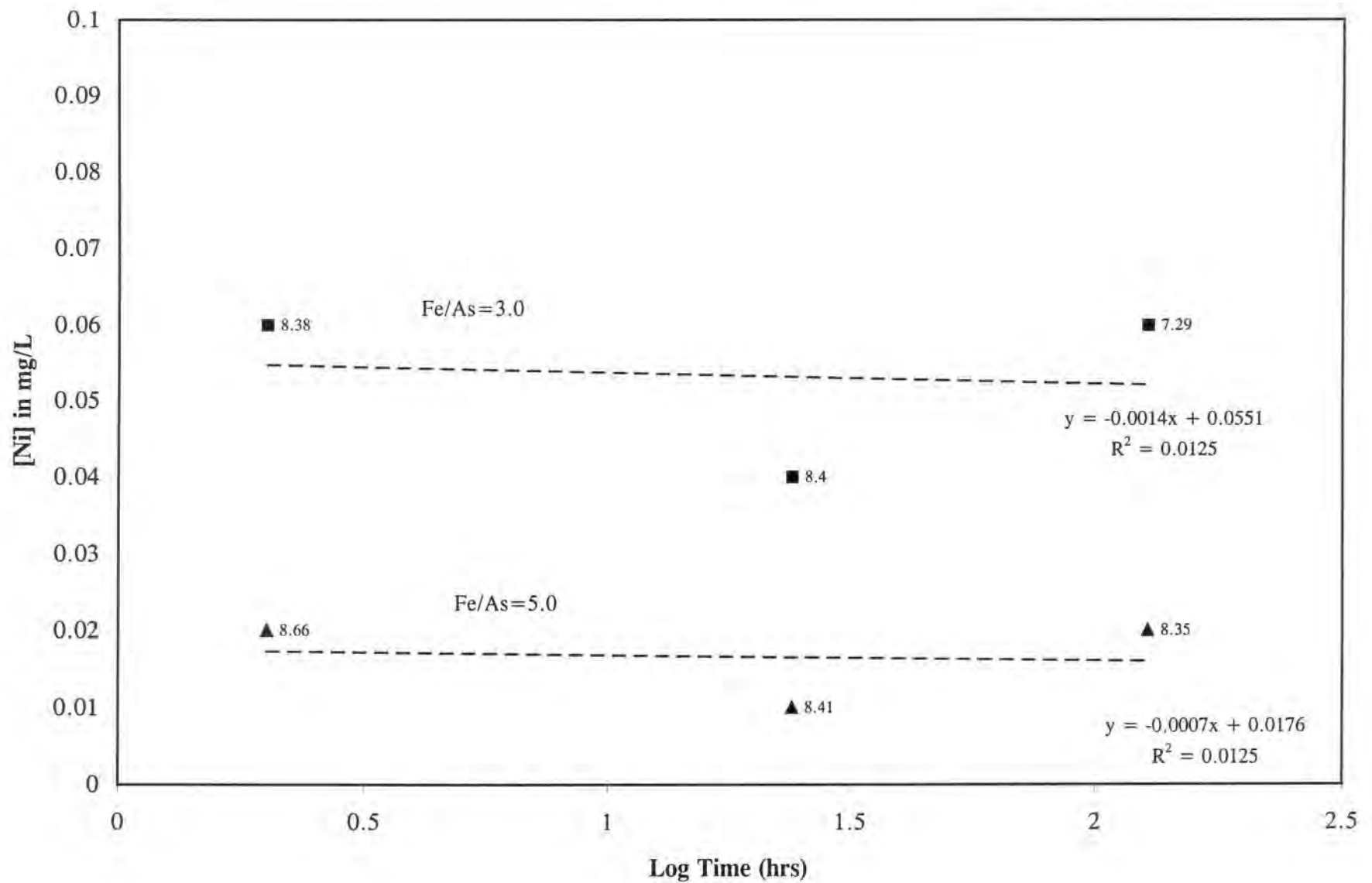
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 25°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 8. ^{Note 1}



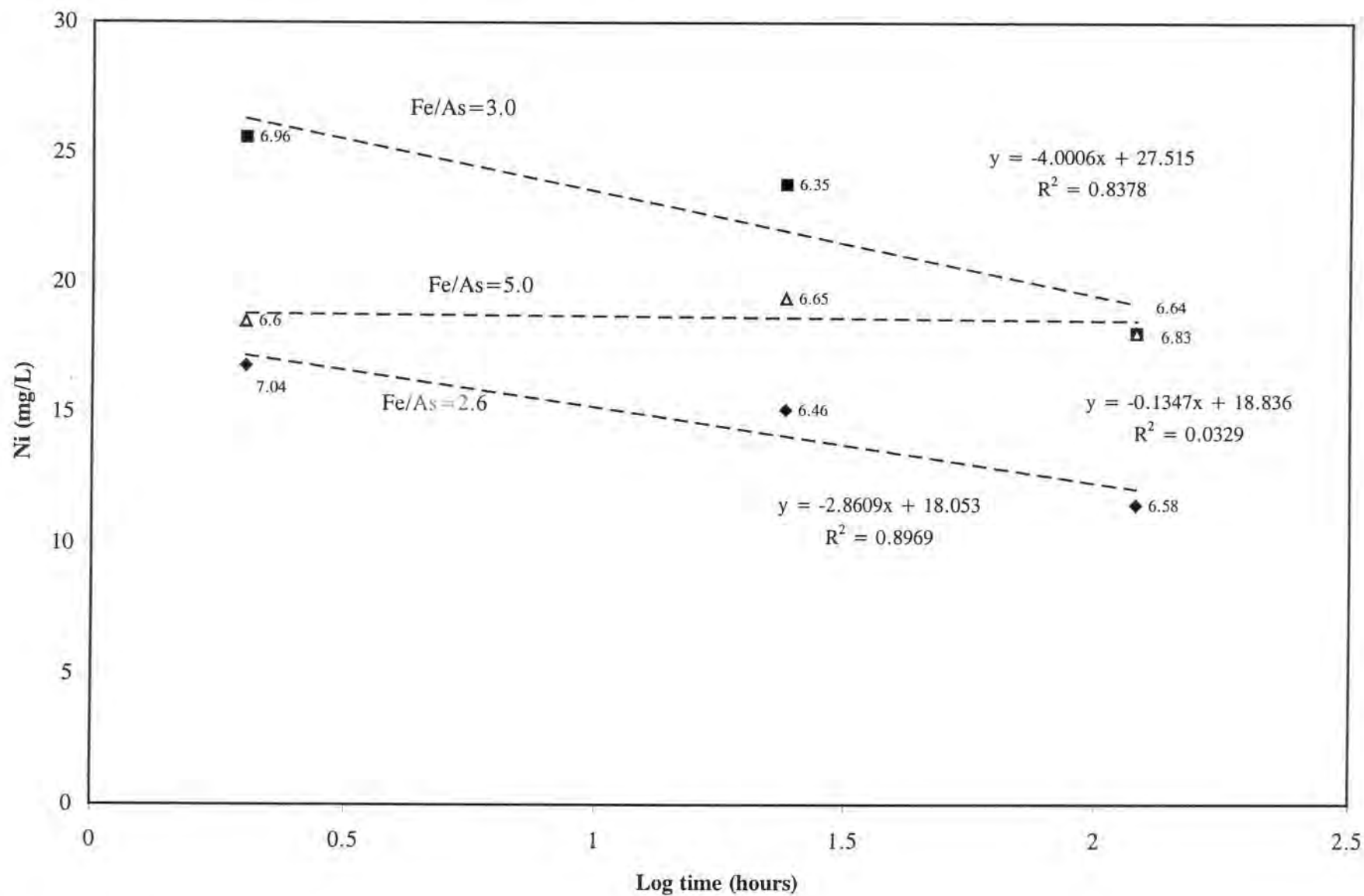
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 25°C, for molar Fe/As ratios of 3.0 and 5.0 and nominal pH 9. ^{Note 1}



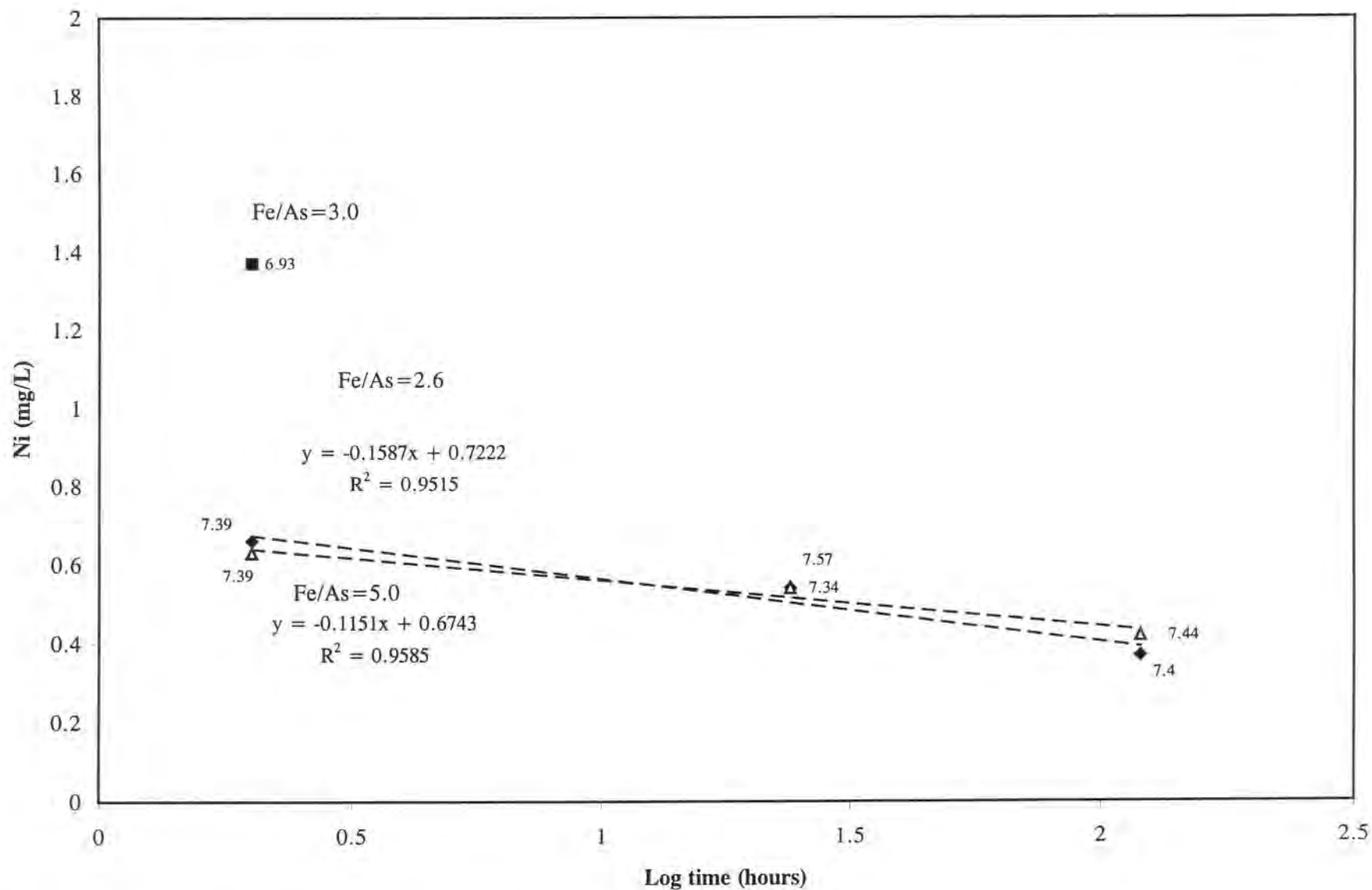
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of JEB tailings at 50°C, for molar Fe/As ratios of 2.6, 3.0, and 5.0 and nominal pH 7. ^{Note 1}



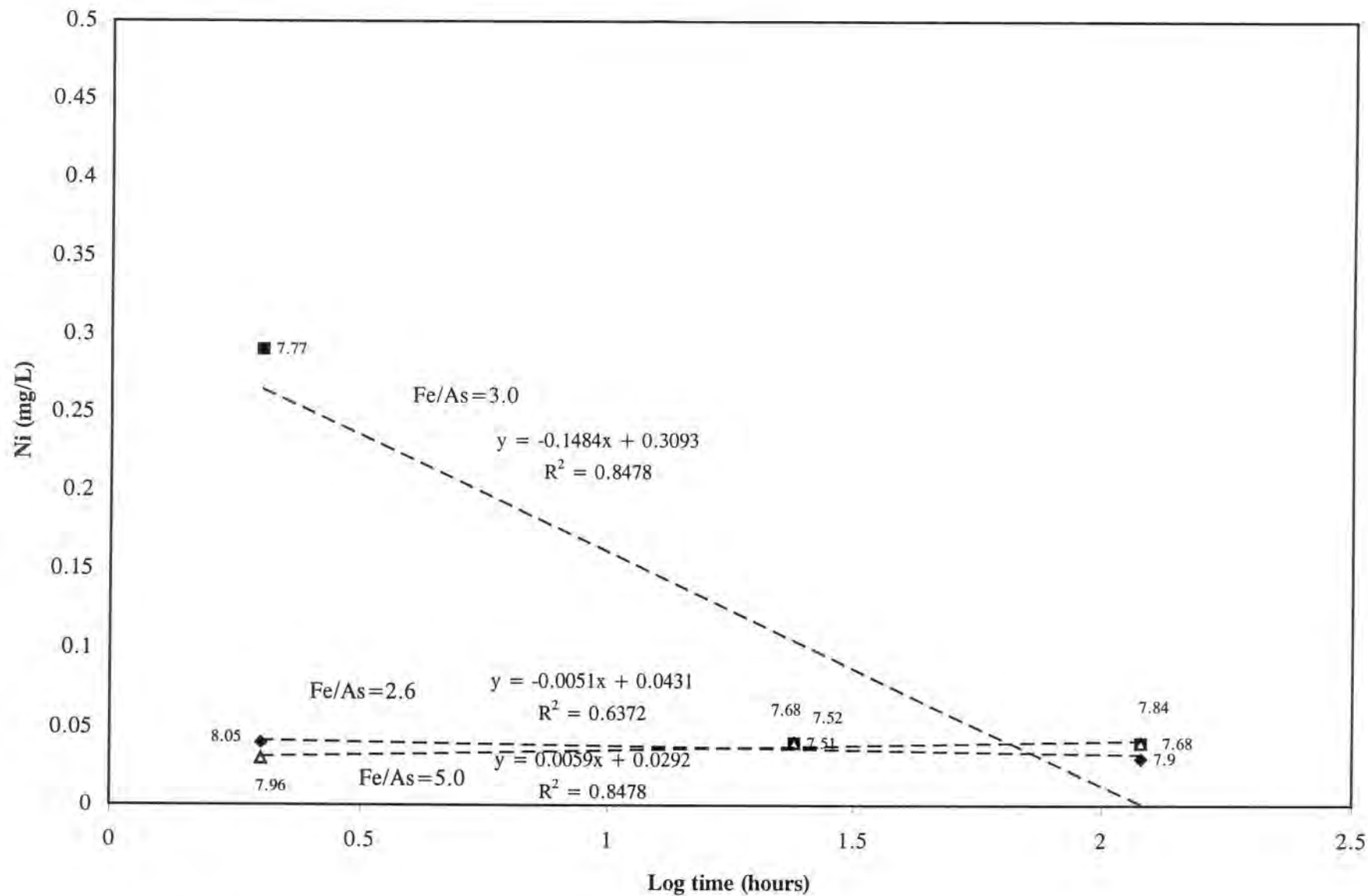
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of JEB tailings at 50°C, for molar Fe/As ratios of 2.6, 3.0, and 5.0 and nominal pH 8. ^{Note 1}



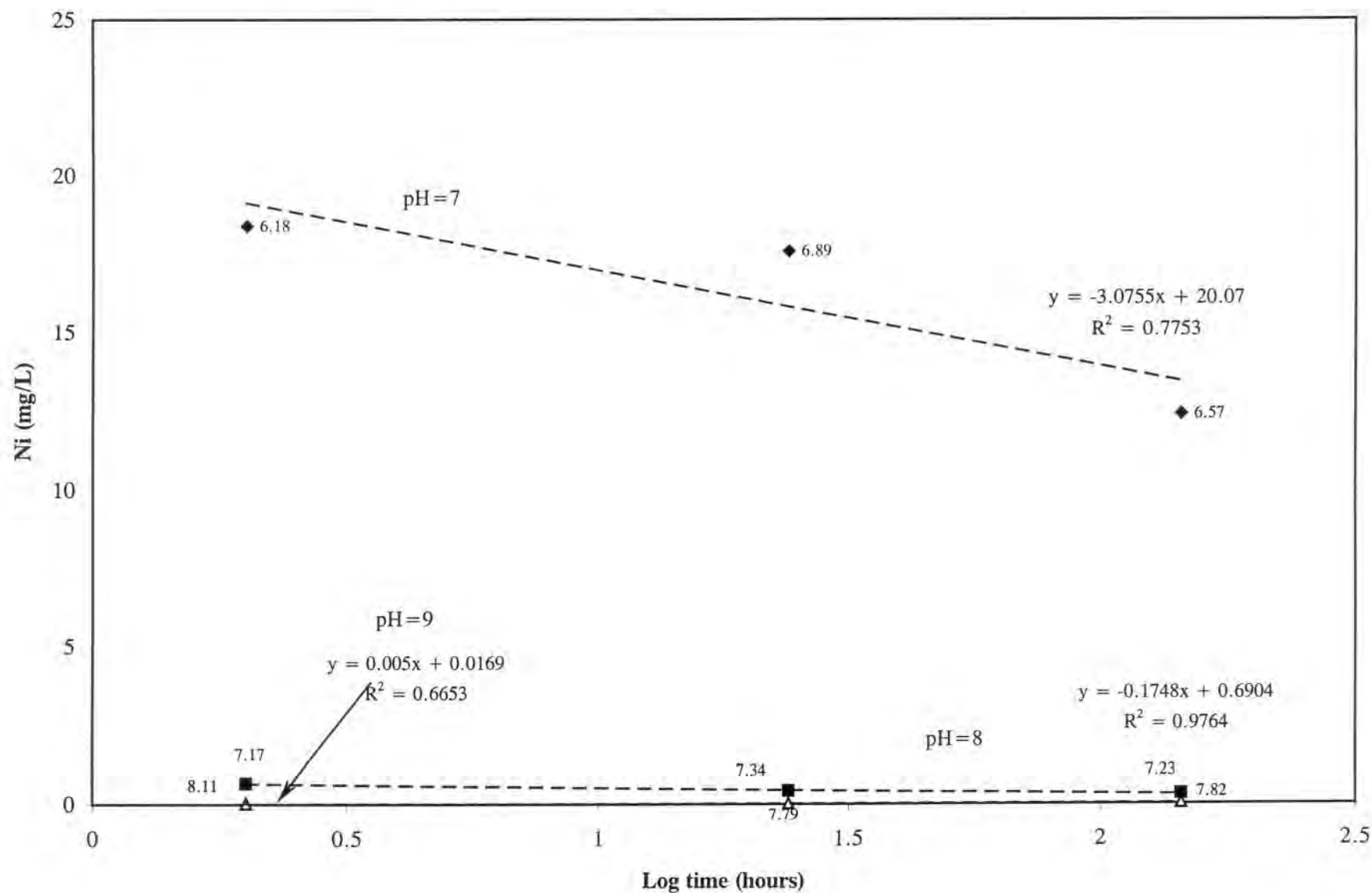
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentrations as a function of time during long-term tests of JEB tailings at 50°C, for molar Fe/As ratios of 2.6, 3.0, and 5.0 and nominal pH 9. ^{Note 1}



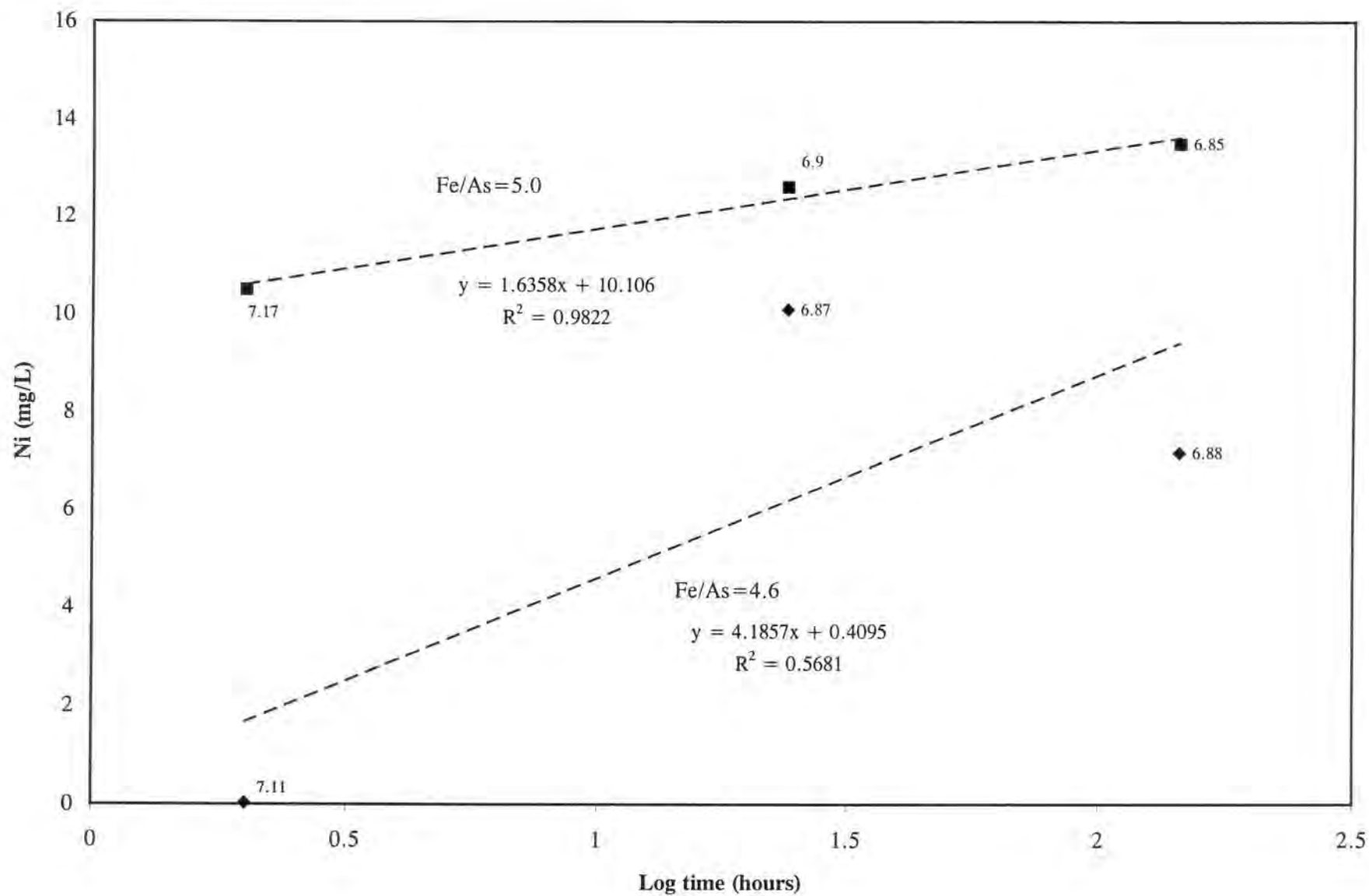
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Sue C tailings at 50°C, for molar Fe/As ratios of 7.7 and nominal pH 7, 8, and 9. ^{Note 1}



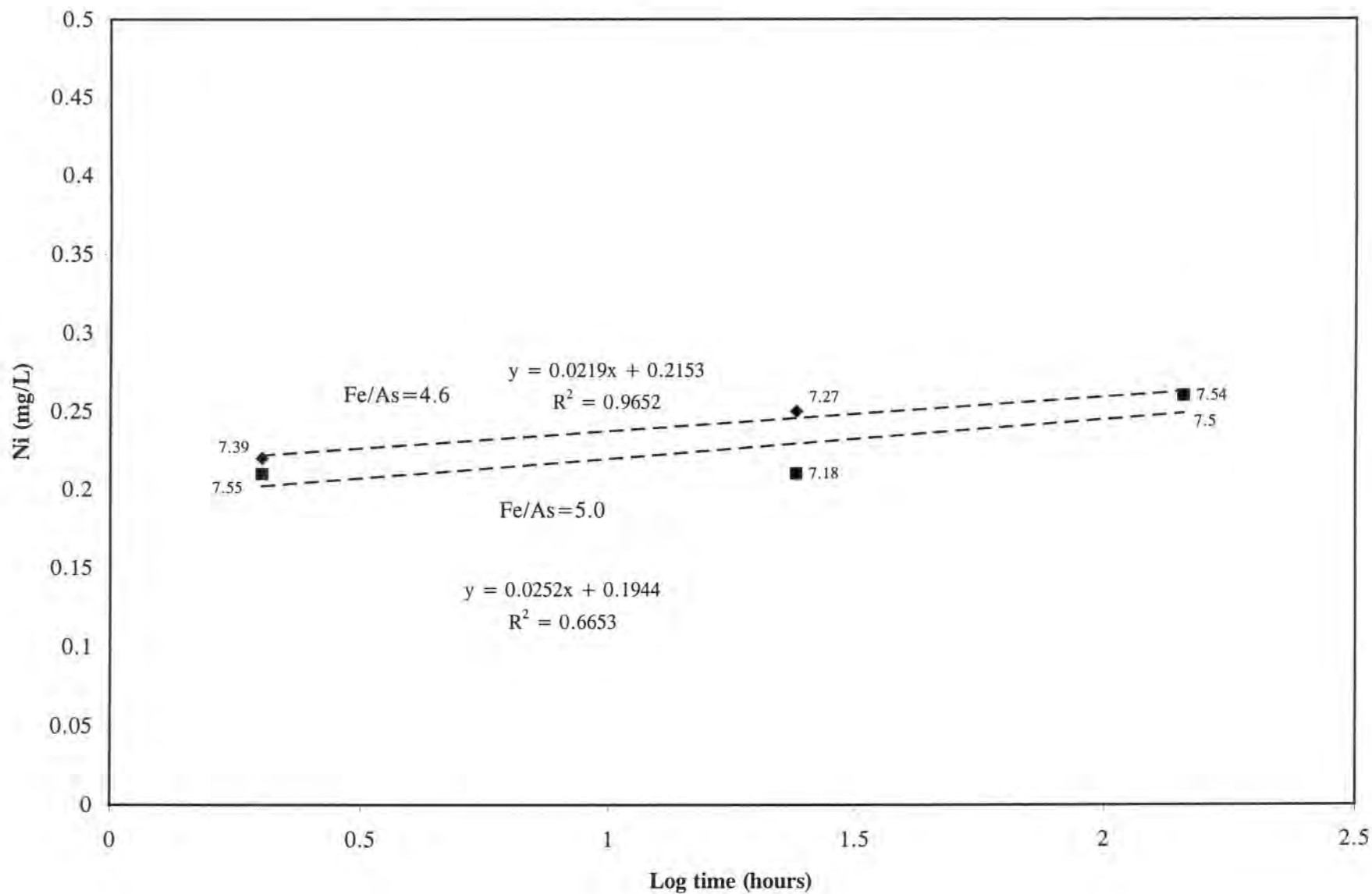
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of McClean Lake tailings at 50°C, for molar Fe/As ratios of 4.6 and 5.0 and nominal pH 7. ^{Note 1}



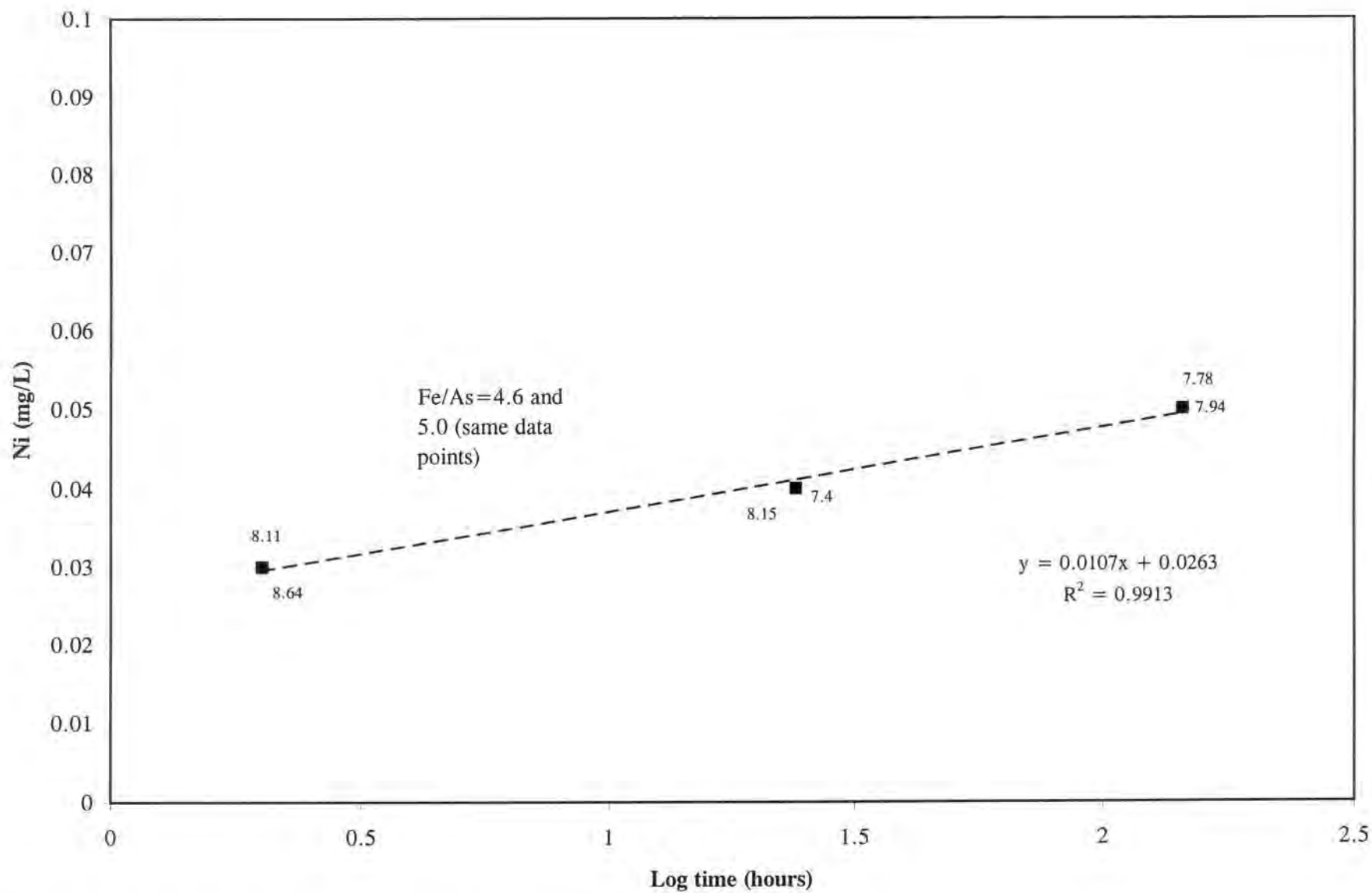
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of McClean Lake tailings at 50°C, for molar Fe/As ratios of 4.6 and 5.0 and nominal pH 8. ^{Note 1}



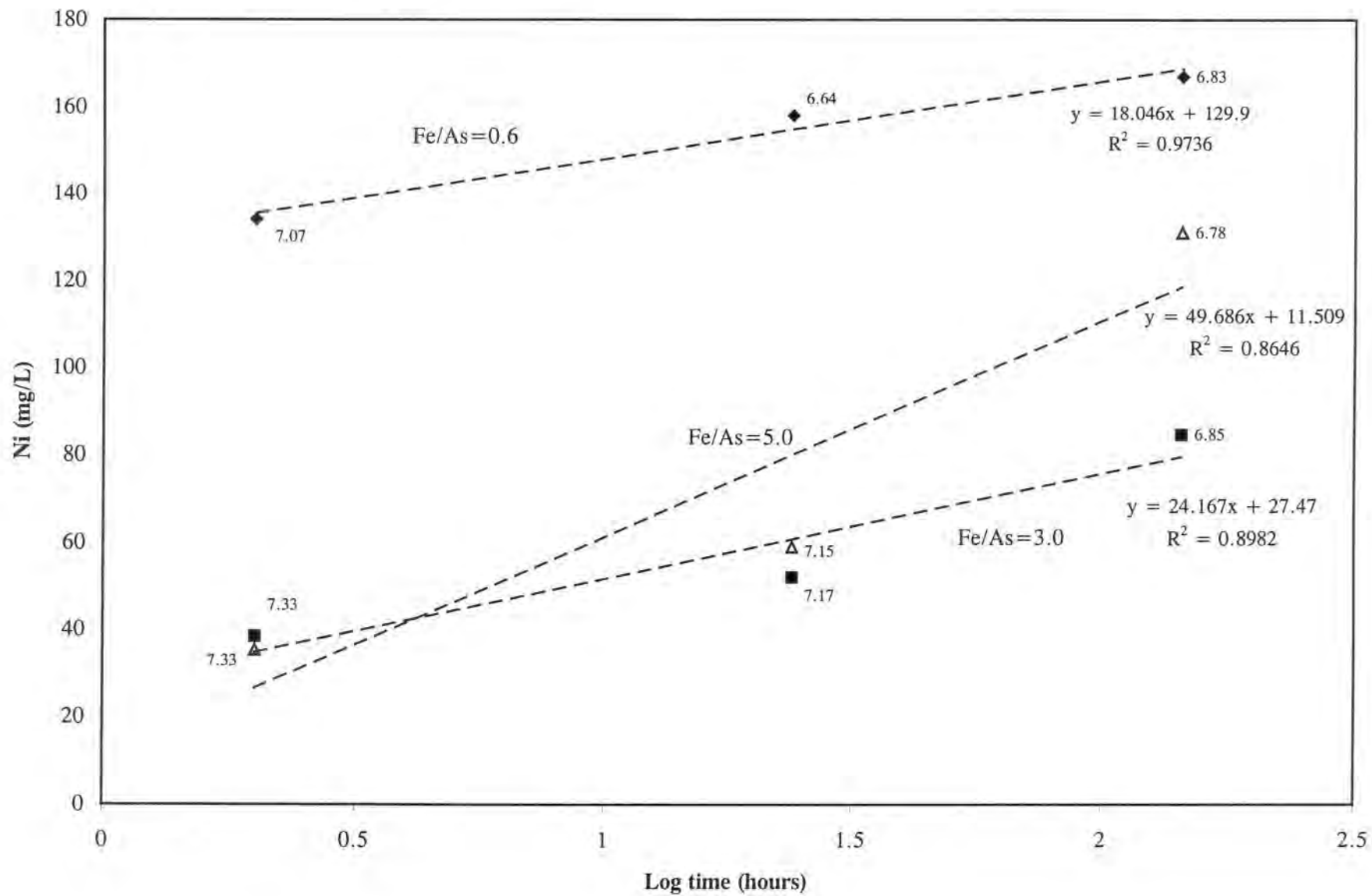
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of McClean Lake tailings at 50°C, for molar Fe/As ratios of 4.6 and 5.0 and nominal pH 9. ^{Note 1}



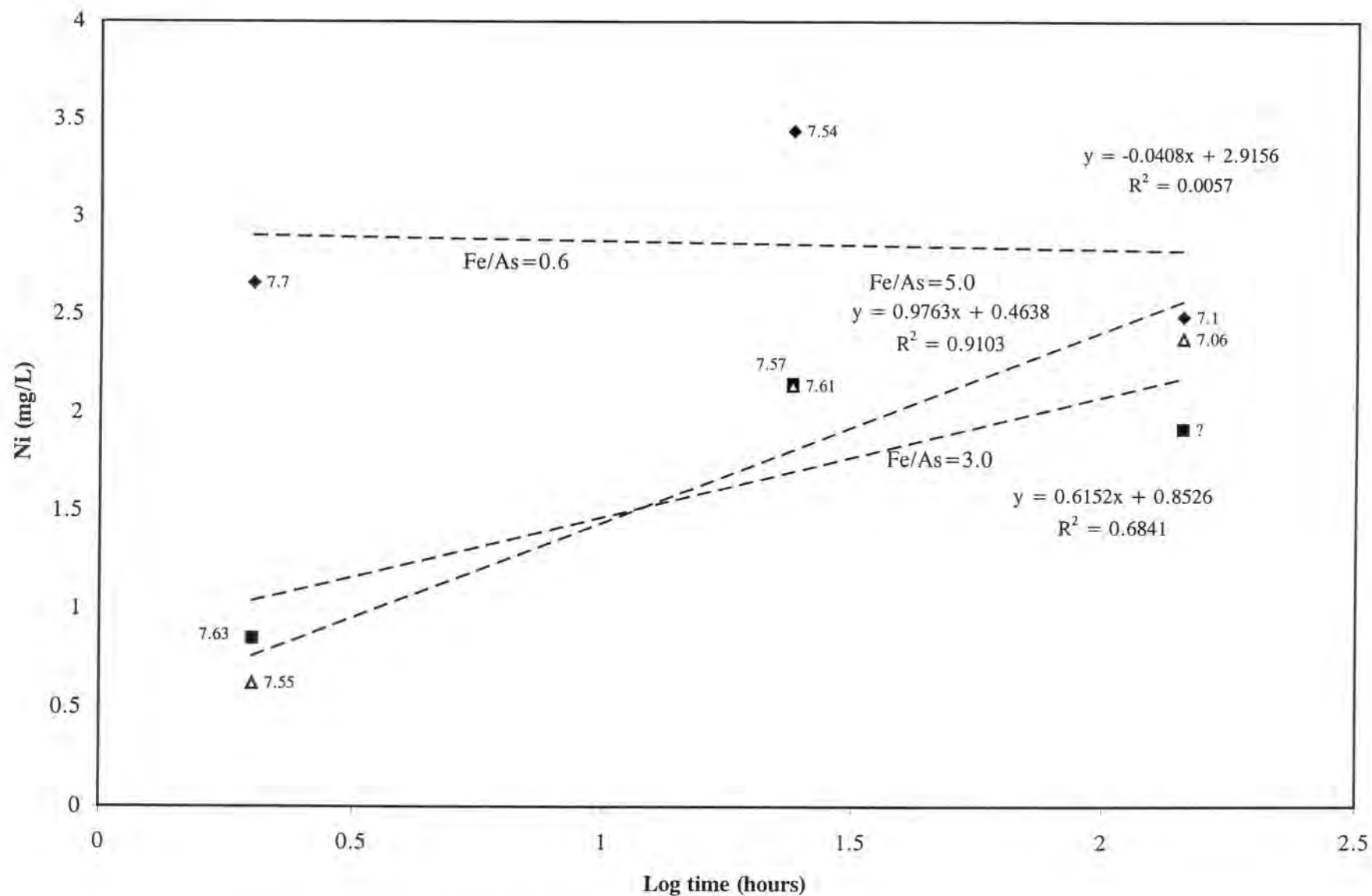
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Sue A+B tailings at 50°C, for molar Fe/As ratios of 0.6, 3.0, and 5.0 and nominal pH 7. ^{Note 1}



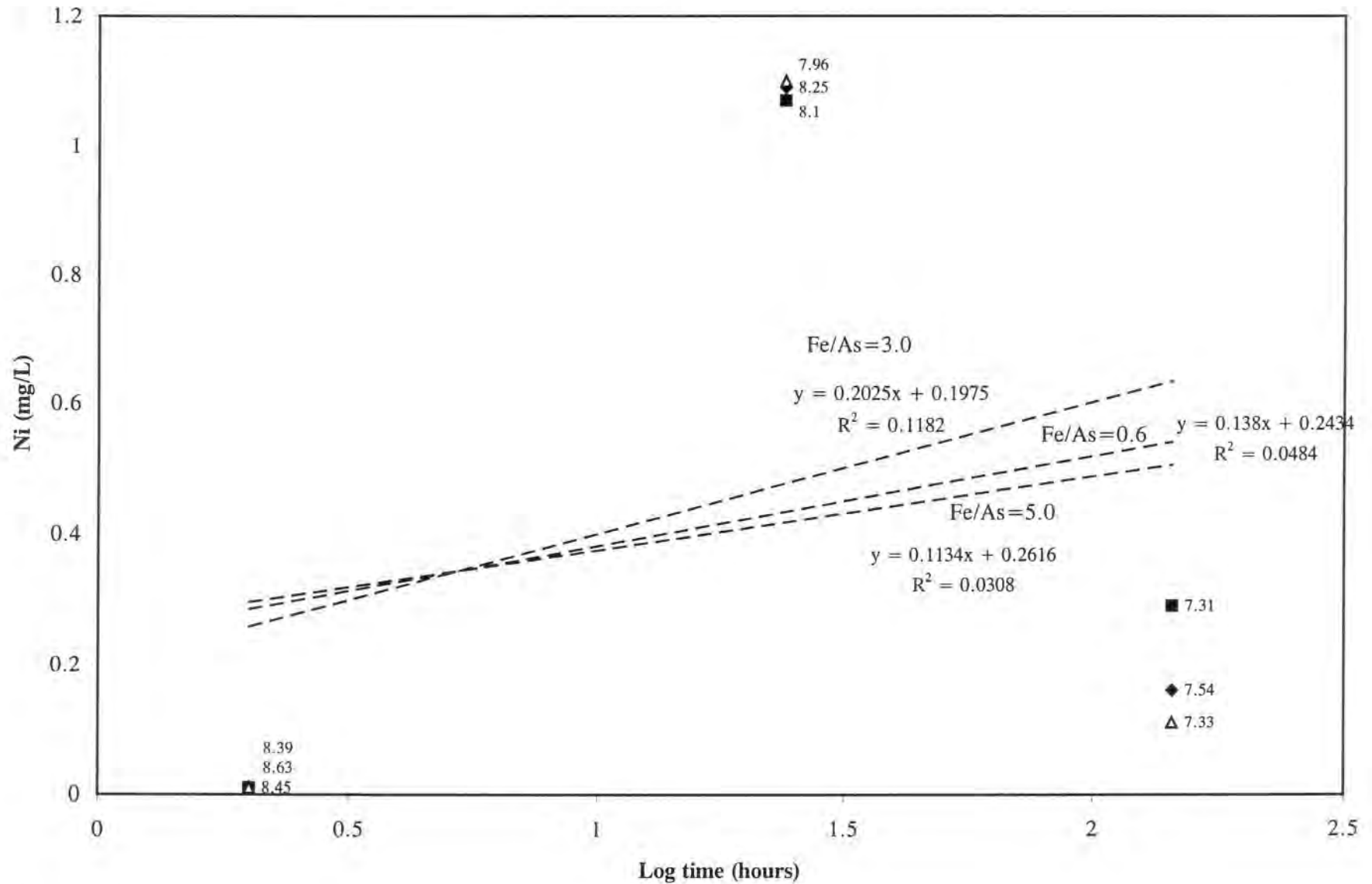
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Sue A+B tailings at 50°C, for molar Fe/As ratios of 0.6, 3.0, and 5.0 and nominal pH 8. ^{Note 1}



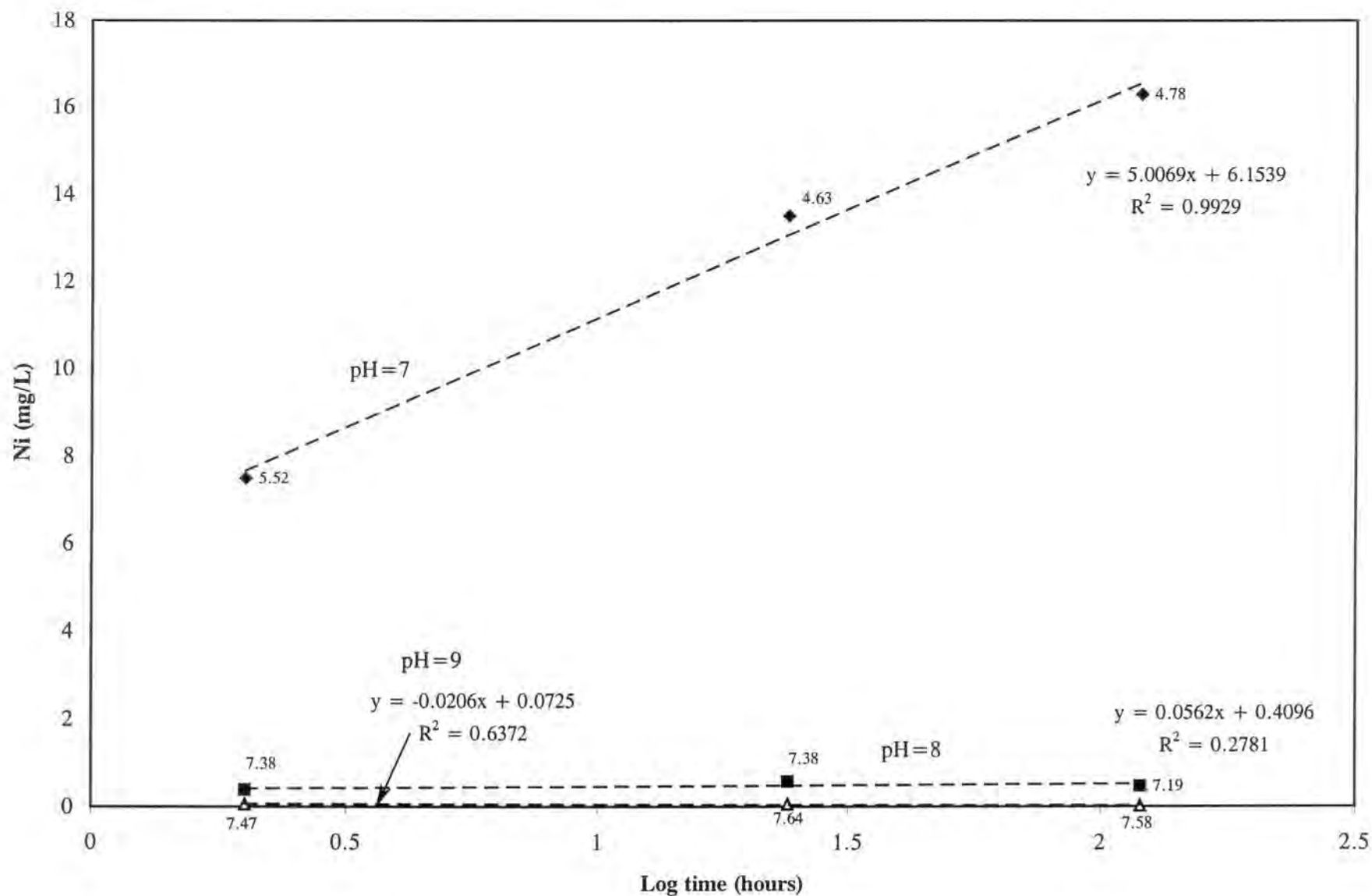
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Sue A+B tailings at 50°C, for molar Fe/As ratio of 0.6, 3.0, and 5.0 and nominal pH 9. ^{Note 1}



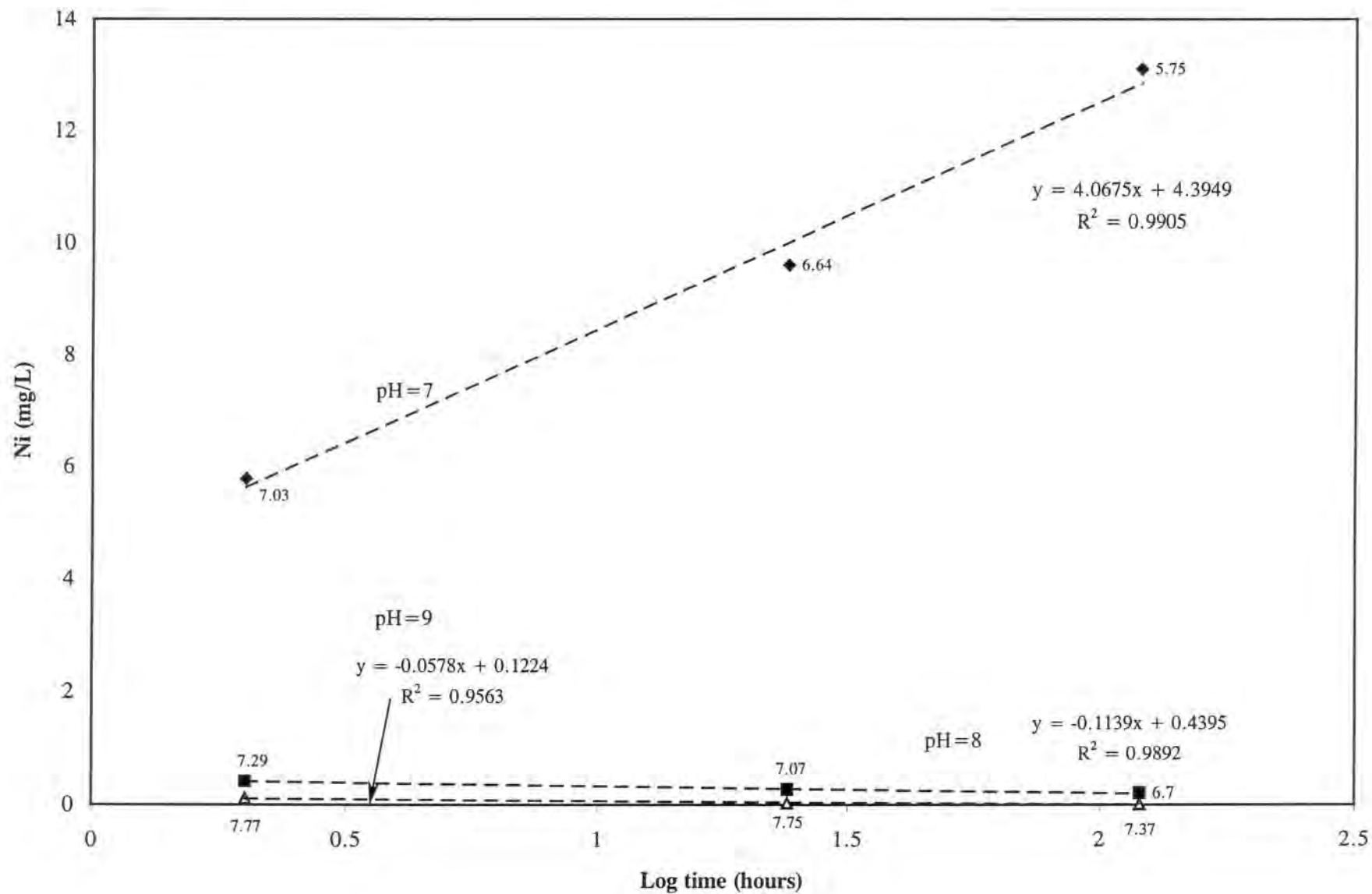
Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Cigar Lake tailings at 50°C, for molar Fe/As ratios of 7.5 and nominal pH 7, 8, and 9. ^{Note 1}



Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

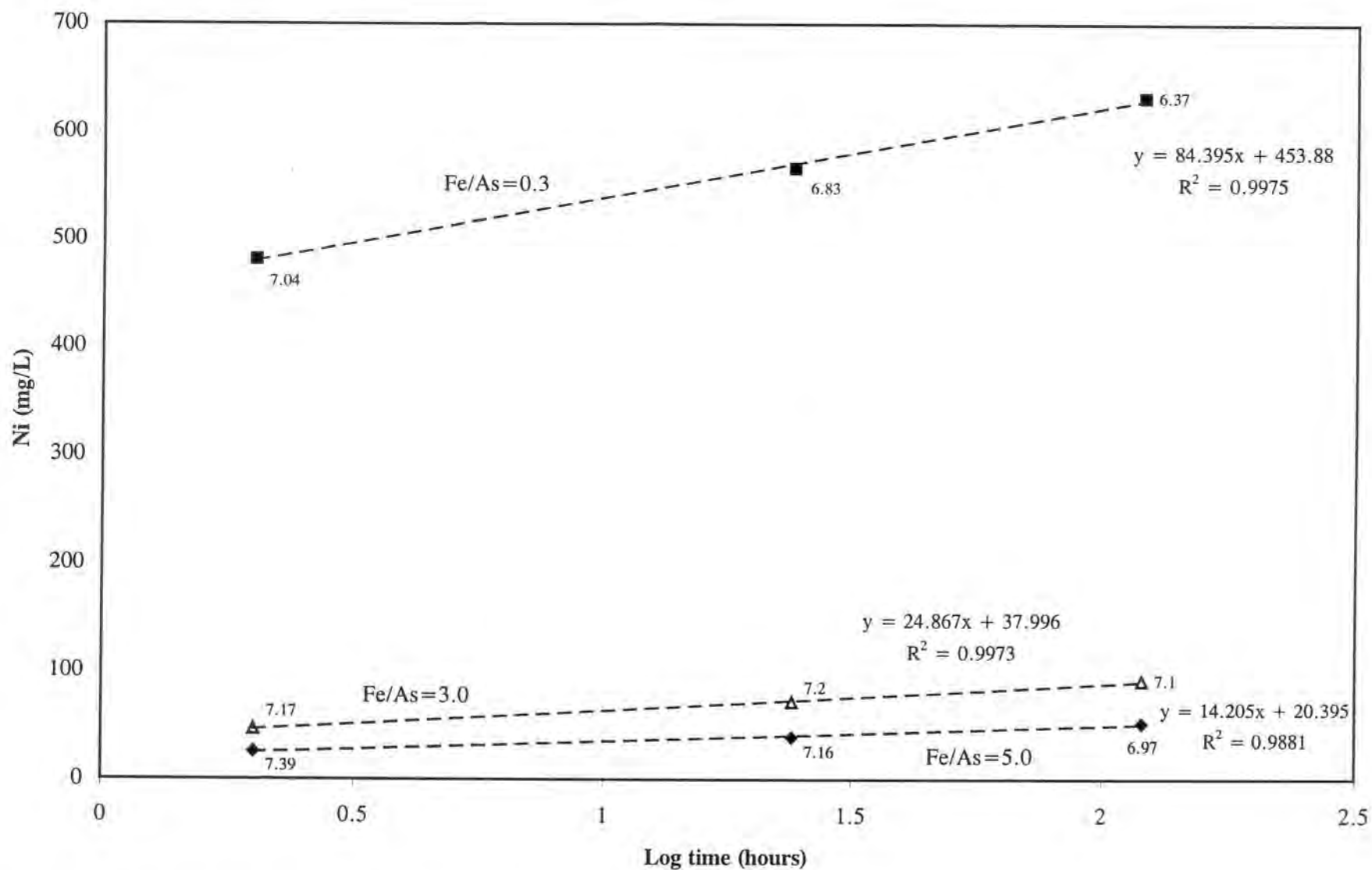
Nickel concentration as a function of time during long-term tests of Blend 1 (75% Sue C + 25% Cigar Lake) tailings at 50°C, for molar Fe/As ratios of 7.7 and nominal pH 7, 8, and 9. ^{Note 1}



Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 50°C, for molar Fe/As ratios of 0.3, 3.0, and 5.0 and nominal pH 7.

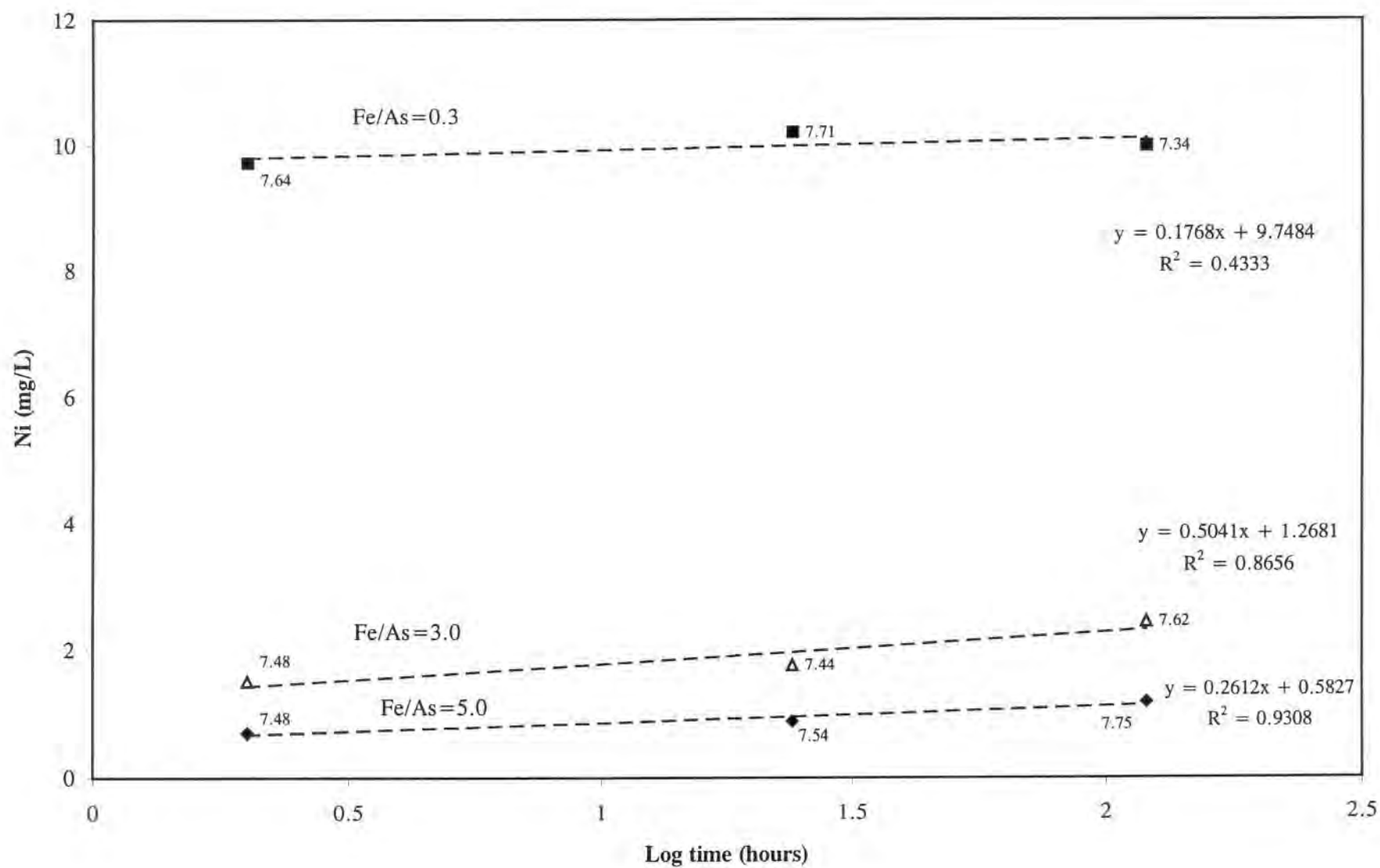
Note 1



Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 50°C, for molar Fe/As ratios of 0.3, 3.0, and 5.0 and nominal pH 8.

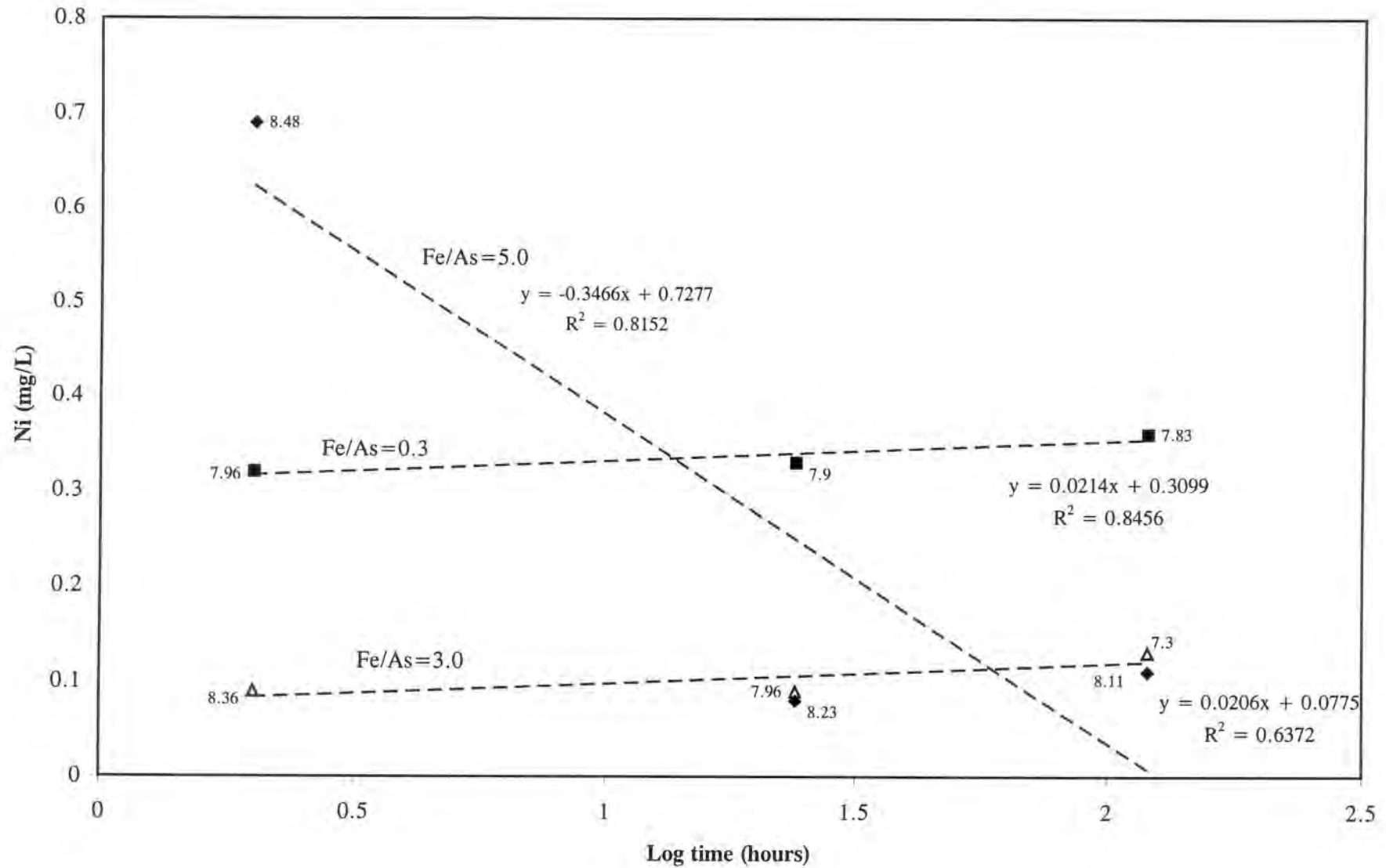
Note 1



Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Nickel concentration as a function of time during long-term tests of Blend 2 (55% Midwest + 15% Sue A+B + 30% Cigar Lake) tailings at 50°C, for molar Fe/As ratios of 0.3, 3.0, and 5.0 and nominal pH 9.

Note 1



Note 1: Also shown are equations for linear regressions of the data, and measured pH values for each data point.

Appendix C

Section C - Part A

Subsection F: Thermodynamic Data for Selected Aqueous Species and Solids of Arsenic and Nickel

Table F1. Dissociation Constants ($-\log K_{(\text{dissoc})}$) values for 1:1 Metal Arsenate Complexes from Whiting (1992)¹.

	H_2AsO_4^-	HAsO_4^{2-}	AsO_4^{3-}
Mg²⁺	1.52	2.86	6.34
Ca²⁺	1.06	2.69	6.22
Mn²⁺		3.74	6.13
Fe²⁺	2.68	3.54	7.06
²Fe³⁺	4.04	9.86	18.9
Ni²⁺		2.90	
Al³⁺	3.07	7.29	14.1

Table F2. Reaction Constants, Reaction Enthalpies (kcal/mol) and Their Sources³.

Reaction	log K	ΔH_r°	Source
$\text{H}_3\text{AsO}_3^\circ = \text{H}_2\text{AsO}_3^- + \text{H}^+$	-9.23	6.56	Wagman et al. (1982)
$\text{H}_3\text{AsO}_3^\circ = \text{HAsO}_3^{2-} + 2\text{H}^+$	-21.33	14.2	Parkhurst (1995) ⁴ . ΔH_r° from Naumov et al. (1974)
$\text{H}_3\text{AsO}_3^\circ = \text{AsO}_3^{3-} + 3\text{H}^+$	-34.74 ⁵	20.25	Parkhurst (1995) ⁶ . ΔH_r° from Naumov et al. (1974)

¹Dissociation reaction written for example, as: $\text{MgH}_2\text{AsO}_4^+ = \text{Mg}^{2+} + \text{H}_2\text{AsO}_4^-$

²Dissociation constants for the ferric arsenate complexes are from Robins (1990).

³Where two values of a parameter are listed, the first value was used in the geochemical modeling calculations.

⁴Lemire (1986) gives log K = -21.36.

⁵Lemire (1986) suggests log K = -34.76

⁶Lemire (1986) suggests log K = -21.36.

Table F3. Solubility Product Constants and Reaction Enthalpies of Important Arsenate Minerals in the Tailings

Mineral	Structural Formula	-log K_{sp}	ΔH_r° kcal/mol	Source
annabergite	$(Ni)_3(AsO_4)_2 \cdot 8H_2O$	28.38	-11.0 ⁹	Nishimura et al. (1990) ¹⁰
scorodite	$FeAsO_4 \cdot 2H_2O$	25.87 ¹¹	-5.5	ΔH_r° Papangelakis & Demopoulos, (1990)

Table F4. Equilibrium Constants and Reaction Enthalpies of Various Arsenic Bearing Minerals

- $$NiAs(niccolite) + 4H_2O = Ni^{2+} + H_3AsO_4^\circ + 5H^+ + 7e^-$$

$$\log K_{eq} = -35.76. \quad \Delta H_r^\circ = 62.14 \text{ kcal/mol (Skeaff et al., 1985)}$$
- $$FeAsS(arsenopyrite) + 8H_2O = Fe^{2+} + AsO_4^{3-} + SO_4^{2-} + 16H^+ + 13e^-$$

$$\log K_{eq} = -93.75. \quad \Delta H_r^\circ = 120.8 \text{ kcal/mol (Vaughan & Craig, 1978)}$$
- $$NiS(millerite) + H^+ = Ni^{2+} + HS^-$$

$$\log K_{eq} = -9.05. \quad \Delta H_r^\circ = 3.9 \text{ kcal/mol (Chase et al., 1982)}$$

⁹ ΔH_r° assumed equal to the corresponding value for vivianite, $Fe_3(PO_4)_2 \cdot 8H_2O$. Data from Langmuir (unpublished).

¹⁰These authors propose $-\log K_{sp} = 27.02$, which when corrected for the presence of the $NiHAsO_4^\circ$ complex leads to the value listed

¹¹Based on $\log K_{sp} = 24.41$ for crystalline scorodite reported by Krause & Ettel (1988), corrected for ferric arsenate complexing by Whiting (1992).

Vaughan, D. J., and Craig, J. R., 1978, Mineral Chemistry of Metal Sulfides. Cambridge Univ. Press, Cambridge, Great Britain.

Wagman, D. D. et al., 1982, The NBS Tables of Chemical Thermodynamic Properties. Natl. Bureau of Stds. (NBS), Washington, D.C. [J. Phys. Chem. Ref. Data, 11, Suppl. No. 2.

Whiting, K.S., 1992, The Thermodynamics and Geochemistry of Arsenic, with Application to Subsurface Waters at the Sharon Steel Superfund Site and Midvale Utah. MS Thesis T-4128. Colorado School of Mines, Golden, CO.

Appendix C

Section C

Part B: Microprobe Analysis

ETUDE 8875

SEPA

CANADA

Echantillon n° 1	♦ JEB	Ech. CEBTP 09.10.97 ; prélèvement 09/01/98
" 2	♦ Mc Clean	Ech. CEBTP 30/10/97 ; prélèvement 09/01/98
" 3	♦ SUE C	Ech. CEBTP 30/10/97 ; prélèvement 09/01/98
" 4	♦ SUE A + B	Ech. CEBTP 03/11/97 ; prélèvement 09/01/98
" 5	♦ SUE A + B / MIDWEST	Ech. CEBTP 05/11/97 ; prélèvement 09/01/98

*

Essai de localisation de l'arsenic dans les résidus miniers

*

J. REYX

COGEMA - GEO - GST

Février 1998

SUMMARY OF MICROPROBE ANALYSIS

Reported by SEPA, 1998

MICROPROBE ANALYSES

Method

- 1 - Arsenic ($L\alpha$ ray) was researched by a sound method, moving polished sections through the electrons flux.
- 2 - When Arsenic was recognized, a qualitative chemical analysis was carried out by EDS (Energy Dispersive Spectrometer).
- 3 - Distribution image in arsenic detected zones is carried out by R.X. scanning to give a more precise relationship between arsenic and associated phases: cryptocrystalline phases more or less crystallized or impregnations in poorly crystallized phases (Wavelength Dispersive Spectrometer).

Note that

- Arsenic concentrations are given under an oxide percentage (from the computer program), this must not be considered as an absolute value as hydration states are not considered (only relative values should be considered), so percentage of more than 100% can be expressed.
- The electronic scan has a diameter of 2 to 3 μm , analyses are altered by a diffusion in surrounding matrix (Is, Al, K, Ca, S), this must also be considered.

Samples origin

Two sets of samples were studied:

- One during summer 1997 from:
 - JEB residue neutralized at pH 8 and 11,
 - Midwest (75%) / Sue A+B (25%) residue neutralized at pH 8 and 11,
 - Cigar Lake residue neutralized at pH 8 and 11.

These residues were obtained only with lime addition (referred to as residues 1).

- One at the beginning of 1998 from:
 - JEB (neutralized residue with Fe addition to meet an Fe/As ration of 3,
 - McClean (no Fe addition as original Fe/As ratio equals: 4.6),
 - Sue C (no Fe addition as natural Fe/As ratio equals: 7.7),
 - Sue A+B (addition of 0.4 kb/t Fe after pH 5 neutralization, Fe/As ratio equals 0.6),
 - Sue A+B (25%) / Midwest (75%), (addition of 19 kg/t Fe after pH 5 neutralized, Fe/As ratio equals 3)

These are referred to as 2 residues.

Original ore samples are different for the two sets of results.

Results

The results can be summarized as follows:

For JEB:

- Arsenic is located in iron phases, with an heterogeneous distribution, (several % As). An adsorption of arsenic is suggested on Fe-oxi(hydroxides) phases (1 and 1).
- Arsenic is also recognized on phosphate phases or Al-Si phosphate phases: phosphates of rare earth where As can be substituted to P in particles from ore.

For McClean:

- Arsenic mainly occurred as Ni-Fe-Si (?) phases where small quantities of As-rich particles (several %) were recognized.

For Sue C:

- Small amounts of arsenic was recognized in iron phases containing also nickel hydroxides.

For Sue A+B:

- Arsenic seems mainly related to Al rich phases suggesting a precipitation of an Al arsenate mineral as an individualized mineral. Arsenic concentration in this mineral is higher than in previous observed composites (JEB, McClean Sue C).

For 75% Midwest / 25% Sue A+B composite and residues 2:

- Arsenic is mainly related to rich iron phases suggesting a precipitation of an Fe-As mineral with minor traces of nickel and calcium.

For 75% Midwest / 25% Sue A+B composite and residues 1:

- Arsenic is mainly present as nickel arsenate containing locally some iron, calcium and aluminum.

Essai de localisation des phases minérales contenant de l'arsenic, dans les rejets de traitement de minerais uranifères de l'Est Athabasca (JEB, MC CLEAN, SUE, MIDWEST).

Etude à la microsonde

Méthode

- 1 *L'arsenic* (raie $L \alpha$) est recherché au moyen d'un bruiteur, en déplaçant les lames polies (confectionnées sans eau, au ketrul) sous le faisceau d'électrons.
- 2 Dès que l'on repère la présence de l'arsenic au bruiteur, *détermination chimique qualitative* du support minéralogique de l'arsenic, par *analyse E.D.S.* (Energy Dispersive Spectrometer).
- 3 *Images de répartition* des divers éléments détectés dans les zones arsenicales, par *balayage R.X.*, afin de déterminer de façon plus précise les éléments auxquels est associé l'arsenic, car il s'agit généralement soit de particules de très petites dimensions, soit de phases cryptocristallines ou $\pm$ mal cristallisées ou bien d'imprégnations $\pm$ diffuses dans des phases minérales mal individualisées, à l'exception cependant des sulfoarséniures ou arséniures primaires encore localement abondants dans certains échantillons.
(Wavelength Dispersive Spectrometer).
- 4 *Analyse (semi) quantitative W.D.S.* (Wavelength Dispersive Spectrometer) sur sélection des plus larges cristallisations repérées.

Attention. Les teneurs en arsenic (estimation « brute »), données en pourcentage d'oxyde, ne doivent surtout pas être considérées en absolu, mais seulement comme des indications relatives les unes par rapport aux autres, car les analyses bouclent très mal, ceci étant dû aux importants états d'hydratation des phases minérales considérées.

Par ailleurs, bien que le faisceau électronique ait en principe un diamètre de 2 ou 3 μ , les analyses sont cependant $\pm$ entachées par une inévitable diffusion des éléments de la matrice environnante (Si, Al, K, Ca, S, ...) dont il faut tenir compte dans l'interprétation.

Minéraux ou phases minérales contenant de l'arsenic.

Echantillon n° 1 / JEB

Sulfoarséniures de fer, de fer-nickel, sulfoarsénirues de fer et cuivre, pyrite arsénicale.

Ces minéraux, relativement abondants, apparemment non affectés par le traitement, proviennent du minerai originel.

Arsenic natif

Assez fréquent ; il provient probablement aussi du minerai primaire.

Phases ferrugineuses

Ces phases, fréquentes, contiennent de l'*arsenic* en petites quantités, distribuées de façon hétérogène (estimation « brute », 6 à 9 % As_2O_5). Il s'agit probablement d'une sorte d'adsorption sur des hydroxydes de fer, qui piègent aussi un peu de *plomb, calcium, vanadium* ...

Phases phosphatées

Ces phases *phosphatés*, ou *silico-alumino-phosphatées* (?) avec un peu de *fer* et de *calcium*, peu fréquentes, contiennent de petites quantités d'*arsenic* (estimation « brute » 4 à 6 % As_2O_5).

Phases stannifères

Composé *arsenic-étain*, très rares. Origine inconnue.

Illustrations

Exemples d'images de répartition (RX) de l'arsenic
et des éléments associés ou non à celui-ci.

*

Les répartitions des éléments considérés sont traduites par les images en blanc. Les intensités des blancs ne sont pas nécessairement proportionnelles aux teneurs ; il ne s'agit que de représentations qualitatives ; les grossissements utilisés sont de 800 ($20\ \mu = 15\ \text{mm}$) et 2000 ($10\ \mu = 18.75\ \text{mm}$) ; ces images de répartition RX présentent des diffusions dont on doit tenir compte à l'interprétation. Tous les éléments présents dans les phases étudiées ne sont pas systématiquement représentés afin de diminuer un peu le temps passé à ces caractérisations.

*

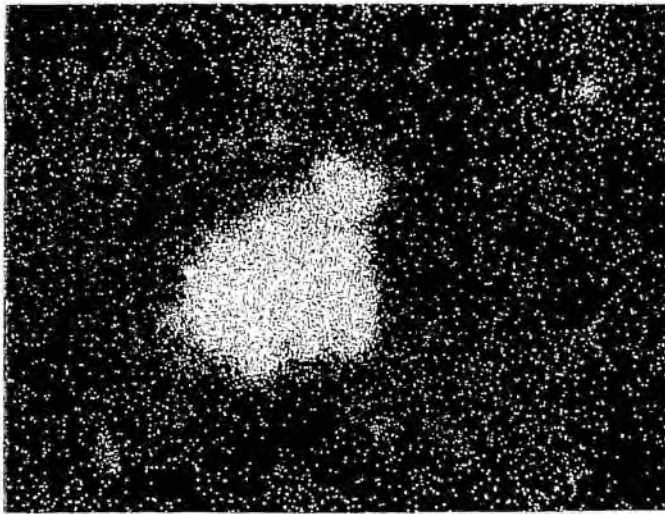
Hydroxydes de fer
(analyses n° 3 à n° 5)

contenant de l'arsenic et un
peu de calcium, de plomb
et de vanadium

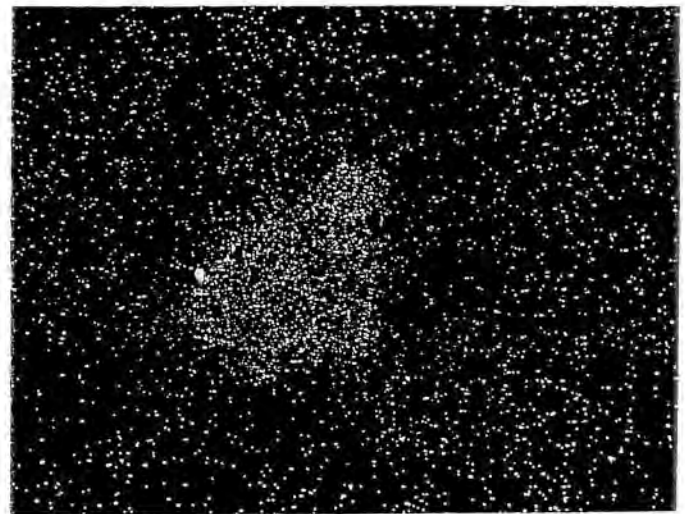


10 μ

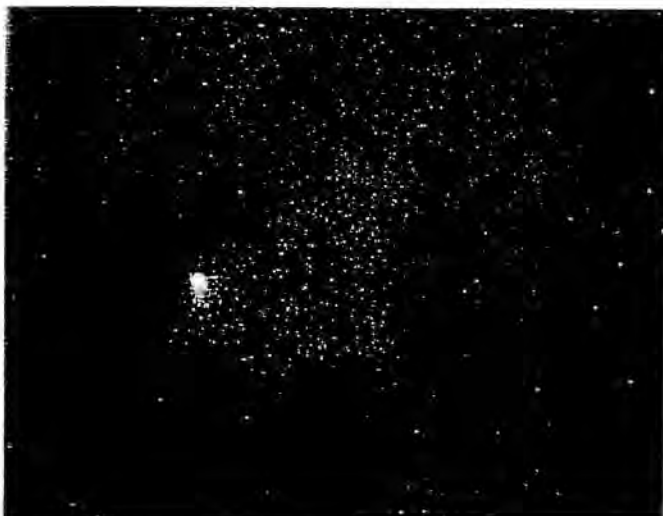
Ca



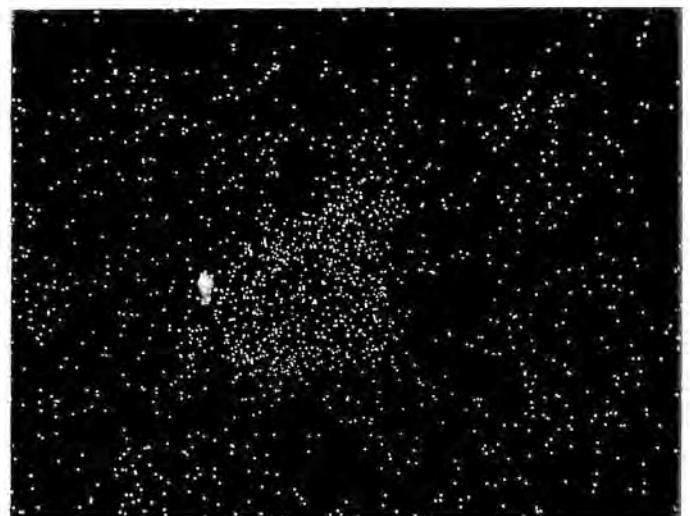
Fe



As

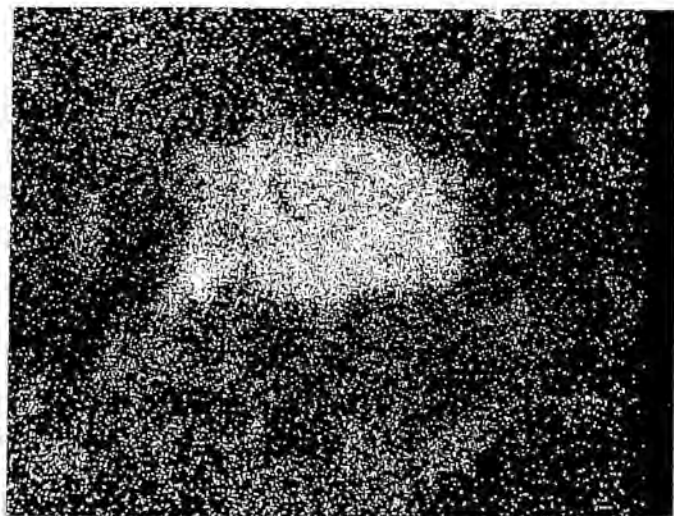
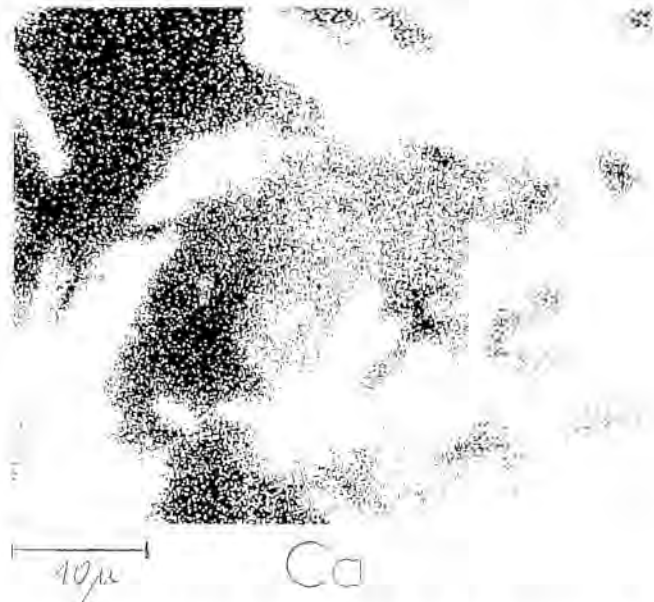


PL

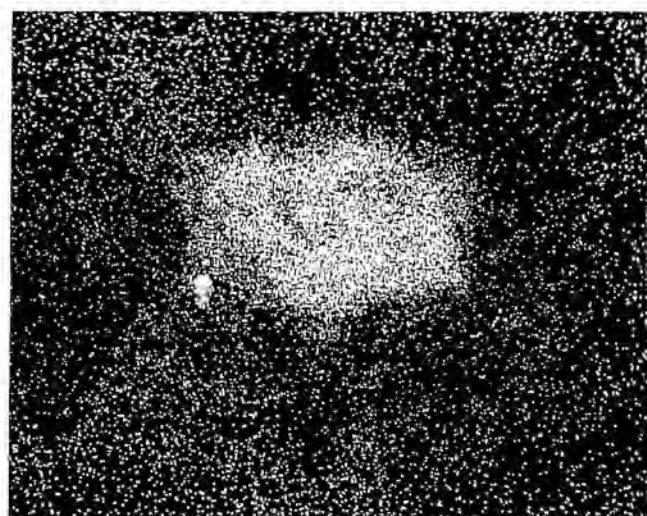


V

Phase fer - arsenic
Arsenates (?)



Fe

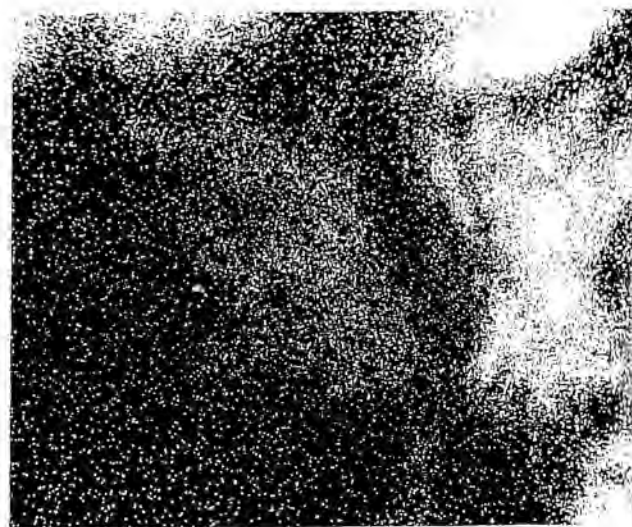


As



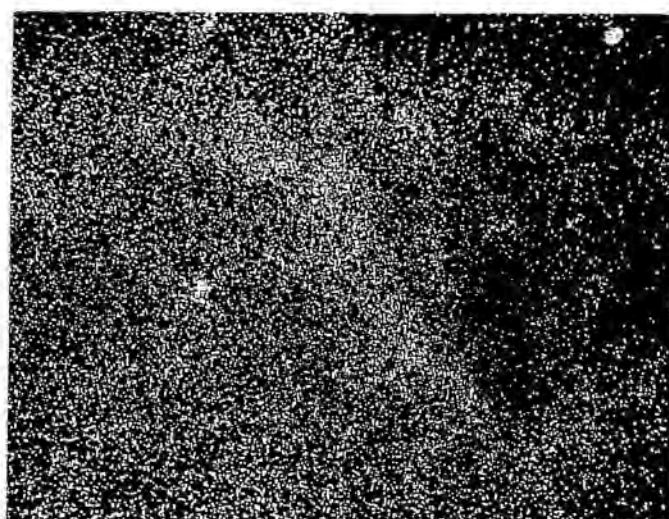
P

Phase phosphatée
arsenicale, contenant un
peu de fer et de calcium
(Analyses n° 9 à n° 11)

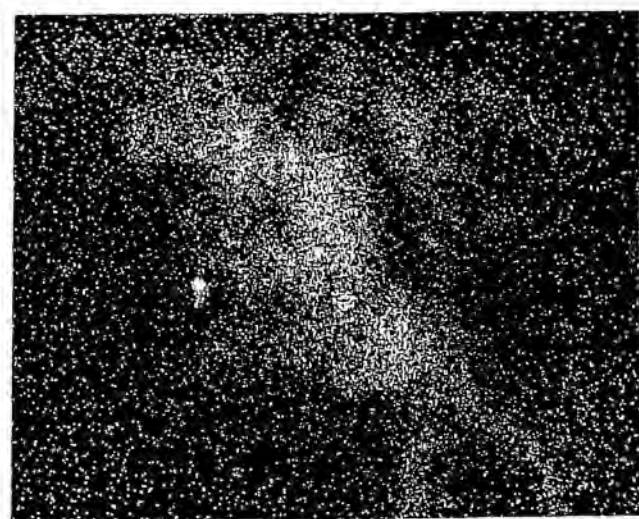


10 μ

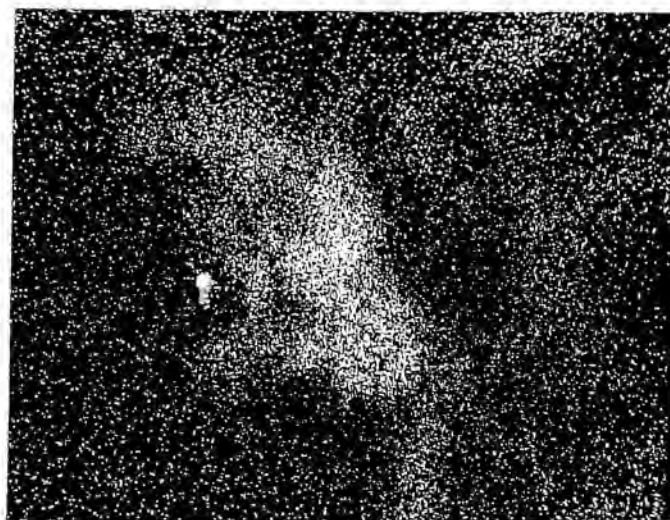
Ca



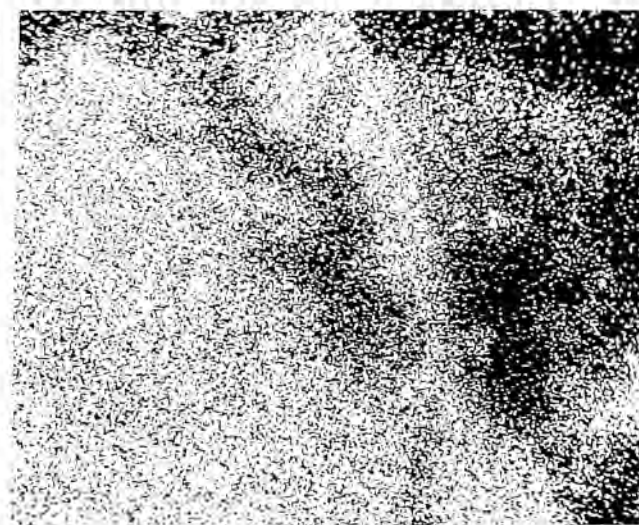
Fe



As



P



Al

Echantillon n° 1
Concentrations poids % d'oxydes

Analy- ses	P	K	Ca	S	Fe	Ni	As	Al	Si	
1	00.26	03.77	02.54	06.77	01.25	00.15	24.01	17.35	29.53	85.64
2	00.18	03.87	06.34	09.89	01.09	00.16	17.47	15.97	26.24	81.21
3	01.33	00.17	02.80	00.93	54.23	00.64	06.81	04.10	08.04	79.05
4	01.46	00.33	02.49	00.81	44.39	00.44	06.19	05.33	08.78	70.22
5	01.78	00.15	02.91	01.02	50.76	00.61	08.22	04.61	08.25	78.32
6	03.47	00.22	04.56	02.88	11.86	00.21	07.85	03.41	03.82	38.28
7	03.96	00.23	05.57	03.40	13.77	00.25	09.06	03.81	04.21	44.26
8	03.25	00.09	03.43	01.73	10.92	00.28	08.24	03.22	03.17	34.34
9	14.47	00.62	04.66	00.93	07.38	00.44	05.62	05.61	09.09	48.83
10	15.89	00.41	04.98	01.30	07.37	00.51	06.13	05.32	08.35	50.26
11	09.93	01.51	02.98	00.53	07.75	00.22	04.22	08.82	15.68	51.63
13	01.49	00.08	02.26	01.09	42.68	00.34	06.72	03.84	07.20	65.70
14	01.71	00.13	02.32	00.99	45.72	00.48	06.91	03.64	06.79	68.70
15	01.57	00.11	02.45	00.93	47.23	00.43	06.91	04.03	07.68	71.33

Echantillon n° 2 / Mac Clean

Sulfoarséniure de fer, de fer-nickel, sulfoarséniures de fer et cuivre, pyrite et bravoïte arsenicales.

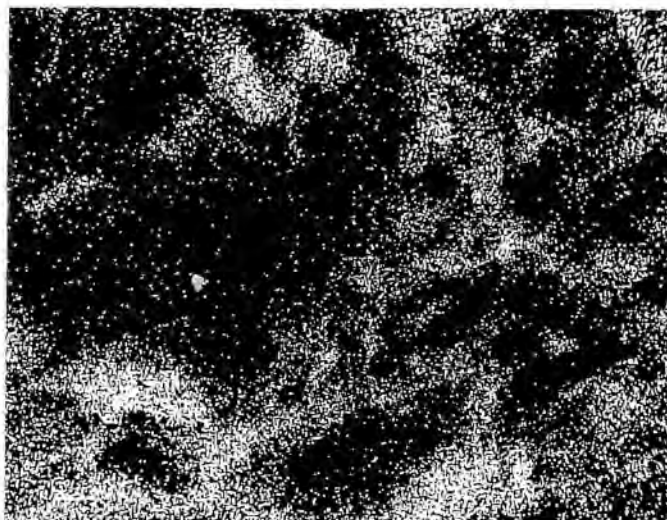
Ces minéraux sont directement hérités du minerai originel.

Arsenic (natif ?).

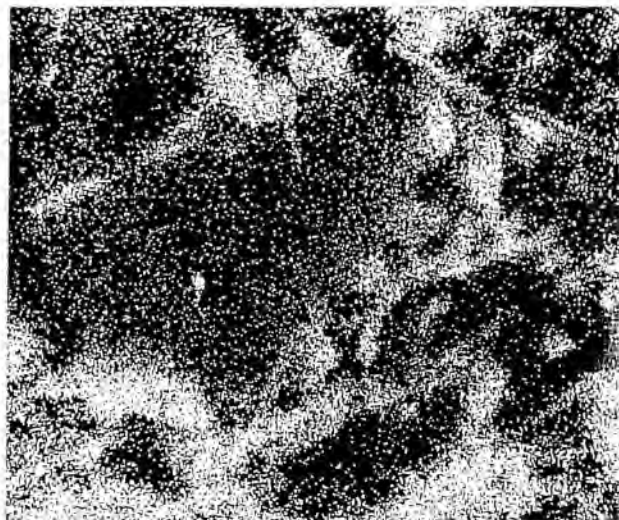
Associé à des grains de silicates ; fréquent. Possible héritage du minerai originel (?).

Phases ferro-nickelifères (silicatées ?).

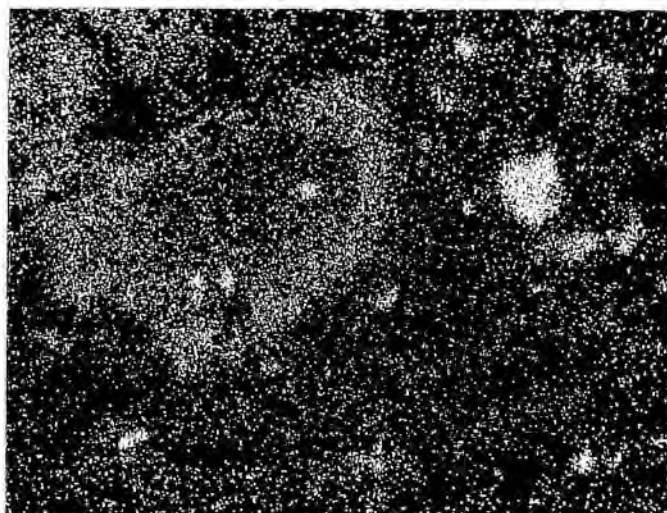
Ces phases, fréquentes, qui semblent représenter l'essentiel des produits arsenicaux néoformés, se présentent souvent sous forme de concrétions contenant de petites quantités d'*arsenic* (estimation « brute » 3 à 4 % As_2O_5).



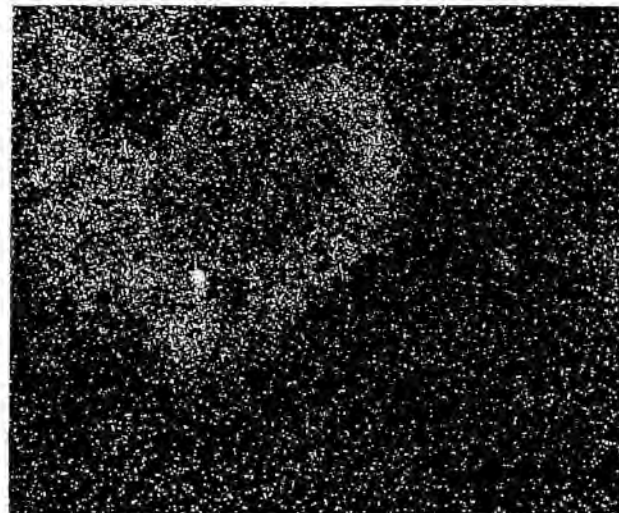
S



Ca

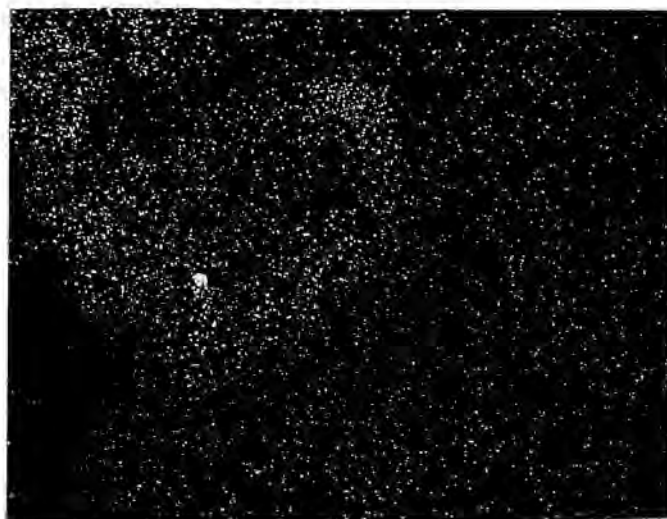


Fe

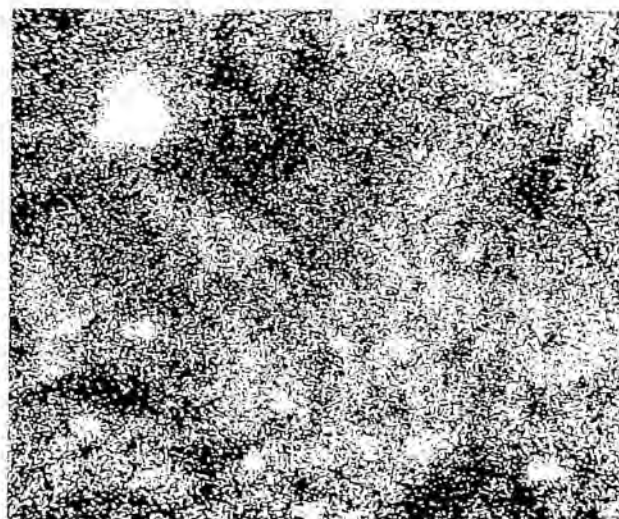


As

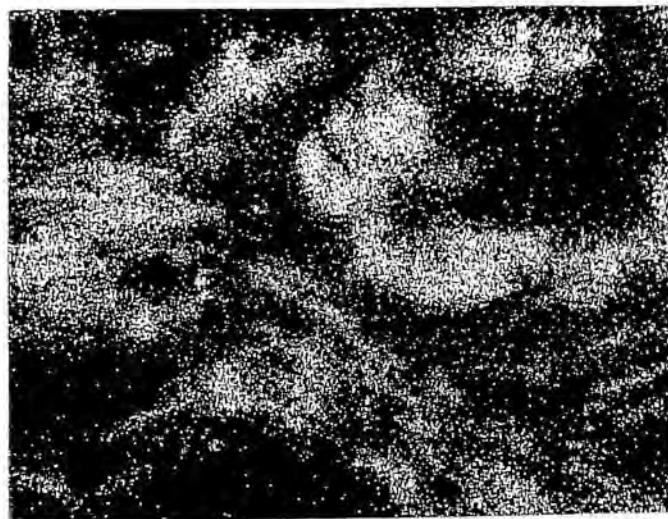
20μ



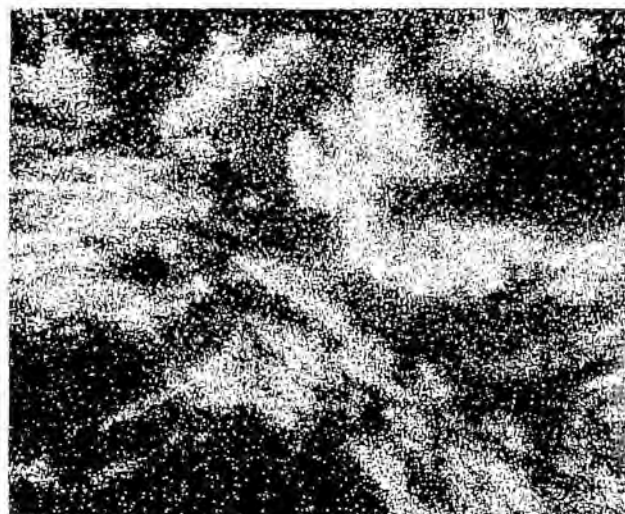
Ni



Si



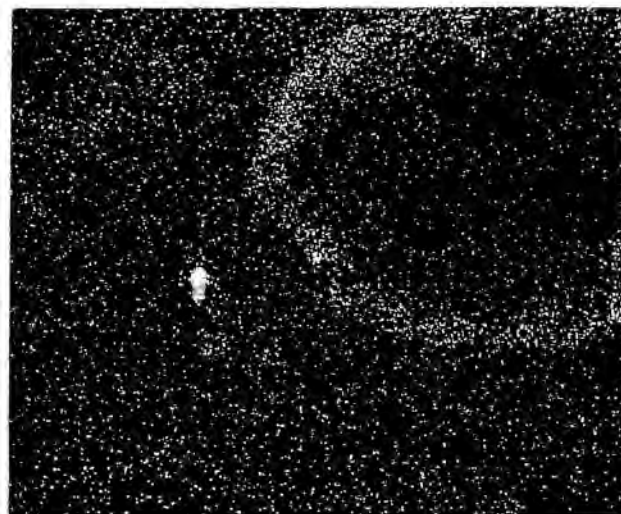
S



Ca

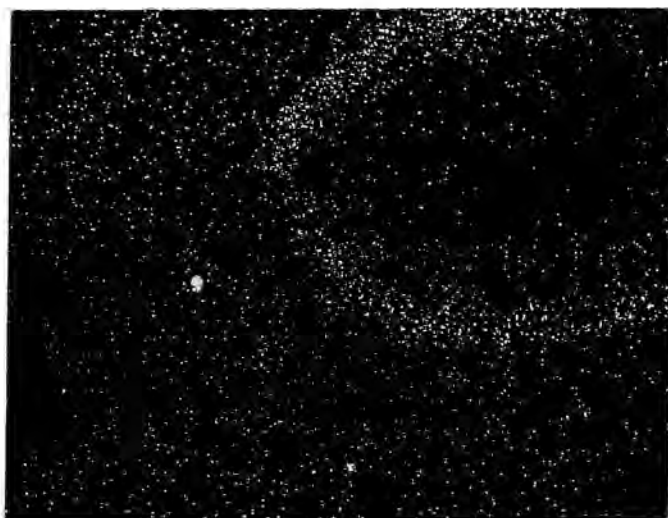


Fe

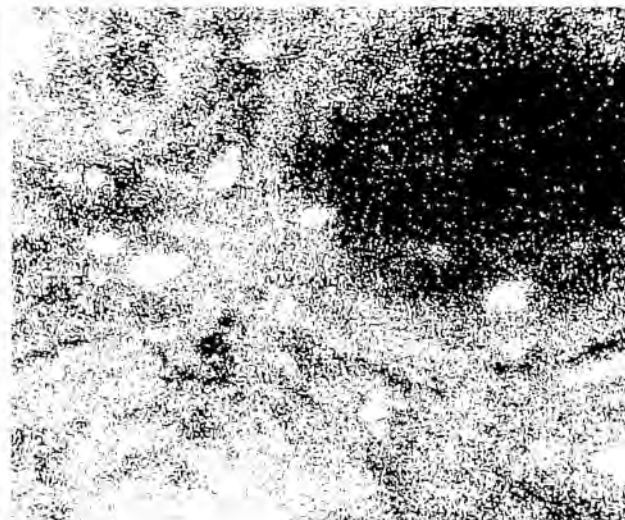


20µ

As

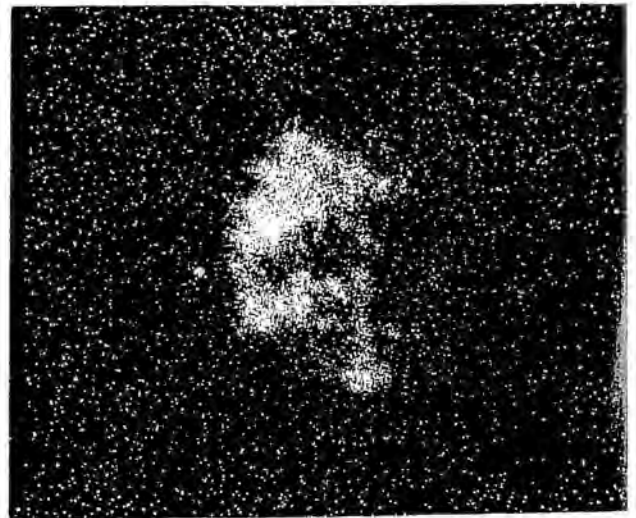


Ni



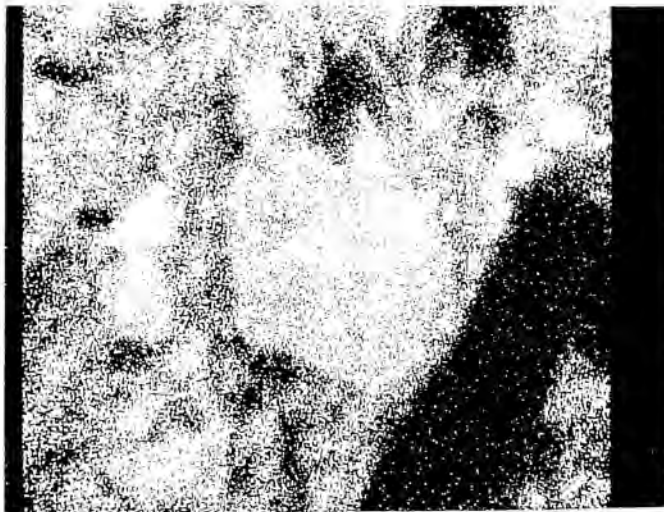
Si

Arsenic (natif ?)
Associé à des grains de
silicates, (feldspaths)

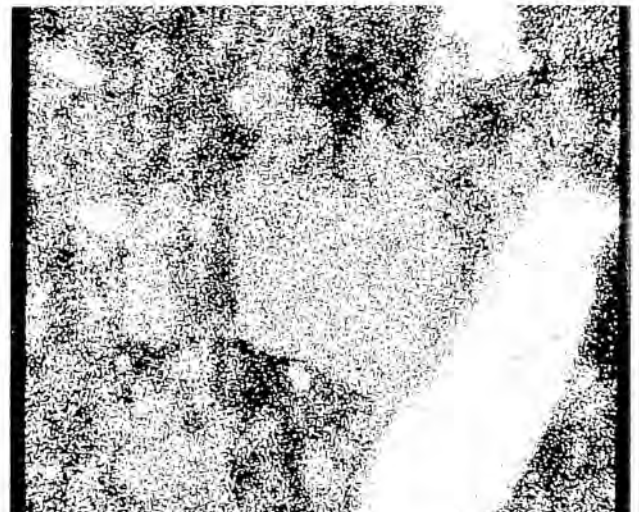


20 μ m

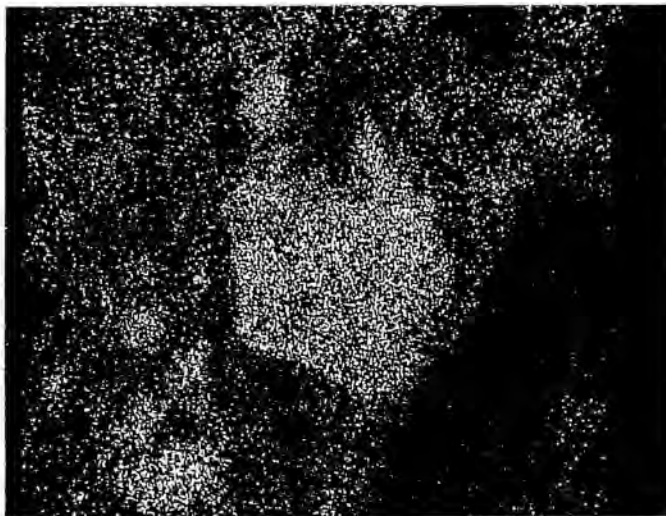
As



Al



Si



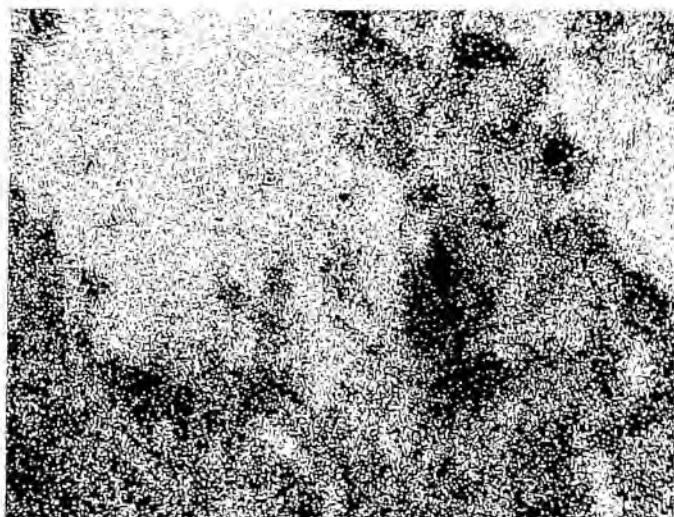
K

Arsenic (natif ?)
Associé à des grains de
silicates

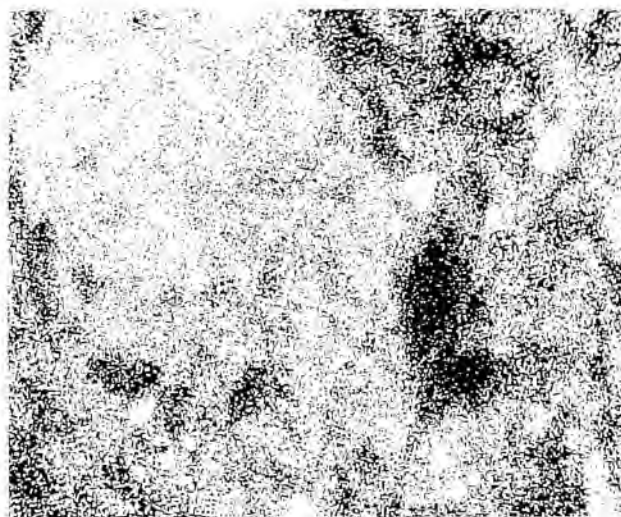


20μ

As



Al



Si

Echantillon n° 2
Concentrations poids % d'oxydes

Analy- ses	P	K	Ca	S	Fe	Ni	As	Al	Si	
1	00.93	06.46	00.38	00.78	01.11	00.08	08.94	26.03	38.04	82.74
2	00.17	06.23	00.28	00.47	01.17	00.00	12.45	21.98	37.33	80.08
3	00.04	06.48	00.20	00.34	01.06	00.11	17.45	24.71	40.16	90.54
4	02.06	04.98	00.49	00.78	01.11	00.06	30.85	25.19	32.79	98.30
5	00.74	05.36	00.40	00.95	01.43	00.00	23.23	21.52	32.72	86.34
6	00.18	04.12	00.20	01.10	00.90	00.01	60.33	16.72	25.46	109.01
7	00.10	02.82	00.19	03.49	01.10	00.34	83.34	16.79	22.28	130.45
8	00.34	00.55	02.59	01.94	18.40	03.10	04.04	10.42	17.18	58.54
9	00.69	00.85	03.88	02.62	08.89	00.67	02.95	22.08	18.57	61.20
10	00.47	00.51	03.62	02.12	21.12	02.38	03.360	19.41	19.79	72.79

Echantillon n° 3 / SUE C

Sulfoarséniures de nickel

Rares phases héritées du minerai originel.

Phosphates d'alumine, terres rares (Ce), et strontium.

Rares phases contenant de faibles ou très faibles quantités d'arsenic.

Possible héritage du minerai originel (?).

Phases ferrugineuses.

Rares ; piégeage d'un peu d'arsenic sur des produits ferrugineux contenant des traces de nickel, de types hydroxydes.

N.B. Cet échantillon ne semble contenir que très peu d'arsenic.

Il contient de fréquents fragments d'uraninite et de galène.

Echantillon n° 4 / SUE A + B

Sulfoarséniures de fer, fer-nickel ± cobalt.

Assez fréquents, héritage du minéral originel.

Phases phosphatées alumineuses, avec cérium et strontium.

Ces phases phosphatées, rares, contiennent des quantités variables d'arsenic (estimation « brute » 8 à 23 % As_2O_5 ; enrichissement local en arsenic en bordure de grain).

Peut être hérité du minéral originel (?).

Phases alumineuses.

Ces phases, qui contiennent aussi de petites quantités de fer et de nickel, sont abondantes et riches en arsenic (estimation « brute » 21 à 26 % As_2O_5). Elles semblent constituer l'essentiel des minéraux arsenicaux néoformés.

Phases ferrugineuses.

Rares ; elles semblent contenir un peu d'alumine et l'arsenic s'y trouve en petites proportions (estimation « brute » 10 à 16 % As_2O_5).

Phases nickelifère / ferro-nickelifère.

Rares ; l'arsenic y semble un peu plus concentré que dans les produits ferrugineux (estimation « brute » 13 à 20 % As_2O_5). Ces phases paraissent aussi contenir un peu d'alumine.

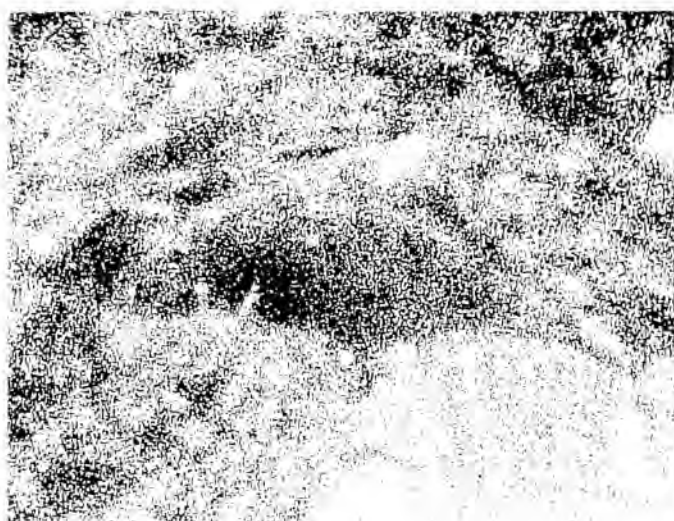
Phases à fer-cérium.

Rares ; l'arsenic s'y trouve en petites quantités.

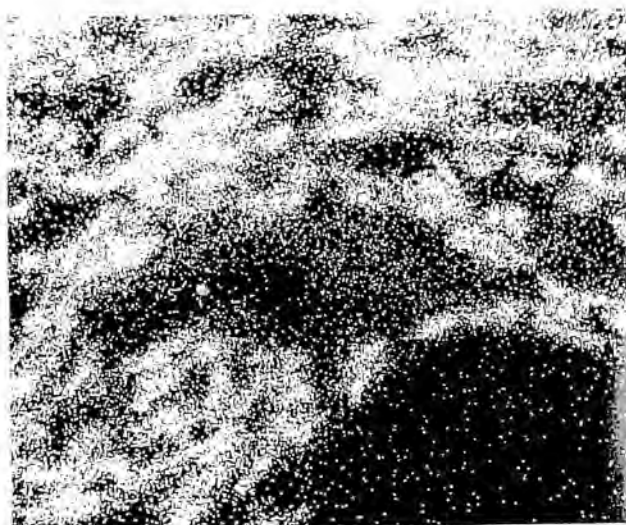
*Phase alumineuse
avec un peu de fer et de
nickel*

8875

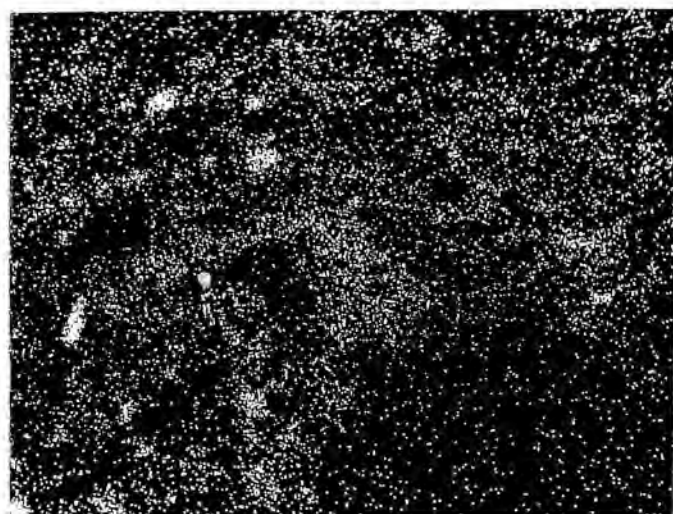
4



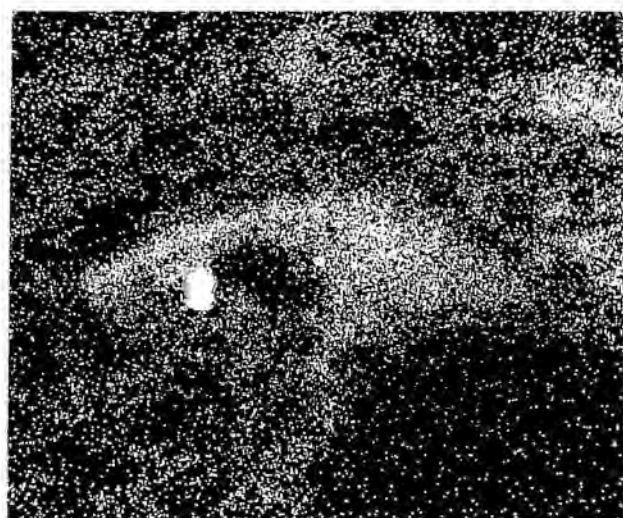
S



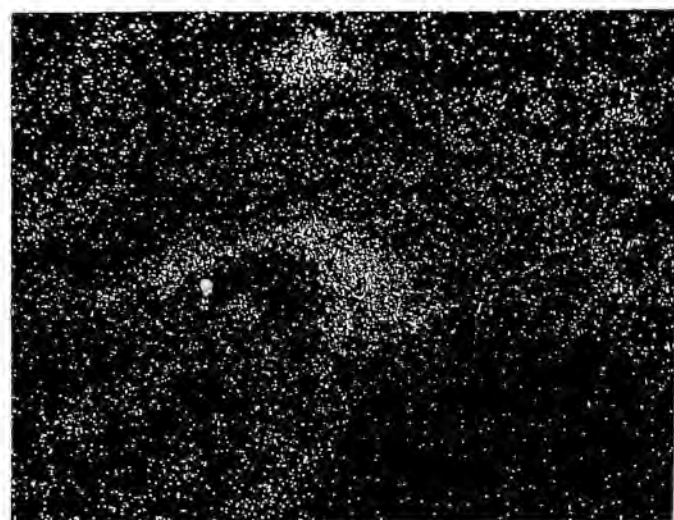
Ca



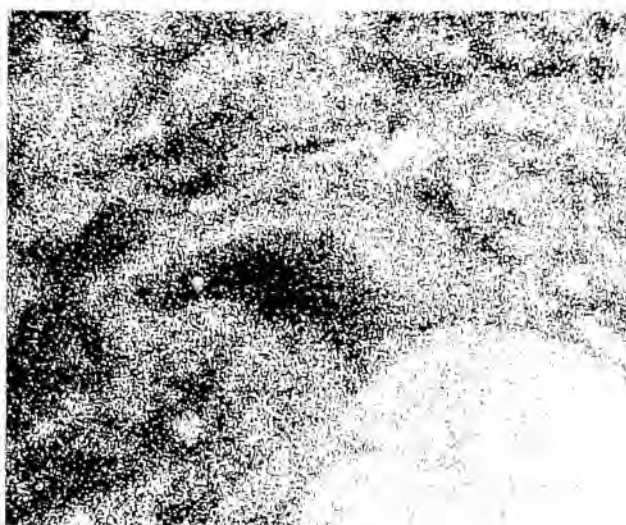
Fe



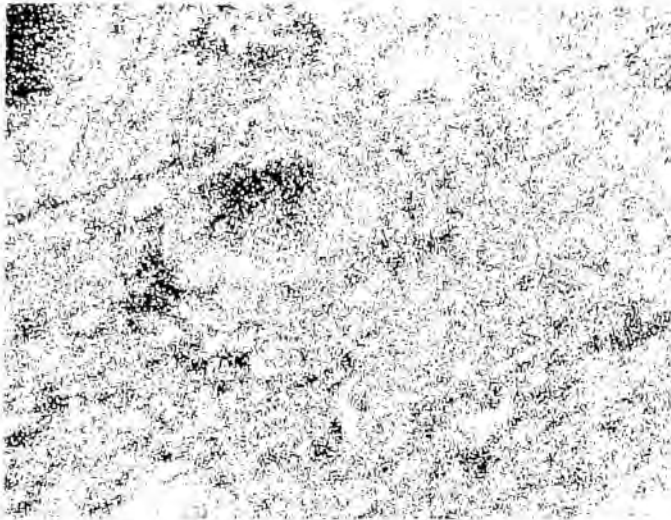
As



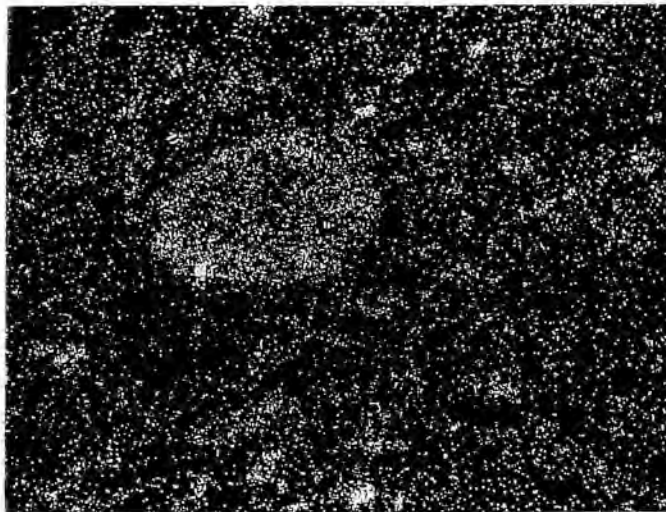
Ni



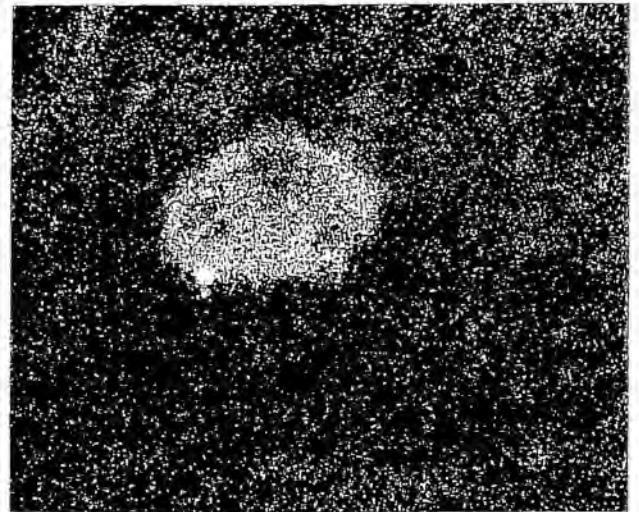
Al



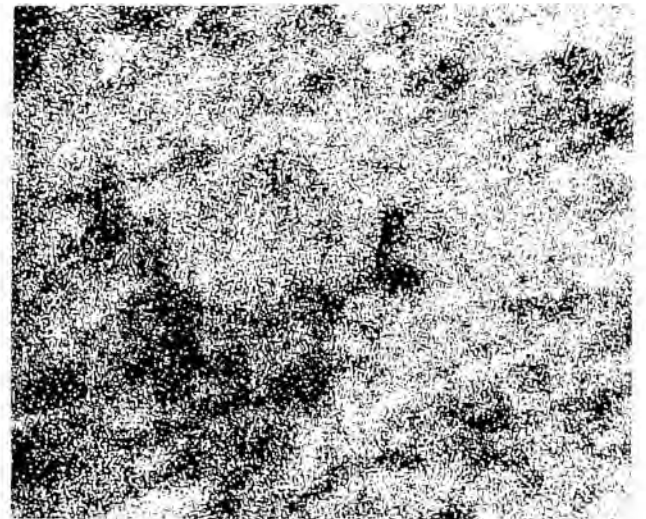
*Phase alumineuse
avec un peu de fer, et de
nickel (ce dernier non
représenté ici)*



Fe



As



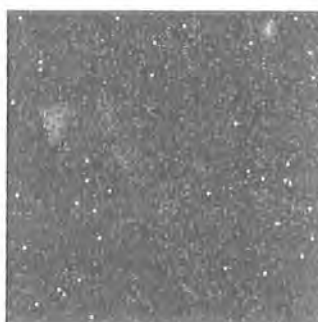
Al



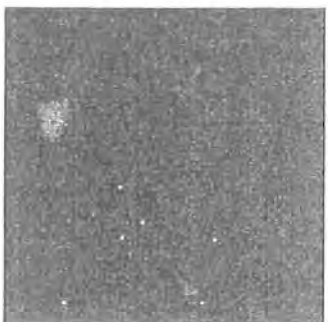
Al



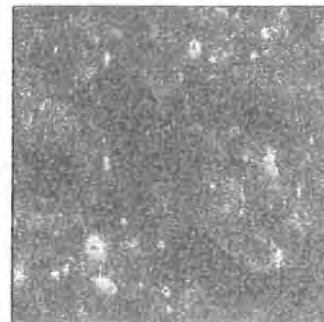
As



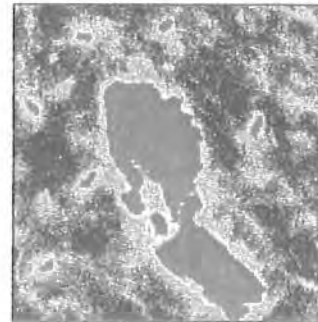
Ce



P



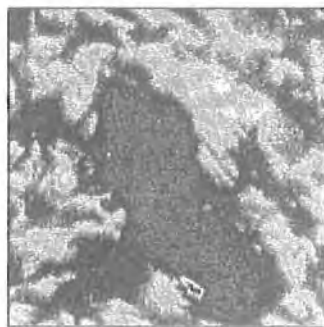
Fe



Si



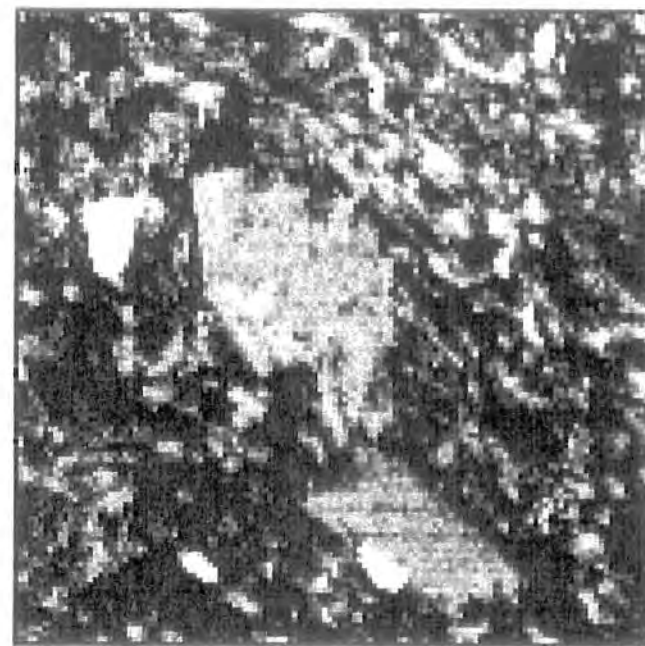
Ca



S



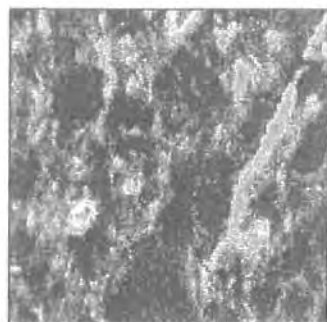
Concentration relative



107 μm

Electrons rétrodiffusés

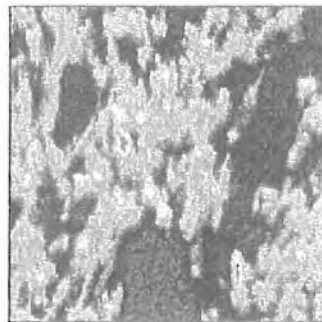
Echantillon n° 4
Phase phosphatée alumineuse avec
cérium, strontium
(non représenté ici)
et des traces de fer



Al



As



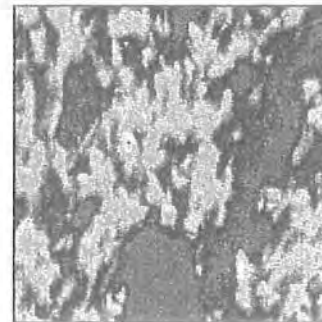
Ca



Ce



Fe



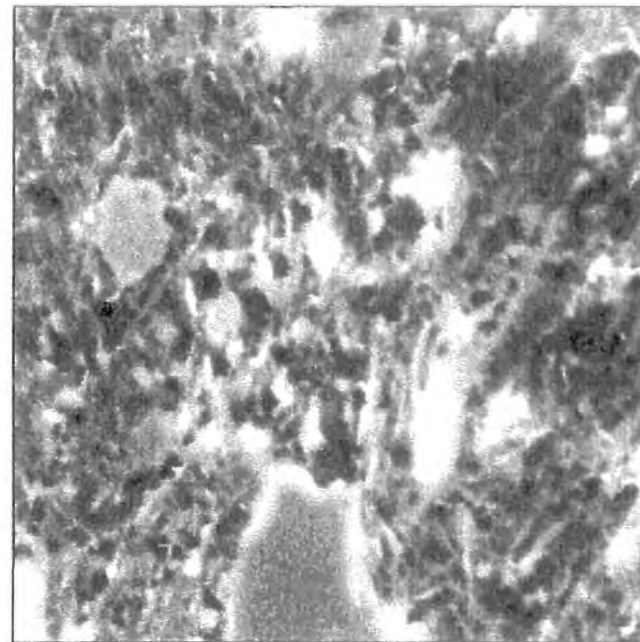
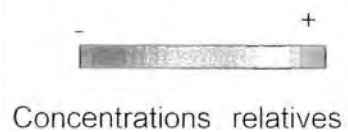
S



Ni



Si



107 μm

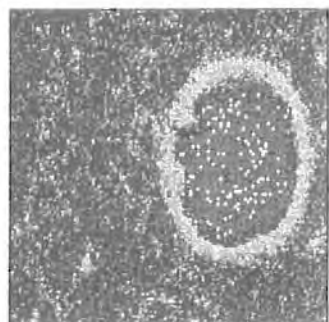
Electrons rétrodiffusés

Echantillon n° 4

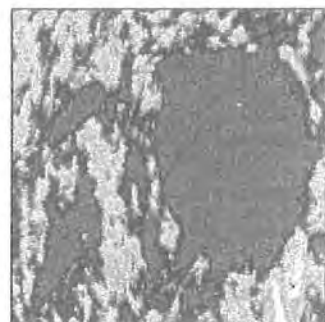
- Phase à fer-cérium (à gauche)
- Phase (ferro)nickelifère (à droite)



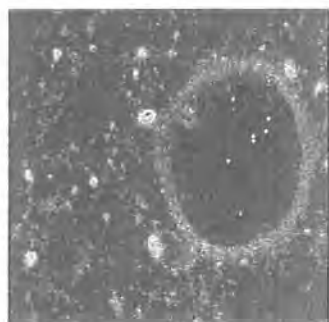
Al



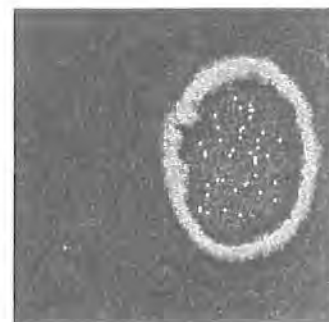
As



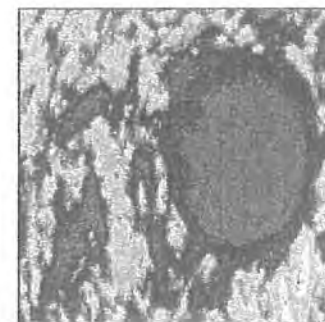
Ca



Fe



Ni



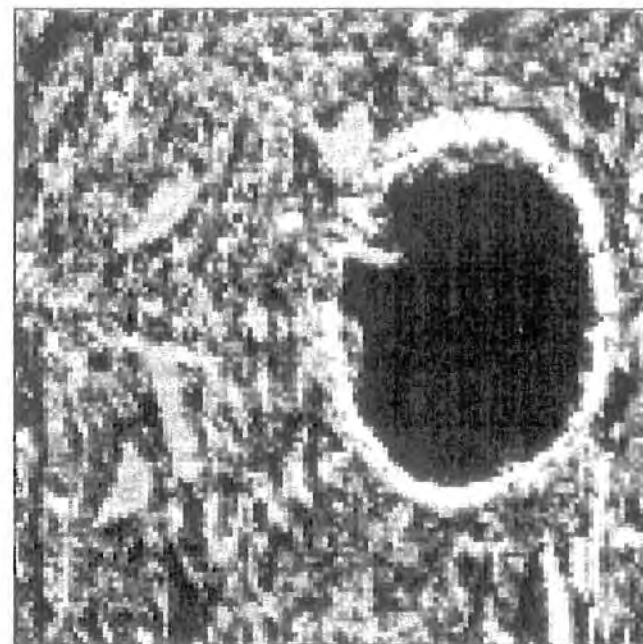
S



Si



Concentrations relatives



107 μm

Electrons rétrodiffusés

Echantillon n° 4
Phase (ferro)nickelifère

Echantillon n° 4
Concentrations poids % d'oxydes

Analy- ses	K	Si	Fe	Ca	As	S	Al	Ni	P	
1	1.962	18.582	7.212	3.853	5.752	5.613	12.283	3.999	0.215	59.472
2	2.061	18.297	6.941	4.242	5.760	5.378	12.319	4.218	0.197	59.414
4	1.612	14.830	3.807	2.748	6.194	4.067	12.234	7.428	0.110	53.029
5	0.441	5.830	7.730	1.198	10.720	3.358	8.279	22.418	0.128	60.103
6	0.838	9.150	18.020	0.916	11.467	2.747	8.654	14.076	0.144	66.013
7	1.947	13.608	5.334	0.782	6.453	2.195	10.700	11.520	0.094	52.633
8	1.505	12.654	6.747	2.300	7.336	3.296	10.430	6.011	0.092	50.370
9	2.022	28.164	3.837	0.848	4.278	1.134	17.725	3.862	0.112	61.982
10	2.177	25.289	5.058	1.543	4.092	2.577	12.595	2.456	0.108	55.895
11	1.709	16.980	9.047	8.917	6.481	9.406	10.237	1.942	0.335	65.053
12	1.267	11.614	12.946	6.067	9.919	6.714	9.079	4.468	0.412	62.487
13	0.337	5.851	7.545	1.303	9.855	2.822	8.287	14.206	0.225	50.430
14	1.353	18.841	4.384	1.781	7.562	1.938	13.455	3.465	0.351	53.128
15	0.695	8.812	7.725	2.526	12.702	3.036	10.817	8.242	0.192	54.747
16	0.777	11.366	7.354	2.492	12.763	3.084	12.072	8.916	0.231	59.056
17	0.890	8.315	8.527	17.017	7.979	17.001	6.556	1.957	0.435	68.679
18	0.683	10.632	5.427	4.294	18.664	3.046	16.942	6.099	0.552	66.341
19	0.862	13.873	5.506	3.026	17.017	1.723	17.020	6.013	0.467	65.507
20	0.673	12.528	7.765	2.832	19.107	1.935	16.383	6.576	0.541	68.340
21	0.817	11.875	10.976	2.933	21.497	1.995	16.937	6.214	0.607	73.810
	0.867	12.211	11.072	3.043	21.406	2.240	16.682	5.763	0.511	73.795
22	1.208	14.789	5.935	3.101	18.096	1.683	18.014	5.343	0.456	68.625
23	1.040	11.360	7.212	3.053	8.729	4.035	9.772	9.737	0.218	55.155
24	0.600	11.075	17.179	4.206	13.621	5.146	9.432	9.716	0.364	71.339
25	0.681	8.425	14.434	3.870	12.285	5.763	9.585	10.765	0.337	66.144

Echantillon n° 4
Concentrations poids % d'oxydes

Analy- ses	K	Si	Fe	Ca	As	S	Al	Ni	P	
26	0.142	4.617	4.306	4.175	25.807	1.288	24.438	3.787	0.967	69.527
27	0.178	4.796	4.569	4.111	25.967	1.151	25.326	3.487	0.887	70.472
28	0.171	4.935	4.444	4.424	26.165	1.156	25.143	4.073	1.036	71.546
29	0.111	4.135	2.849	3.169	21.091	1.428	22.000	3.011	0.937	58.732
30	0.084	4.905	2.385	3.334	23.150	1.144	26.197	2.500	0.994	64.695
31	1.167	10.883	5.411	1.554	8.232	2.454	12.202	8.376	0.121	50.401
32	0.359	6.377	1.756	1.862	11.263	1.084	14.760	2.072	0.568	40.101
33	0.264	6.386	1.836	1.886	11.404	0.941	14.717	1.972	0.555	39.961
34	1.279	11.019	22.174	1.388	11.860	1.698	7.305	1.175	0.275	58.172
35	1.106	10.677	20.805	2.040	16.402	3.179	8.397	2.395	0.401	65.401
36	0.934	9.445	20.842	8.485	10.301	9.081	6.741	0.963	0.355	67.148
37	0.030	1.204	3.720	3.678	11.869	1.970	27.174	0.164	14.772	64.582
38	0.058	1.050	2.812	3.403	9.360	1.693	28.799	0.151	17.861	65.187
39	0.146	3.089	4.176	3.712	11.599	1.648	24.534	0.351	14.215	63.471
40	0.141	4.779	5.958	2.555	21.799	0.764	7.783	5.558	0.591	59.929
41	0.211	4.856	4.648	3.502	25.954	1.091	23.265	4.170	0.784	68.481
42	0.140	4.552	3.973	3.529	25.680	0.944	22.690	3.554	0.926	65.988
	00.00	2.087	2.639	2.052	18.818	3.920	24.545	0.000	9.838	76.795
	00.00	1.275	1.930	2.441	7.900	2.019	25.575	0.000	8.596	54.892
	00.00	1.820	1.732	1.917	8.580	2.565	25.227	0.000	7.264	54.689
	00.00	1.132	4.003	1.817	23.197	3.551	25.284	0.000	8.546	81.628
	00.00	3.757	4.924	2.175	19.142	4.818	8.650	22.056	0.000	69.461
	0.530	6.185	14.246	1.928	20.438	4.166	7.198	21.742	0.000	79.700
	0.431	7.630	1.654	1.574	12.935	3.708	8.785	15.520	0.000	56.079

Echantillon n° 5 / SUE A + B et MIDWEST

Sulfoarséniures de fer, fer-nickel.

Assez fréquents ; héritage du minerai originel.

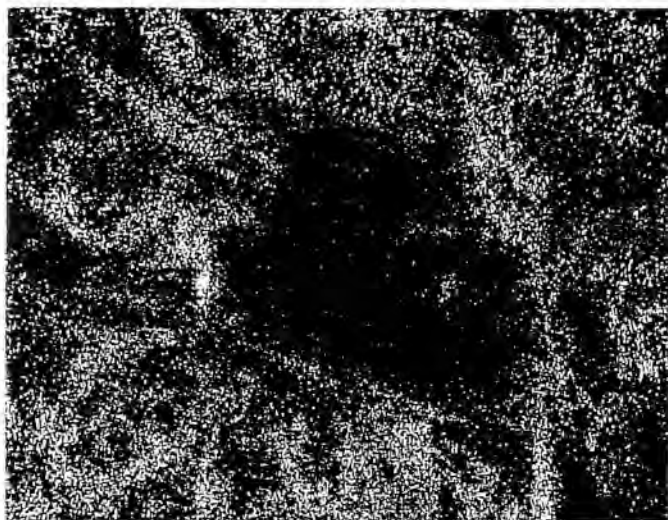
Phases arsenic-fer [As > Fe].

Il s'agit probablement des phases arsenicales néoformées principales ; ces phases abondantes contiennent des traces de *nickel* et de *calcium*.

L'arsenic s'y trouve en forte proportion (estimation « brute » 21 à 38 % As_2O_5).

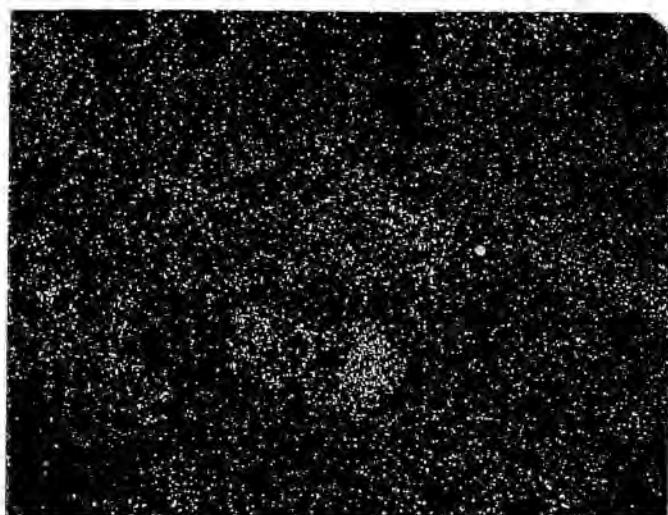
Phases arsenic-fer [As < Fe].

Rares ; ces phases contiennent néanmoins aussi de fortes proportions *d'arsenic*.

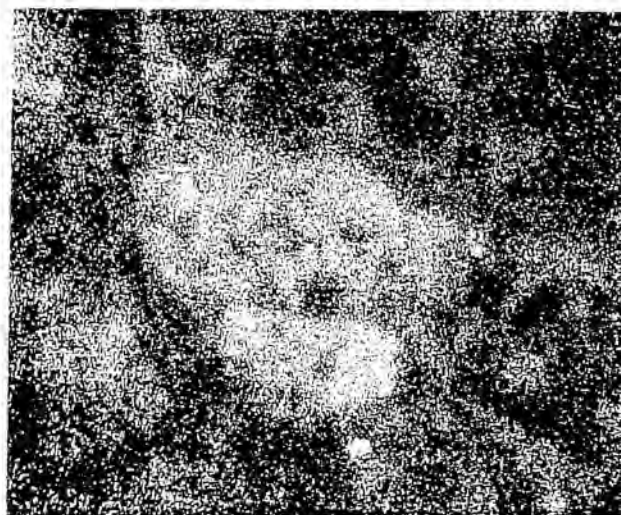


Phase arsenic-fer
avec un peu de nickel et
des traces de calcium
(non représentées ici)
(Analyses n° 8 à n° 11)

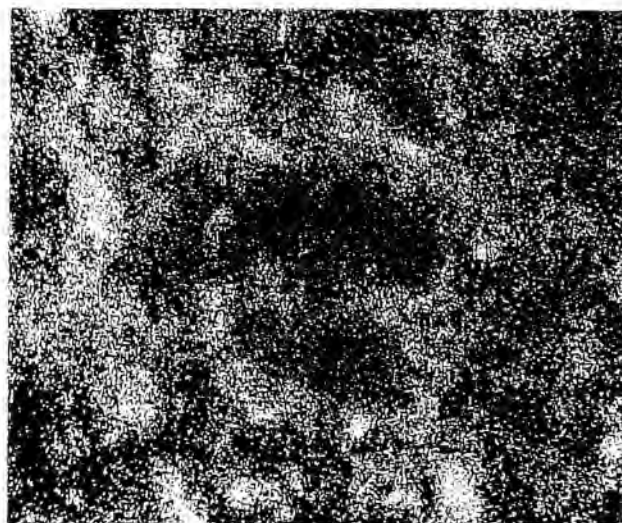
S



Fe

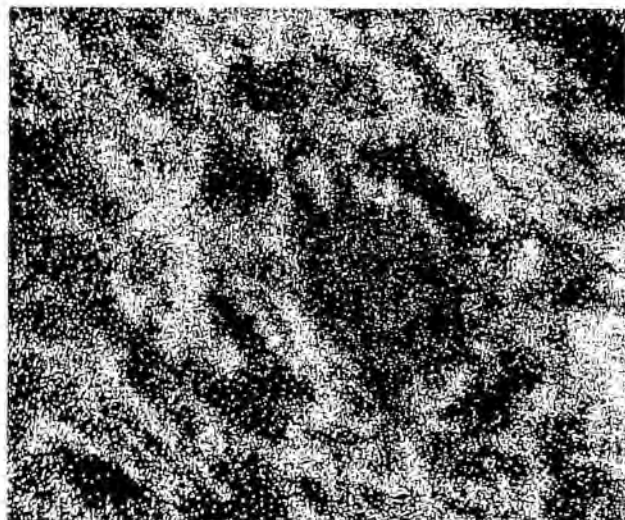


As

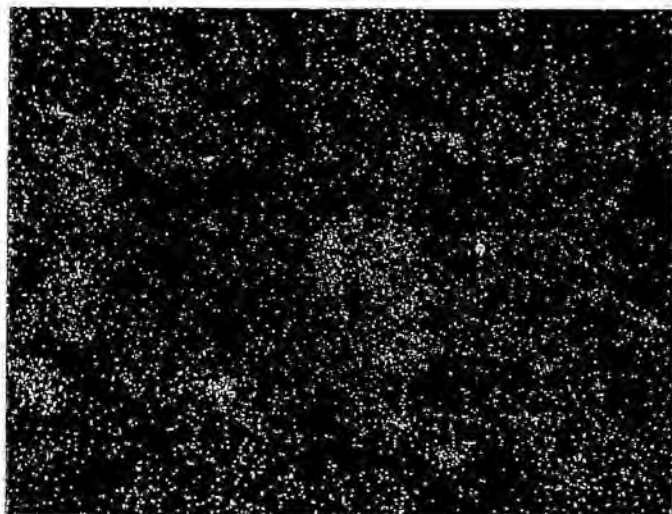


Al

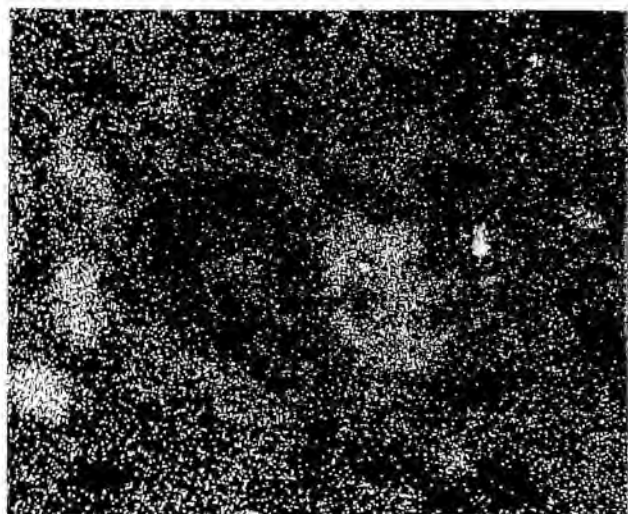
Phase arsenic-fer
avec un peu de fer, de
nickel (non représenté ici)
et de calcium



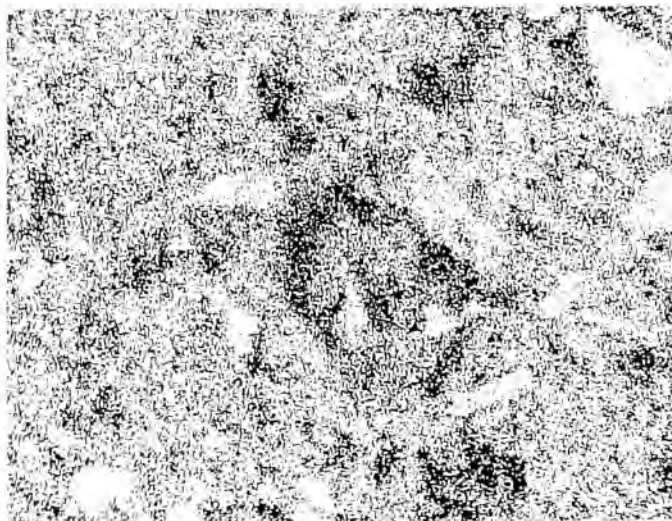
Ca



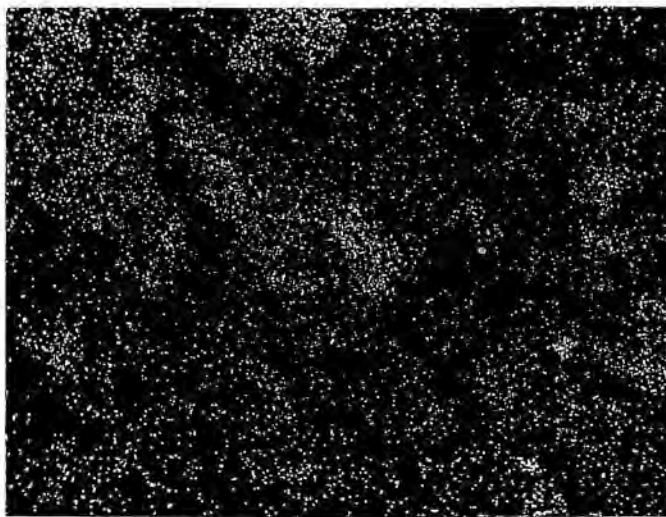
Fe



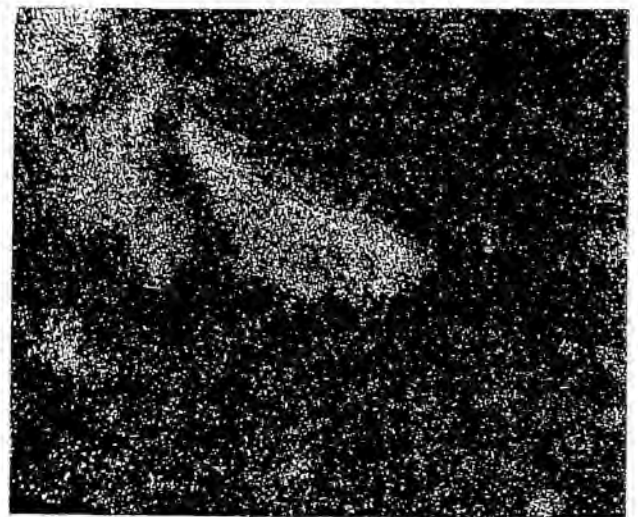
As



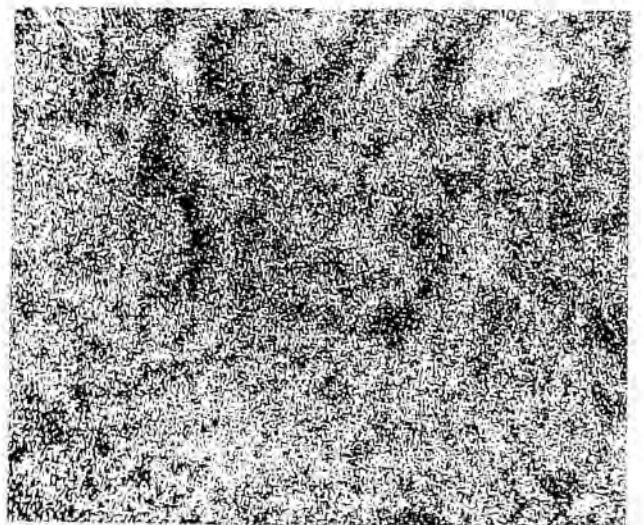
Phase arsenic-fer, avec traces de nickel et de calcium
(non représentées ici)



Fe



As



Echantillon n° 5
Concentrations poids % d'oxydes

Analy- ses	K	Si	Fe	Ca	As	S	Al	Ni	P	
1	0.140	4.552	3.973	3.529	25.680	0.944	22.690	3.554	0.926	65.988
2										
3	0.317	2.787	17.807	4.144	35.236	0.562	2.885	5.138	0.170	69.046
4	0.881	8.932	10.969	3.331	21.356	1.268	6.313	4.008	0.082	57.140
5	0.305	4.653	13.058	6.440	23.947	3.745	2.796	4.151	0.119	59.214
6	0.284	4.266	19.969	4.903	32.188	0.727	5.421	5.913	0.174	73.844
7	0.193	1.568	20.120	5.381	38.274	0.642	4.790	6.343	0.238	77.550
8	0.245	3.382	21.710	5.447	40.172	0.769	6.031	5.946	0.236	83.938
9	0.114	0.546	17.271	3.685	35.440	0.322	1.697	4.993	0.167	64.236
10	0.087	0.640	17.957	3.747	37.435	0.172	1.564	4.932	0.057	66.592
11	0.107	0.659	20.368	3.995	39.014	0.449	1.927	5.600	0.181	72.300
12	0.122	1.352	18.362	4.658	38.349	0.929	4.618	5.789	0.046	74.224
13	0.193	1.455	18.602	5.510	38.716	1.184	4.174	6.211	0.188	76.232
14	0.136	1.303	11.601	3.157	25.534	0.639	3.484	3.328	0.085	49.266
15	0.173	2.118	13.835	3.729	29.709	0.432	4.208	4.027	0.158	58.390
16	0.145	1.145	16.984	3.981	34.414	0.355	1.653	4.806	0.151	63.632
17	0.236	1.512	19.193	4.813	37.610	0.494	1.816	5.790	0.110	71.574
18	0.123	2.569	13.595	4.287	30.289	0.834	6.050	6.987	0.154	64.888
19	0.208	3.889	17.603	5.243	38.376	0.814	7.378	7.943	0.291	81.745
20	0.264	3.724	17.780	5.303	37.681	0.866	7.265	8.507	0.309	81.699
21	0.245	3.102	15.364	3.765	30.754	0.607	3.299	5.247	0.117	62.498
22	0.249	1.025	14.919	3.754	30.709	0.444	5.200	4.925	0.096	61.321
23	0.011	1.453	50.832	2.292	23.456	0.577	0.183	2.549	0.000	81.352
24	0.049	1.844	55.833	2.184	26.642	0.697	0.040	2.578	0.110	89.977

Appendix C

Section C

Part C: Letter Dated April 23, 1998



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April 23, 1998

Dear Jean,

Re: Arsenic Source Term ---- McClean Lake Project

As per your fax of April 17, 1998, I have critically reviewed the draft document "Geochemistry of JEB Pit Uranium Mill Tailings: The Arsenic Source Term", dated April 16, 1998, prepared by Drs. D. Langmuir and J. Mahoney on behalf of Cogema Resources Inc.. An almost identical version of the same document dated April 14 had been made available to me earlier (on April 15) by Dr Nicholson of Beak International along with a draft copy of the Summary Document entitled "Arsenic and Other Source Terms" (Section 3.0).

As per your specific instructions, I have focused my review onto assessing the soundness, credibility, accuracy of the data interpretation and approach outlined in D. Langmuir and J. Mahoney's document as to the predictions made for the long term arsenic concentration expected in the JEB Tailings Management Facility. My comments are presented in three sections: (1) First the proposed arsenic control process is briefly evaluated on the basis of the Summary Document provided to me by Beak International; (2) Second and more importantly the method of analysis employed by D. Langmuir and J. Mahoney in interpreting the laboratory test results and in predicting the rate and mechanism of arsenic release are critically reviewed; and (3) Additional specific comments are made from the point of improving the presentation of the results.

(1) Proposed Arsenic Control Process

The proposed method of neutralization of the acidic mill effluents with the combined addition of ferric sulfate to maintain Fe/As molar ratios of at least 3 represents the best

demonstrated available technology today for the immobilization of arsenic from As-bearing mining acidic effluents (Harris and Krause, 1993). By adding ferric sulfate to the acidic effluent prior to lime addition, (as illustrated in Figure 3.1 of the Summary Document) as opposed to together with lime, ensures the fixation of the bulk of arsenic in the form of ferric arsenate (as well as other metal arsenates) with the remaining soluble fraction of arsenic fixed via chemisorption on the co-precipitated ferric hydroxide (otherwise called ferrihydrite or hydrous ferric oxide – HFO).

For optimum results arsenic should be present as arsenate (i.e. in its pentavalent state). According to Langmuir and Mahoney's document (top of p.7), the JEB raffinate may contain As(III) up to 6% (or even higher, see Table 1.4.2.1); however, no traces of As(III) were detected in Dr. Slaughter's characterization work (see bottom paragraph of p.5a in Langmuir and Mahoney's document). Apparently As(III) was oxidized to As(V) during neutralization. Hence, aeration is vital (not shown in Fig 3.1 of the Summary Document) in ensuring both iron and arsenic are in their highest oxidation states (i.e. Fe(III) and As(V)) in order to obtain optimum immobilization of arsenic via ferric arsenate precipitation and adsorption on HFO.

Finally on the issue of "Optimization of Nominal Neutralization pH" (Section 3.4 in Summary Document), where a nominal pH of 8.5 as opposed to pH 8 is advocated with the rationale of avoiding pH dropping below 7 in the tailings pore water as this might cause an increase in nickel concentration, an alternative pH stabilization (in the region of 7 to 8) approach is proposed. This involves the use of a mixture of CaCO_3/CaO as opposed to only lime (CaO) for neutralization (i.e. add CaCO_3 in the first tank to bring pH to around 3-4 and lime in the second tank to bring pH to 8). The use of CaCO_3 will ensure a certain unutilized fraction of it to report to the tailings; hence providing buffering action against an excessive pH drop.

(2) Arsenic Geochemistry

2.1 Nature of Arsenic Species in the Tailings

The presented mineralogical evidence in D. Langmuir and J. Mahoney's document (based on the work of Dr. Slaughter) clearly confirms the presence of iron arsenate ("scorodite") and nickel arsenate ("cabrerite-annabergite") phases in the treated tailings. Such formation of ferric arsenate during neutralization of effluents with high Fe/AS ratios is in agreement with previous laboratory and plant observations as documented by Harris and Krause (1993). Arsenic is present according to the document also in the form of arsenic adsorbed by HFO and other phases which is also expected according to literature. The presented chemical equilibrium modeling work (Section 1.6.1) very clearly and authoritatively proves that the bulk of arsenic has reported in the tailings in the form of ferric (and nickel) arsenate precipitates with the balance (a small portion) of it absorbed with ferric hydroxide solids (HFO).

Throughout the report the arsenic phases are given mineral names (i.e. scorodite for ferric arsenate and cabrerite-annabergite for nickel arsenate). This would suggest then that the respective arsenate precipitates are crystalline phases. According to Dr. Slaughter's report, the "scorodite-like" phases were identified to be partially crystalline and partially amorphous. On the

other hand, the cabrerite-annabergite phases appeared to possess a higher degree of crystallinity. This finding is significant since according to my own research experience and that of others, ambient temperature neutralization leads normally to the production of amorphous and not crystalline scorodite (Demopoulos et al. 1995, Krause and Ettel, 1989). It appears, therefore, from the presented mineralogical evidence that upon neutralization and accelerated aging partial crystallization of the arsenate phase(s) has occurred resulting in enhanced arsenic stability. The multi-tank neutralization approach, the presence of large quantity of solids that practically have acted as seed material (this is indirectly confirmed in Dr. Slaughter's report who notes "all arsenate phases coat larger grains"), and accelerated aging are all factors believed to have contributed to the partial crystallization of the ferric and nickel arsenate precipitates.

2.2 Long Term Release of Arsenic

According to the aging test results (aging up to 50 days) the release of arsenic for the presented tailings was very low, typically less than ~ 0.5 mg/L at nominal pH 8 with $\text{Fe/As} \geq 3$ at 4°C . Statistical treatment of the experimental data and extrapolation to 10 000 years give arsenic concentrations in the area of ≤ 1 mg/L. These very low levels and slow rates of arsenic release have been explained on the basis of thermodynamic, kinetic and crystallization principles (Section 1.6. in D. Langmuir and J. Mahoney's document). Their presented theoretical interpretation is based on sound chemical reasoning.

Continuing on the observation I made in the previous section about the partial crystallization of the precipitated ferric (and nickel) arsenate, I would like to offer some additional comments as to why the rates of arsenic release are expected to be very slow. Arsenic, according to the characterization work done on the samples, is expected to be mostly present in the tailings emplaced in the JEB TMF in the form of ferric arsenate and nickel arsenate phases on one hand, and on the other hand arsenic adsorbed on ferric hydroxide (HFO). The fresh arsenate precipitates will be most likely amorphous or partially crystalline. All these solids will undergo over the years phase transformation reactions dictated by the thermodynamics of the tailings/water system. As recent advances in colloid and surface chemistry have shown (Blesa and Matijevic, 1989) such phase transformation reactions in aqueous media proceed via the dissolution-recrystallization mechanism. According to this mechanism the least stable phase forms first as a consequence of Stranski's or Ostwald Step Rule (see Blesa and Matijevic, 1989). The order of stability of iron(III) arsenate/hydroxide/oxides in the pH region of interest here, i.e. pH 7-8 is as follows: $\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}_{(\text{am})} < \text{FeAsO}_4 \cdot 2\text{H}_2\text{O}_{(\text{cr})} < \text{Fe}(\text{OH})_3_{(\text{am})} (\equiv \text{HFO}) < \text{FeOOH}_{(\text{cr})}$ (A similar order can be written for the nickel arsenate/hydroxide system). Due to the neutral pH environment, the low temperature of 4°C , and the lack of water flow inside the tailings facility, the dissolution and recrystallization of the solids is expected to be extremely slow. In particular, the conversion of crystalline scorodite into $\text{Fe}(\text{OH})_3$ (See, in addition to Section 1.6.2 in Langmuir and Mahoney's document, Demopoulos et al. 1994) and the crystallization of the latter (i.e. HFO) into goethite (see Section 1.6.4) are judged to be the slowest of these phase transformation processes.

As a further evidence in support of the extremely slow conversion of scorodite into iron (III) oxyhydroxide is the well documented occurrence of scorodite in nature in a wide range of climatic and pH regions in co-existence among other minerals with goethite/limonites (Gonzalez

and Monhemius, 1988). This might be so because of the likely blockage of the reaction upon the formation of surface layers of ferric oxyhydroxide on the grains of scorodite.

(3) Some Additional Comments on Langmuir and Mahoney's Document (mostly Editorial)

p4/2nd paragraph/2nd line: revise "remove As and Ni from tailings pore waters" to "from mill effluent waters".

p7/Fig 2: Provide source of data (thermodynamic calculations or experimental values)? Data are somewhat lower than those reported by Krause and Ettel (1989).

p7/Section 1.3.3: Some of the pH values and regions mentioned need correction. Thus change "pH 6" in "... about 10 mg/L below pH 6" to pH 8 (see Fig 2). Also change "pH 8-9" in "... about 10 mg/L As near pH 8-9" to "pH 7-8". Also change the words "between pH 7-8" with "above pH 3 and 7" in the phrase "... are unstable between pH 7-8 relative...."

p8/middle of top paragraph: The statement "most of the arsenic removed in these experiments was probably precipitated in scorodite" it should be revised to "... precipitated in the form of ferric arsenate" to reflect the lack of crystallinity of the precipitate.

p10/First line of 2nd paragraph in Section 1.1.1: Add the word "precipitation", i.e. Revise as follows: "Given the extensive published work on arsenic precipitation and adsorption with Fe(III) ion...."

p11./Table 1.4.2.1.1: Ni data should be included too.

p14(section 1.6.2): Were thermodynamic or solubility data used to calculate K_{eq} of Reaction (1)? I was able to obtain a value close to the one reported in the report (i.e. $10^{-11.17}$ versus $10^{-12.5}$) only when I used solubility data. (The data used were those of Krause and Ettel (1989)) (?)

p16/Eq.(6): Term A_w is the specific surface area (i.e. m^2/g) as opposed to simply the surface area (i.e. m^2) stated in the text.

p17/Bottom of 1st paragraph: It should read "... at some pH between 5 and 6" and not "...below...."

p17/Last sentence: "A survey of published mineral dissolution rate studies...." Give reference.

p19a/Section 1.6.5: Revise 2nd sentence by clearly mentioning that adsorption is a secondary mode of arsenic fixation with arsenic precipitation be the primary one; e.g. "This HFO in addition to the precipitated ferric and nickel arsenate is the other major arsenic carrier in the tailings".

p20/Last sentence of top paragraph: The sentence "Further breakdown... with time" becomes insignificant and contradictory in view of the evidence presented earlier on the extremely slow transformation rate of it."

p20/Section 1.7/bottom of 2nd paragraph: Correct the word arsenides to arsenates.

I will be happy to provide you with any clarifications you might have on the above review.

Sincerely,



G.P. Demopoulos
Professor and Chair

cc: Drs. D. Langmuir, and J. Mahoney (Hydrologic Consultants)
Dr. R. Nicholson (Beak International Inc.)

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