



# **Anvil Range Mining Complex: Rose Creek Tailings Deposit Assessment of Zinc Attenuation**

**2005/06 Task 22h(ii)**

*Prepared for:*

**DELOITTE & TOUCHE INC.**

*on behalf of the*

**FARO MINE CLOSURE PLANNING OFFICE**

*Prepared by:*



*Project Reference Number:*  
**SRK 1CD003.076**

**July 2006**



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Rose Creek Tailings Deposit  
Assessment of Zinc Attenuation**

**2005/06 Task 22h(ii)**

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On behalf of

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**July 2006**

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## Executive Summary

The primary objectives of this program were to i) obtain samples of tailings, organic materials and aquifer soils, ii) determine where the zinc is being removed from solution; and, iii) identify the dominant zinc removal mechanisms.

A drilling program was undertaken to obtain tailings and soil samples for the proposed testing program. Soil and tailings samples were submitted to Vison Scitec in Vancouver. A limited program of mineralogical examination was carried out on selected samples, in parallel with the Phase 1 laboratory program.

Field results indicated that migration of tailings into the underlying soils has occurred. The contamination of the underlying soils with tailings has somewhat confounded the interpretation of the results. However, the static test work and the mineralogical observations indicate that zinc attenuation is not occurring by neutralization or secondary mineralization mechanisms.

Mineralogical observations and correlations in the chemical analyses suggest that organic material is the most significant attenuating phase and a good correlation was observed between total carbon content and total zinc content of the soils underlying the tailings deposit. Zinc on the organic carbon of the soils typically reached 8 to 9 % by weight. These estimates corresponded well with cation exchange capacities reported in the literature.

Results further indicated significant amounts of total and organic carbon are present in the underlying soils to depths of 3 m below the surface organics. Organic rich silt layers were identified, and organic material was also noted in sand and gravel units. The results suggest an average total carbon content in the underlying soils of about 3.24 %. At this concentration the soils may attenuate about 10,000 tonnes of zinc within the first 1 m of soil below the tailings (area of about 196 ha). At the estimated current loadings of about 200 tonnes per year, this capacity is sufficient to limit the mobility of zinc for about 50 years and is consistent with water quality results in the underlying aquifer.

While reversibility of attenuation was not assessed, pH dependence correlations reported in the literature indicate that the cation exchange capacity will decrease as pH decreases, which suggests that zinc will be released from the organics should the pH in the underlying soils become acidic. Additional testing to verify this would be valuable.

Should it become necessary that the reversibility of the attenuation mechanism be assessed, alternate methods for obtaining undisturbed and un-contaminated soil samples from below the tailings or elsewhere should be investigated. Elution tests can then be undertaken to assess zinc desorption rates.

\* \* \*

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## Table of Contents

Executive Summary .....	i
<b>1 Introduction .....</b>	<b>1</b>
<b>2 Materials and Methods .....</b>	<b>2</b>
2.1 Sample Locations and Selection .....	2
2.2 Methods .....	2
<b>3 Results of Phase 1 Laboratory Testing.....</b>	<b>4</b>
3.1 Metal Content.....	4
3.2 Total Carbon and Total Inorganic Carbon .....	8
3.3 ABA Parameters .....	14
3.4 Porewater .....	15
3.5 Leachable Metals .....	15
3.6 Mineralogy.....	17
3.7 Comparison with Literature Values .....	18
<b>4 Organic Carbon Distribution.....</b>	<b>19</b>
4.1 Introduction .....	19
4.2 Approach.....	19
4.3 Information Sources.....	19
4.4 Results and Discussion.....	20
4.4.1 Correlation between Organic Matter and Terrain Units .....	20
4.4.2 Distribution of Organic Matter in Borehole Logs .....	20
<b>5 Summary and Conclusions.....</b>	<b>25</b>
<b>6 Recommendations.....</b>	<b>26</b>
<b>7 References.....</b>	<b>28</b>

## List of Tables

Table 3.1	Summary of Sulphur Speciation and Elemental Analyses .....	5
Table 3.2	Summary of Carbon Speciation in Soil Samples.....	9
Table 3.3	Summary of Calculated Correlation Coefficients.....	11
Table 3.4	Estimated Mass of 'Free' Zinc not Associated with Tailings.....	12
Table 3.5	Summary of Acid Base Account Results.....	14
Table 3.6	Estimated $K_d$ -Values .....	16
Table 3.7	Summary of Solute Ratios in Porewater and Leach Extraction Eluate .....	16

## List of Figures

Figure 2-1	Natural Attenuation Borehole Locations .....	3
Figure 3-1	Correlation between Zinc and Lead Content in Soil Samples.....	7
Figure 3-2	Zinc Content as a Function of Total Sulphur Content.....	7
Figure 3-3	Lead Content as a Function of Total Sulphur Content.....	8
Figure 3-4.	Relationship Between Zinc Content and Total Carbon Content of Natural Soils Underlying the Rose Creek Tailings. ....	10
Figure 3-5	Correlation between Calculated Mass Zn 'Free' and Total Carbon .....	13
Figure 3-6	Correlation between Calculated Zn Content of Carbon and Total Carbon Content.....	13
Figure 3-7	Correlation between Zinc Concentrations and pH in Shake Flask Leachates .....	17
Figure 3-8	pH Dependency of Cation Exchange Capacity of Soil Organic Carbon (Scheffer & Schachtschabel, 2002) .....	18
Figure 4-1	Delineation of Borrow Areas in the Rose Creek Tailings Area .....	22
Figure 4-2	Delineation of Geomorphological Units in the Rose Creek Tailings Area .....	23
Figure 4-3	Recorded Occurrence of Organic Matter .....	24

## List of Appendices

Appendix A:	Drill Logs and Field Parameters
Appendix B:	Laboratory Testing Program Design and Methods
Appendix C:	Laboratory Test Results
Appendix D:	Mineralogical Assessment

# 1 Introduction

As described in the October 10, 2005 memo “Rose Creek Tailings Attenuation Testing Program”, a two phase program was proposed for the investigation into zinc attenuation mechanisms. The primary objectives of this program were to:

- Obtain samples of tailings from depths that have been exposed to porewater with elevated zinc concentrations, but that still remain neutral in pH;
- Obtain samples of organic materials and aquifer soils that have been exposed to high levels of soluble zinc from the overlying tailings;
- Analyze the samples to determine where the zinc is being removed from solution; and,
- Carry out a series of tests to attempt to identify the dominant zinc removal mechanisms.

A drilling program was undertaken to obtain tailings and soil samples for the proposed testing program. Soil and tailings samples were submitted to Vison Scitec in Vancouver. A limited program of mineralogical examination was carried out on selected samples, in parallel with the Phase 1 laboratory program.

Results of the Phase 1 laboratory investigation have been completed, including repeated tests and mineralogical examination of materials from immediately below the tailings-original ground interface. The report summarizes the key results from Phase 1, and then provides recommendations for Phase 2 investigations.

## **2 Materials and Methods**

### **2.1 Sample Locations and Selection**

Figure 2-1 provides a plan of the drillhole locations (NA-05-01 to NA-05-04, NA-05-4A and NA-05-5 to NA-05-12). The location of Drillhole NA-05-1 (background) was selected upstream of the tailings deposit, and was sited on an undisturbed area adjacent the cleared access. The remainder of the drillholes were located in the Original, Secondary, and Intermediate tailings impoundments. Drillholes were sited to sample a variety of geochemical conditions related to degree of tailings oxidation and to identify the location of the contaminant front relative to underlying soils. Additionally, drillhole locations were selected in an attempt to intersect tailings above and below the water table. This was, however, not possible in all instances. Drill logs are provided in Appendix A. All samples selected for further testing were vacuum sealed in airtight bags to minimize oxidation prior to testing.

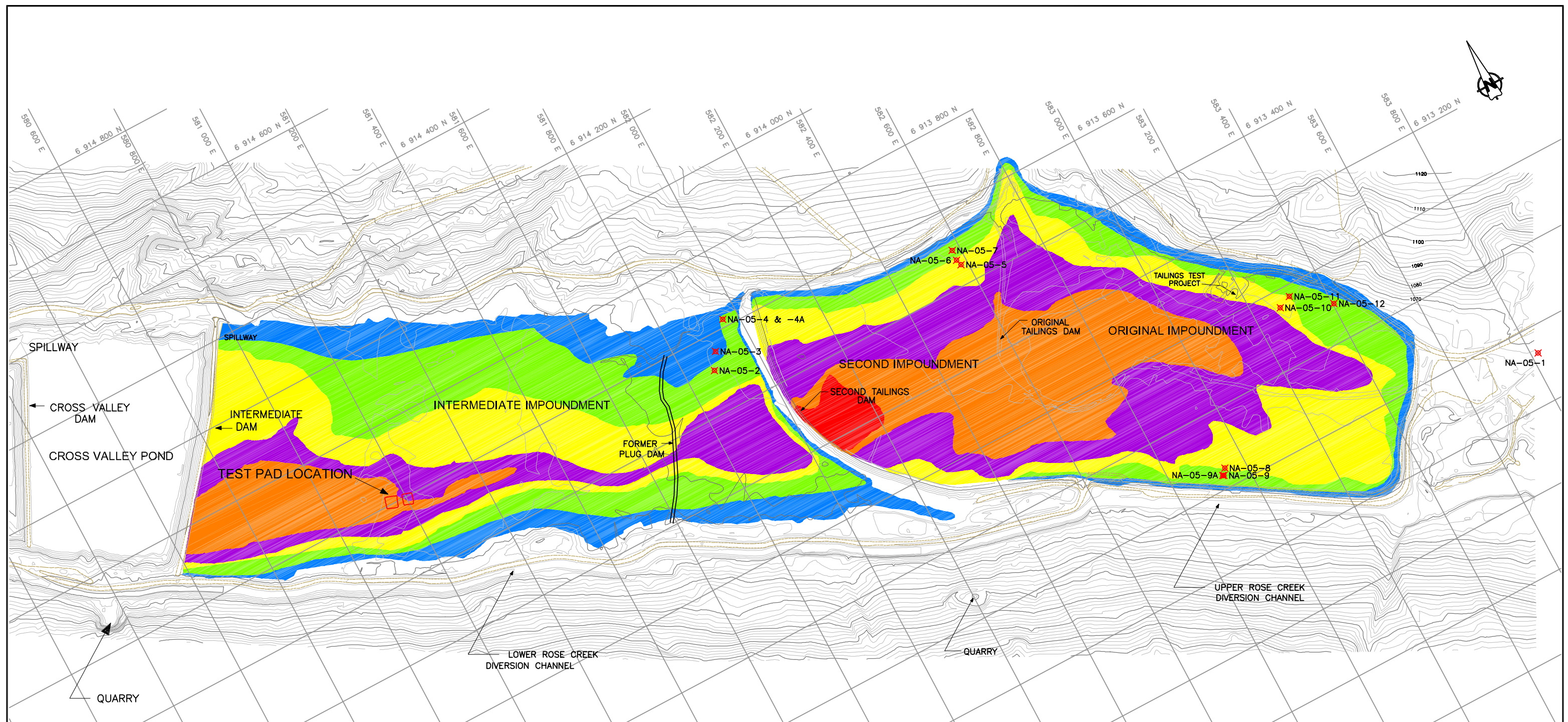
### **2.2 Methods**

A detailed laboratory testing program was developed from the findings of the field investigation, including the field parameters. The laboratory testing program and methods are described in Appendix B and comprised:

- Multi-element analyses of the tailings and soils, including organic and total carbon analyses;
- Acid base properties;
- Porewater extractions and analyses;
- Leach extraction tests and leachate analyses; and
- Mineralogical examinations.

The results from the laboratory investigation are summarised in the next section.

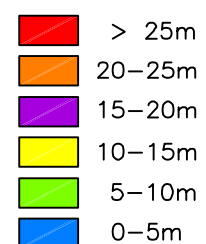




Date of Photography: 2003/07/25  
Scale of Photography: 1:20000  
Survey control derived from existing 1:20000 photography  
Survey control based on: UTM Projection, NAD27  
Compiled by The ORTHOSHOP, Calgary, September 2003  
WO 8856  
CONTOUR INTERVAL = 2m  
TAILINGS THICKNESSES SHOWN ARE AS OF SEPT. 17, 1990.

0 100 200 300 400 Metres  
SCALE 1 : 10,000

#### LEGEND



Borehole Location



SRK JOB NO.: 1CD003.076

Acad-Fara\2006 Acad drawings\Tailings-Isopachs2006\_Task22h(ii).dwg

**Deloitte  
& Touche**

Anvil Range Mining Complex

Rose Creek Tailings Deposit -  
Assessment of Zinc Attenuation

**Natural Attenuation  
Borehole Locations**

DATE:  
July 2006

APPROVED:  
DBM

FIGURE:  
2-1



## 3 Results of Phase 1 Laboratory Testing

The Phase 1 laboratory program focussed on testing of the natural soils underlying the tailings. The laboratory program included metal analysis of the soils underlying the tailings, porewater extraction of soils and tailings, shake flask extractions on soils and tailings, acid-base accounting on soils, and total carbon / inorganic carbon analysis.

### 3.1 Metal Content

All samples subject to Phase 1 laboratory testing were submitted for metal analysis by ICP-MS following four-acid digestion; a total of 22 samples were analyzed. Table 3.1 provides a summary of the metal content of the samples analyzed. Sulphur speciation, where undertaken, has been included in the summary table for comparison with metal contents.

The samples tested have been categorized on the basis of total sulphur content in two groups as soil (no tailings contamination), and as tailings/soil mix, as shown in the table. A third group of samples, consisting of pure tailings material, were not subject to any laboratory testing.

Samples from drillhole NA-05-1, located upstream of the Rose Creek Tailings deposit, represents background soil samples. It is apparent from the total and sulphide sulphur contents that some of the soil samples immediately below the tailings – soil contact have been contaminated by tailings. These samples have been classified as tailings/soil (mixed) samples in the table on the basis of a sulphur content in excess of 0.5 %. The contamination may have occurred during drilling or during tailings deposition.

The background samples indicate that the near-surface soils are enriched with zinc and lead. This enrichment may have been a natural phenomenon (due to the proximity of the deposition) or due to dust contamination. Below this surface horizon, the zinc content is on average about 105 ppm, and the lead content is about 24 ppm.

Iron content of the soils samples ranged from 2.3 to 12.2%, and manganese content ranged from 329 to 657 mg/kg. Iron and manganese were generally well correlated up to iron concentrations of 6%. The three samples with iron content in excess of 6% (NA-05-7 from 2.2 to 2.4 m and from 2.4 to 2.6 m, and NA-05-8 from 6.7 to 7.4 m) did not show proportional increases in manganese concentrations. These three samples indicated an elevated total sulphur and zinc content. When compared to the tailings properties, it is apparent that these three samples have been contaminated with tailings since the manganese content of the tailings is only about 500 ppm.

**Table 3.1 Summary of Sulphur Speciation and Elemental Analyses**

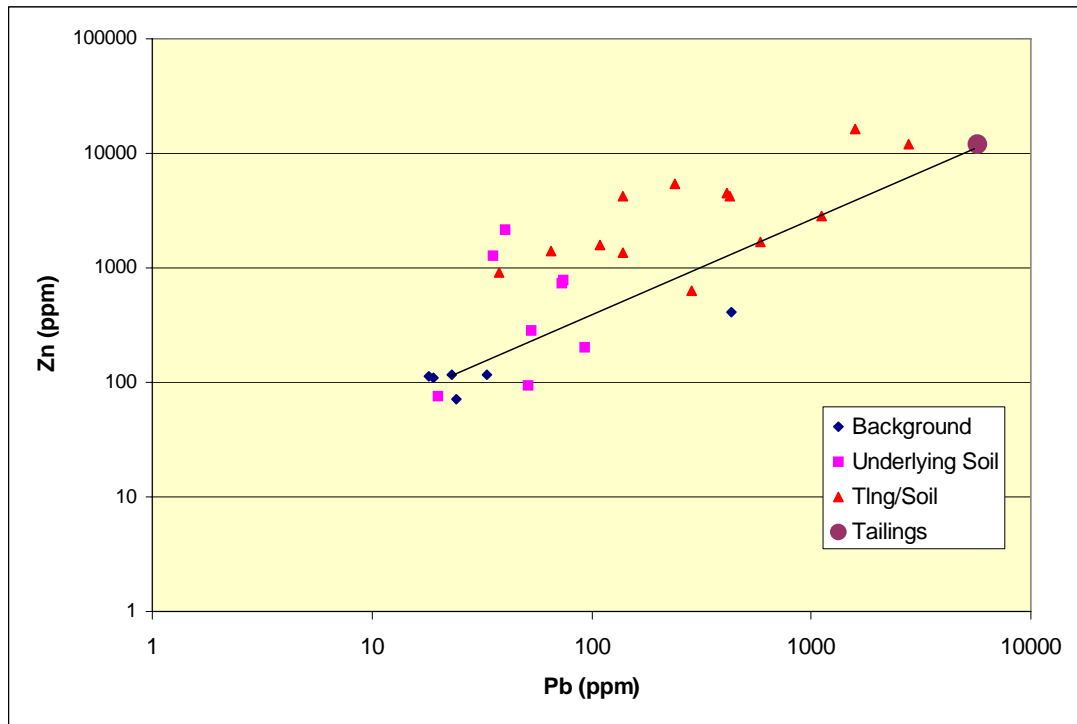
Sample Hole	From (m)	To (m)	Class	S(T) %	S(SO4) (Wt.%)	S(S2-) (Wt.%)	As ppm	Cd ppm	Cu ppm	Fe %	Mn ppm	Pb ppm	Zn ppm
NA-05-1	0	0.1	Soil	0.06	0.03	0.02	15.1	0.86	46.5	3.29	597	434	410
	0.1	0.6	Soil	0.04	0.03	< 0.01	6.3	0.22	19.4	2.94	748	33.6	117
	0.6	3.2	Soil	0.03			6.1	0.42	20.9	2.97	828	23.2	117
	3.2	3.6	Soil	0.01			6.6	0.31	18.3	2.43	427	24.3	71
	3.6	4.3	Soil	0.03	0.03	< 0.01	9.3	0.53	34.6	3.84	582	19.0	108
	4.3	9	Soil	0.03			8.9	0.8	33.8	3.32	471	18.2	113
NA-05-2	8.8	13.3	Soil	0.25	0.04	0.14	12.2	0.26	24.1	2.78	346	93.1	201
NA-05-3	6.4	6.6	Tailings/Soil	2.01	0.20	1.92	56	1.05	101.5	5.37	554	590	1685
	6.6	6.63	Soil	0.22		0.18	20.5	0.2	19.2	3.31	520	73.9	784
	6.63	7.35	Soil	0.16	0.09	<0.06	12.4	0.23	19.8	3.41	506	53	287
NA-05-4A	5.7	5.85	Tailings/Soil	2.19	0.26	1.95	42.1	13.65	334	4.66	520	429	4210
	5.85	5.95	Tailings/Soil	0.66	0.13	0.53	16.4	3.21	77.7	3.22	383	109	1580
	7.5	7.7	Soil	0.46	0.27	0.03	9.5	0.64	36.5	3.33	367	40.5	2140
NA-05-5	8.9	9	Tailings/Soil	1.62	0.72	0.74	13.9	5.08	48.9	4.96	657	240	5470
	9	9.1	Tailings/Soil	0.65	0.29	0.24	9.0	0.61	27.1	3.91	526	65.7	1415
	9.1	10.9	Soil	0.5	0.34	0.11	7.0	0.35	24.4	3.57	425	35.7	1265
NA-05-6	6.7	7.3	Soil	0.2	0.16	<0.01	7.2	0.43	22.2	2.89	379	73.4	741
	7.3	7.8	Tailings/Soil	1.84	0.47	1.38	23.2	0.94	62.5	5.01	521	139.5	1350
	8.6	8.9	Soil	0.28			6.7	0.25	23.8	3.2	409	20	77
NA-05-7	2.2	2.4	Tailings/Soil	7.5	2.64	4.82	86.8	13.85	232	9.72	616	1580	16200
	2.4	2.6	Tailings/Soil	3.22	1.47	1.56	28.2	1.56	75.5	6.62	596	414	4440
NA-05-8	6.7	7.4	Tailings/Soil	7.72			141	3.49	311	10.05	621	1110	2880
	7.4	8.8	Tailings/Soil	1.6		1.70	33.3	1.01	95.7	4.7	607	284	637
NA-05-10	12.9	13.5	Soil	0.07	0.03	0.00	4.4	0.18	22.9	2.54	358	553*	280
	13.5	16.5	Soil	0.04	0.03	<0.01	6.8	0.25	17.2	2.32	532	51.4	95
NA-05-12	5.9	6	Tailings/Soil	>10.0	1.76	9.48	91.7	4.26	287	12.2	512	2770	12200
	6	6.4	Tailings/Soil	1.51	0.99	0.57	9.9	0.76	38.7	4.71	329	138	4190
	6.4	7.2	Tailings/Soil	0.6		0.57	9.8	0.42	27.5	4.21	479	37.7	903

Note: \* reported analysis appears to be out by an order of magnitude based on comparison of Pb contents of other soil class samples.

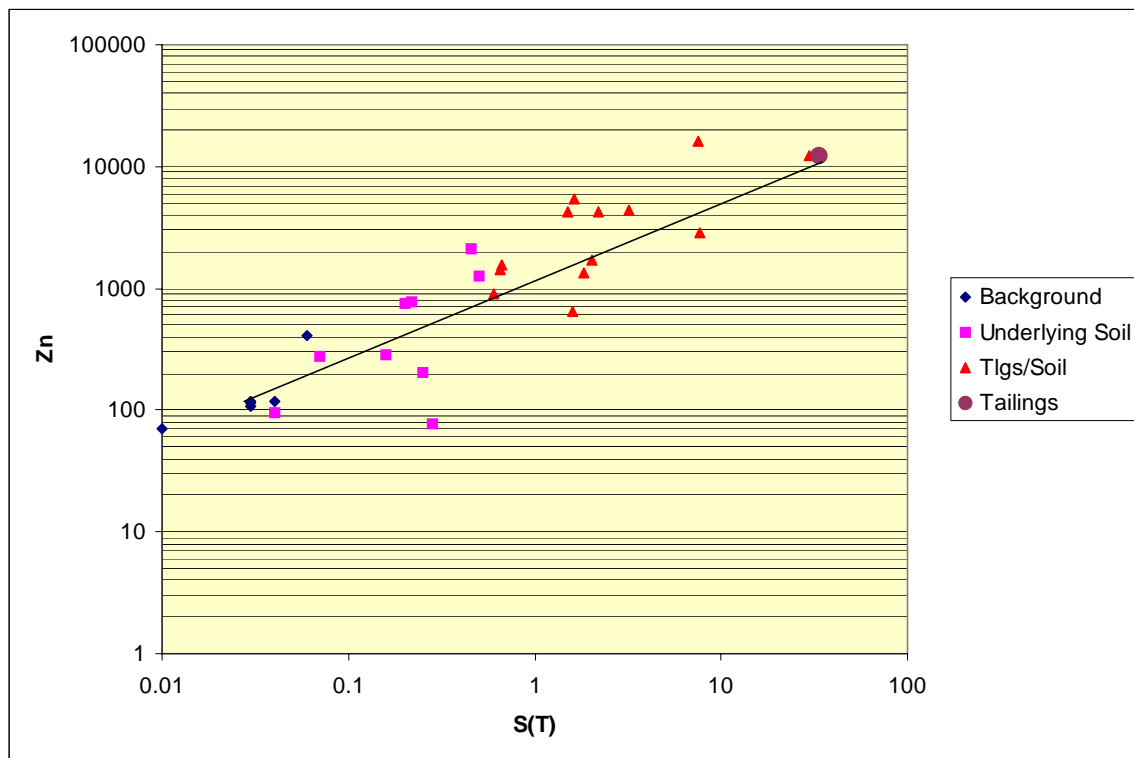
Zinc content of the underlying soil samples ranged from about 77 ppm to 2140 ppm (or 0.21% by weight). Lead content ranged from 20 to 553 ppm, however, the single analysis of 553 mg/L is considered to be anomalous when compared to the zinc and sulphur content of that sample (not shown in plot). Excluding that analysis, the lead content ranged from 20 to 74 ppm. It is apparent from these results that, compared to the background samples, these underlying soil samples are enriched with respect to zinc, and less so with respect to lead. This is not unexpected since lead mobility in a high sulphate environment is limited. A plot of zinc relative to lead is provided in Figure 3-1. For comparison, an average tailings analysis was included in the plot. The tailings analysis was obtained from the Gartner Lee assessment (Gartner Lee, 2002) which indicated a zinc content of about 1.2 % and a lead content of about 0.58 %. The plot shows the results for the background samples, the underlying soil samples and the samples that have may have been contaminated with tailings. The relative abundance of points above the straight line provides confirmation of zinc enrichment in the soil samples.

The zinc and lead contents of the soil samples have also been compared to sulphur contents as shown in Figure 3-2 and Figure 3-3, respectively (note that the plots show log-log correlations to enable presentation of the entire data range on a single plot). As shown in the plot for zinc, the straight line represents the expected zinc content in samples that comprise a mixture of background soil and tailings. However, the majority of the data points are above the line again indicating relative enrichment compared to 'mixed' samples.

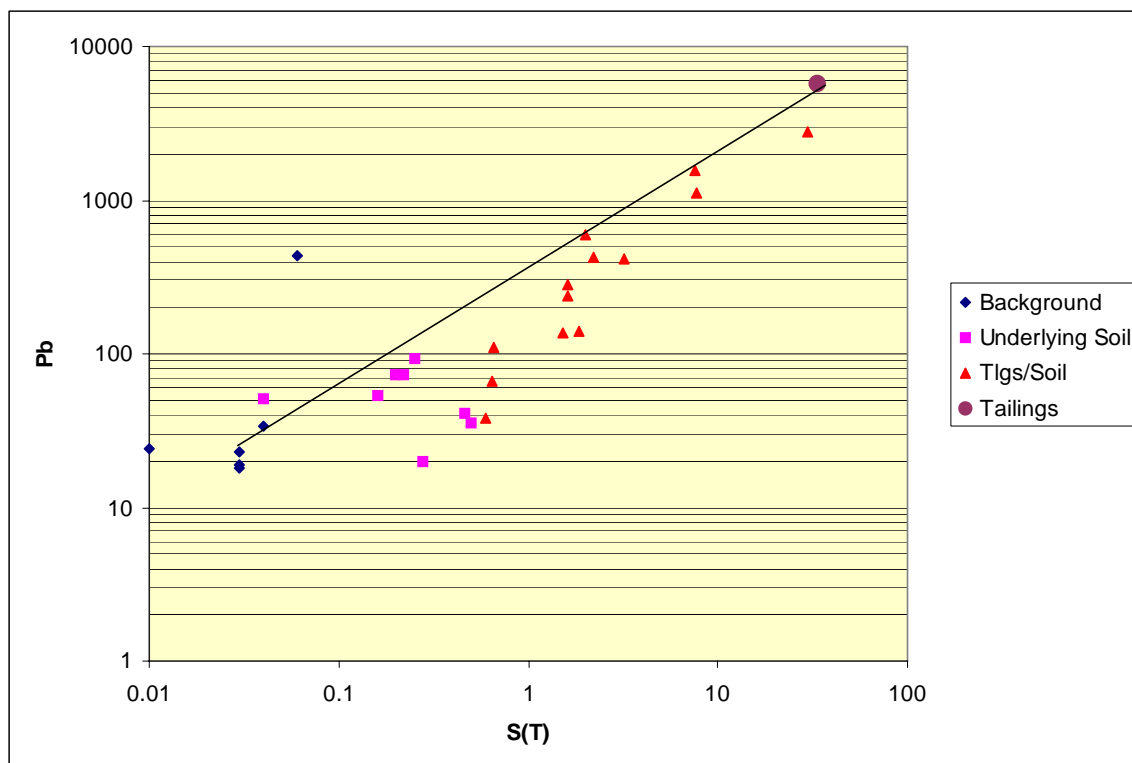
The corresponding results for lead presented in Figure 3-3 are predominantly below the inferred straight line. The lead in the 'soil' samples is marginally elevated above background, however. As opposed to zinc, the results appear to suggest that the lead has been 'depleted' from the 'tailings contaminated' samples. However, since the mobility of lead in a sulphate rich environment is expected to be substantially lower than zinc, the results infer an enrichment of sulphur. Sulphide analyses were completed for only a limited number of samples, however, these results yield similar relationships between sulphide and zinc and lead, respectively. The discrepancy in the lead – sulphur correlation, when compared to the zinc correlation, suggests that some of the sulphur may not have originated from tailings contamination. The results may potentially be indicative of secondary sulphide mineralization in the underlying soils.



**Figure 3-1 Correlation between Zinc and Lead Content in Soil Samples**



**Figure 3-2 Zinc Content as a Function of Total Sulphur Content**



**Figure 3-3 Lead Content as a Function of Total Sulphur Content**

## 3.2 Total Carbon and Total Inorganic Carbon

Selected samples were submitted for total carbon and total inorganic carbon, and organic carbon was inferred from the difference between these results. The results are summarized in Table 3.2.

Total carbon in the samples ranged from 0.11 % to 16 %, with an average of about 3.25 %. Total carbon typically was at its highest concentration immediately below the tailings – soil contact, and decreased with depth. However, in contrast to the background drillhole, where total carbon was elevated only in the first 0.1 m of depth, at some locations below the tailings, elevated levels of total carbon were detected well below the contact. For example, NA-05-4A, NA-05-5, NA-05-6, NA-05-7 and NA-05-8 all showed layers with an elevated total carbon content well below the contact.

The inorganic carbon content ranged from 0.003 to 0.108 % in the 17 samples selected for testing, indicating that only a small proportion of the total carbon is inorganic. The trends in organic carbon content therefore reflect those for total carbon.

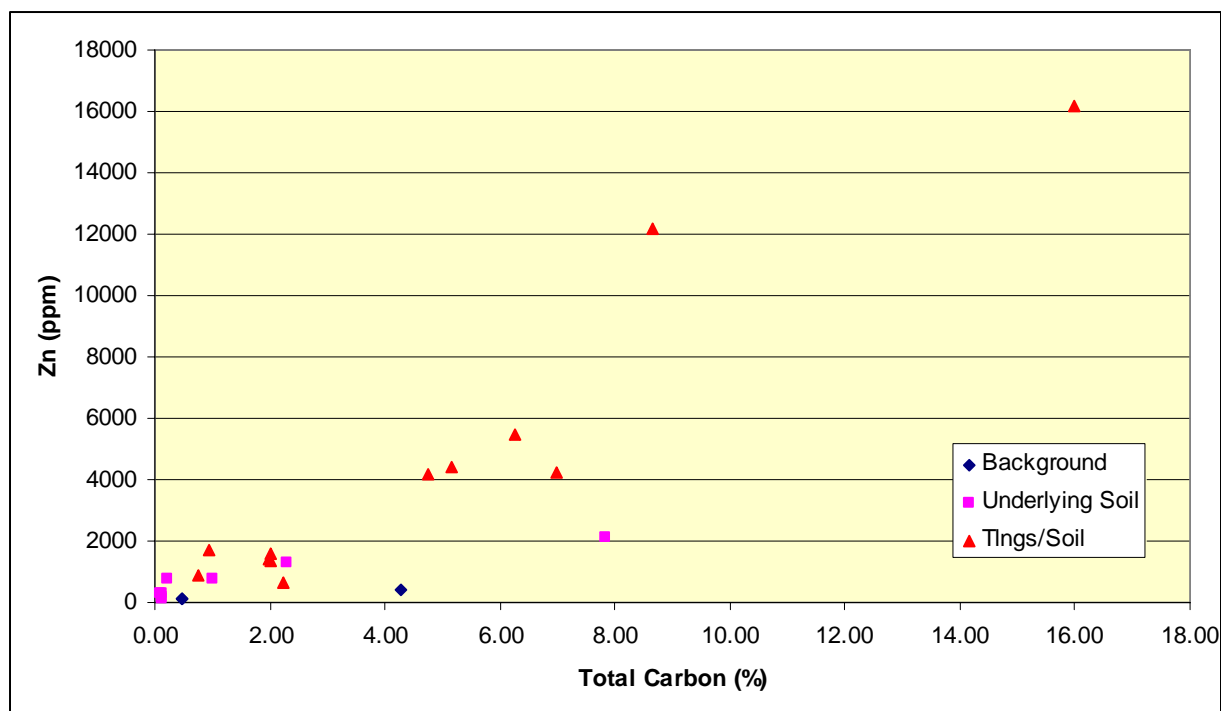
The correlation between the total carbon and zinc content of the soil samples is shown in Figure 3-4. As shown, there appears to be a direct correlation between carbon content and zinc content in the soil samples. Even though the correlation is strong, it should be noted that it likely is confounded by two factors. First, contamination by tailings solids was highest in the soil layer immediately below the contact, which coincidentally also had the highest carbon content. Second, if indeed secondary



sulphide mineralization is occurring, then it is likely that this too would be coincident with the organic carbon layers since the organic carbon may serve as a substrate for sulphate reducing bacteria.

**Table 3.2 Summary of Carbon Speciation in Soil Samples**

Sample ID			Total	Inorganic	Organic
Hole	From (m)	To (m)	Carbon (Wt.%)	Carbon (Wt.%)	Carbon (Wt.%)
NA-05-1	0	0.1	4.28	-	-
	0.1	0.6	0.46	-	-
	3.6	4.3	0.46	-	-
NA-05-2	8.8	13.3	0.140	0.010	0.130
NA-05-3	6.4	6.6	0.940	0.103	0.838
	6.6	6.63	1.00	-	-
	6.63	7.35	0.120	0.003	0.118
NA-05-4A	5.7	5.85	6.99	0.075	6.92
	5.85	5.95	2.02	0.025	2.00
	7.5	7.7	7.83	0.010	7.82
NA-05-5	8.9	9	6.26	-	-
	9	9.1	1.99	0.020	1.97
	9.1	10.9	2.31	0.018	2.29
NA-05-6	6.7	7.3	0.220	0.020	0.200
	7.3	7.8	2.00	0.005	2.00
NA-05-7	2.2	2.4	16.0	0.093	15.9
	2.4	2.6	5.16	0.038	5.12
NA-05-8	6.7	7.4	-	0.108	-
	7.4	8.8	2.22	0.038	2.18
NA-05-10	12.9	13.5	0.110	0.005	0.105
	13.5	16.5	0.120	0.008	0.113
NA-05-12	5.9	6	8.65	0.065	8.585
	6	6.4	4.76	0.015	4.75
	6.4	7.2	0.750	-	-



**Figure 3-4. Relationship Between Zinc Content and Total Carbon Content of Natural Soils Underlying the Rose Creek Tailings.**

To further assess the potential relationships between carbon and zinc, correlation coefficients were calculated as summarised in Table 3.3. The correlation coefficients were calculated for each subset of samples, as well as the combined underlying soils (background excluded).

As shown, within the tailings/soil samples ( $S > 0.5\%$ ), there is a good correlation between lead and sulphur, which would be expected for tailings contaminated soils. As expected (and as noted above), there is some correlation between the total carbon and total sulphur. However, the correlation between zinc and total carbon appears to be stronger than between zinc and total sulphur. This is evidence for zinc enrichment of the carbon.

Within the underlying soils subset, there is very pronounced correlation between total carbon and zinc, providing further evidence for zinc enrichment of the organic carbon.

The results for the combined tailings/soil samples indicate zinc to be correlated to both carbon and total sulphur.

In conclusion, the results provide evidence for zinc removal by enrichment of the organic carbon present in the underlying soils.

The mass of zinc not associated with tailings particles can be estimated by assuming that the sulphur present in each sample is a result of tailings contamination, and, that the zinc to total sulphur ratio in the tailings remain constant (these assumptions do not allow for the potential effects of secondary

mineralization). The results of these calculations are summarized in Table 3.4 and illustrated in Figure 3-5. As shown in Figure 3-5, there is a very good correlation between the estimated mass of 'free' zinc (i.e. not associated with the tailings) and the total carbon content. The estimated mass of 'free' zinc ranged up to 13,328 mg/kg, with an average of about 2,300 mg/kg.

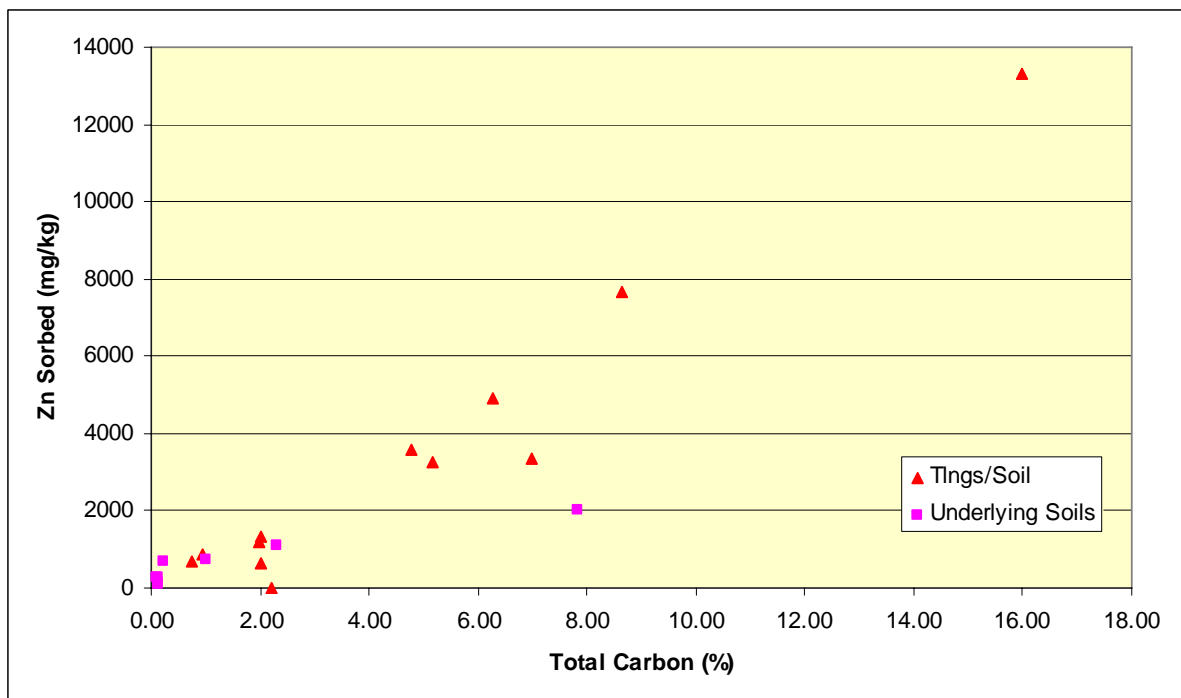
The right-most column in Table 3.4 shows the calculated loading of zinc sorbed on the carbon. The results suggest that the loading on the carbon may be as high as 24 %. However, as shown in Figure 3-6, the higher estimates were derived for samples with a low carbon content. The analytical and calculation errors are likely to be magnified for such low concentrations. Figure 3-6 suggests that the more typical zinc loading on the carbon is on the order of 8 to 9 %. The calculated average, disregarding the results for the low carbon content samples, is about 6%. Whether any of the samples had zinc loading reflecting the maximum attenuation capacity of the sample material is unknown at this time.

**Table 3.3 Summary of Calculated Correlation Coefficients**

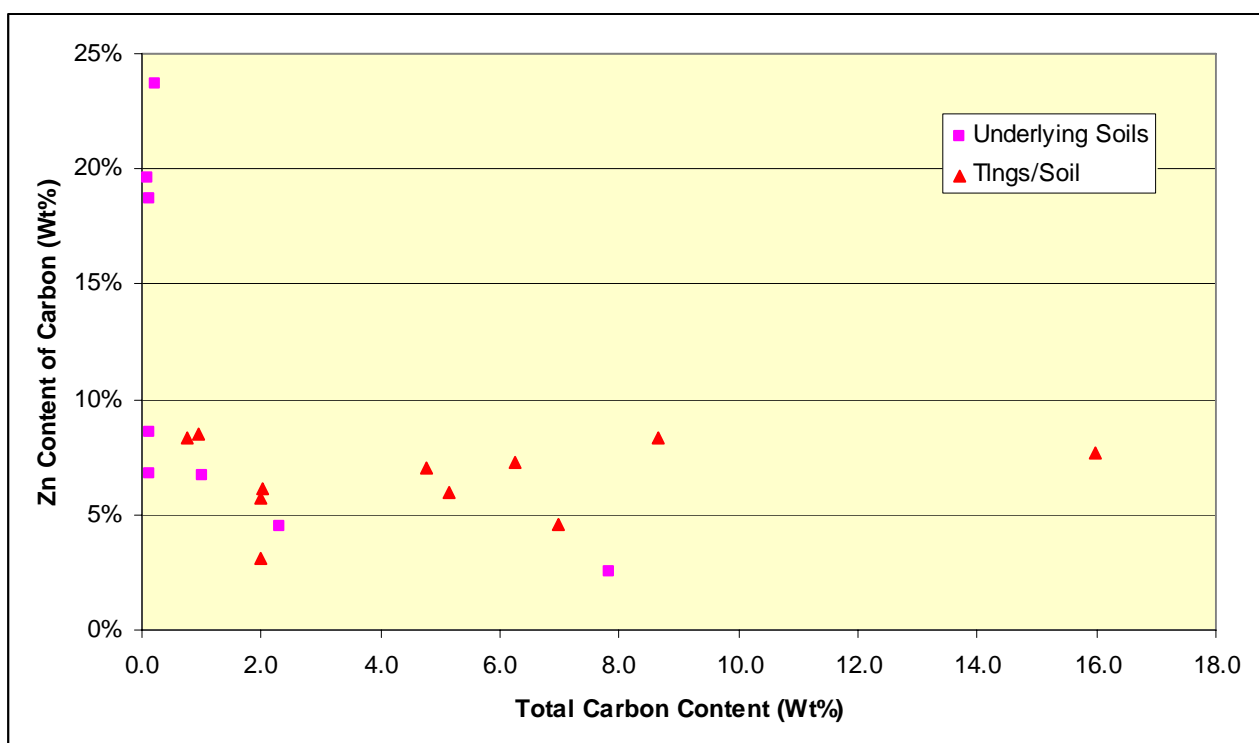
Tailings/Soil Samples (N=12)				
	<i>TC</i>	<i>TS</i>	<i>Pb</i>	<i>Zn</i>
TC	1.00			
TS	0.72	1.00		
Pb	0.66	0.99	1.00	
Zn	0.96	0.86	0.82	1.00
Underlying Soils (N=9)				
	<i>TC</i>	<i>TS</i>	<i>Pb</i>	<i>Zn</i>
TC	1			
TS	0.59	1.00		
Pb	-0.51	-0.31	1.00	
Zn	0.94	0.75	-0.50	1.00
Combined Tailings/Soils and Underlying Soils (N=21)				
	<i>TC</i>	<i>TS</i>	<i>Pb</i>	<i>Zn</i>
TC	1.00			
TS	0.72	1.00		
Pb	0.65	0.98	1.00	
Zn	0.92	0.89	0.84	1.00

**Table 3.4 Estimated Mass of 'Free' Zinc not Associated with Tailings**

Sample Hole	From (m)	To (m)	Total Carbon (Wt.%)	Total Sulphur (Wt.%)	Zn ppm	Zn (as S <sub>2</sub> -) ppm	Zn Sorbed ppm	Zn on Total Carbon (Wt%)
NA-05-2	8.8	13.3	0.140	0.18	201	69	132	9%
NA-05-3	6.4	6.6	0.940	2.12	1685	816	869	8%
	6.6	6.63	1.00	0.18	784	69	715	7%
	6.63	7.35	0.120	0.03	287	12	275	19%
NA-05-4A	5.7	5.85	6.99	2.21	4210	851	3359	5%
	5.85	5.95	2.02	0.66	1580	254	1326	6%
	7.5	7.7	7.83	0.30	2140	115	2025	3%
NA-05-5	8.9	9	6.26	1.46	5470	562	4908	7%
	9	9.1	1.99	0.53	1415	204	1211	6%
	9.1	10.9	2.31	0.45	1265	173	1092	5%
NA-05-6	6.7	7.3	0.220	0.15	741	58	683	24%
	7.3	7.8	2.00	1.85	1350	712	638	3%
NA-05-7	2.2	2.4	16.0	7.46	16200	2871	13329	8%
	2.4	2.6	5.16	3.03	4440	1166	3274	6%
NA-05-8	7.4	8.8	2.22	1.70	637	654	-17	0%
NA-05-10	12.9	13.5	0.110	0.03	280	12	268	20%
	13.5	16.5	0.120	0.02	95	8	87	7%
NA-05-12	5.9	6	8.65	11.24	12200	4326	7874	8%
	6	6.4	4.76	1.56	4190	600	3590	7%
	6.4	7.2	0.750	0.57	903	219	684	8%



**Figure 3-5 Correlation between Calculated Mass Zn 'Free' and Total Carbon**



**Figure 3-6 Correlation between Calculated Zn Content of Carbon and Total Carbon Content**



### 3.3 ABA Parameters

Total sulphur concentrations ranged from 0.02 to 11.2% in 20 samples, with reported sulphate sulphur ranging from 0.03 to 2.64% in 17 samples tested, as shown in Table 3.5. Negative neutralization potentials were measured for a number of samples, including two samples with total sulphur contents of 0.30 % or less. This is likely due to the presence of ferrous iron in the pore water, which will have oxidized after sampling and before testing to yield the low paste pH values and the negative NP values. The carbonate NP values in general were low compared to the background samples, suggesting that the NP, if present in the natural soil samples, had largely been depleted. Positive NNP values were measured only for samples with a total sulphur content of less than 0.14 %.

**Table 3.5 Summary of Acid Base Account Results**

Sample Hole	From (m)	To (m)	Class	Paste pH	T(S) (Wt.%)	S(SO4) (Wt.%)	S(S2-) (Wt.%)	AP	NP	CO3-NP	NNP
NA-05-1	0	0.1	Soil		0.05	0.03	0.02	1			
	0.1	0.6	Soil	5.67	0.02	0.03	<0.01	<0.3	12	-	12
	0.6	3.2	Soil	-	-	-	-	-	-	-	-
	3.2	3.6	Soil	-	-	-	-	-	-	-	-
	3.6	4.3	Soil	7.21	0.02	0.03	<0.01	<0.3	101	-	101
	4.3	9	Soil	-							
NA-05-2	8.8	13.3	Soil	6.33	0.18	0.04	0.14	4	31	0.9	26
NA-05-3	6.4	6.6	Tailings/Soil	5.42	2.12	0.20	1.92	60	23	9.3	-36
	6.6	6.63	Soil	-	0.18	-	0.18	6			
	6.63	7.35	Soil	5.07	0.03	0.09	<0.06	<1.9	26	0.2	27
NA-05-4A	5.7	5.85	Tailings/Soil	4.82	2.21	0.26	1.95	61	-30	6.8	-90
	5.85	5.95	Tailings/Soil	4.89	0.66	0.13	0.53	17	1	2.3	-15
	7.5	7.7	Soil	5.00	0.30	0.27	0.03	1	-20	0.9	-20
NA-05-5	8.9	9	Tailings/Soil	3.14	1.46	0.72	0.74	23	-137	-	-159
	9	9.1	Tailings/Soil	3.42	0.53	0.29	0.24	8	-21	-	-28
	9.1	10.9	Soil	-	0.45	0.34	0.11	3	-	1.6	-
NA-05-6	6.7	7.3	Soil	3.82	0.15	0.16	<0.01	<0.3	-11	1.8	-10
	7.3	7.8	Tailings/Soil	3.12	1.85	0.47	1.38	43	-57	0.5	-99
	8.6	8.9	Soil	-	-	-	-	-	-	-	-
NA-05-7	2.2	2.4	Tailings/Soil	2.87	7.46	2.64	4.82	151	-451	8.4	-601
	2.4	2.6	Tailings/Soil	2.94	3.03	1.47	1.56	49	-234	3.4	-283
NA-05-8	6.7	7.4	Tailings/Soil	-	-	-	-	-	-	9.8	-
	7.4	8.8	Tailings/Soil	6.96	1.70	-	1.70	53	22	3.4	-30
NA-05-10	12.9	13.5	Soil	6.95	0.03	0.03	0.00	0	17	0.5	16
	13.5	16.5	Soil	-	0.02	0.03	<0.01	<0.3	-	0.7	-
NA-05-12	5.9	6	Tailings/Soil	2.85	11.24	1.76	9.48	296	-296	5.9	-592
	6	6.4	Tailings/Soil	3.09	1.56	0.99	0.57	18	-157	1.4	-175
	6.4	7.2	Tailings/Soil	-	0.57	-	0.57	18	-	0.0	-

Note: NP, AP and NNP in units of kgCaCO<sub>3</sub>/tonne

### 3.4 Porewater

Due to low levels of saturation, it was not possible to complete the anticipated series of porewater extractions. Porewater was successfully recovered only from a single soil sample collected from a drillhole on the Intermediate Impoundment (NA-05-8, from 7.5 to 8.0 m). The porewater from this sample had a zinc concentration of 2.94 mg/L, an iron concentration of 15 mg/L, and a sulphate concentration of about 650 mg/L. This sample was collected from within 0.2 m of the tailings interface. Unfortunately, it was not possible to obtain a tailings porewater sample immediately above the interface.

Porewater was successfully extracted from 3 tailings samples located immediately above the tailings/porewater interface in drillholes NA-05-2, NA-05-7 and NA-05-10. The samples were from each of the three tailings impoundments. The porewater in the samples from the Secondary and Original impoundments were found to have zinc concentrations of 6,000 to 7,000 mg/L, and sulphate concentrations on the order of 60,000 to 90,000 mg/L. The porewater sample from the Intermediate Impoundment had a zinc concentration of 130 mg/L and a sulphate concentration around 10,000 mg/L.

Complete porewater extraction results are provided in Appendix C.

### 3.5 Leachable Metals

Distilled water shake flask extractions were carried out at a 3:1 water:solids ratio on 17 samples. Sulphate concentrations in leachate ranged from 78 to 11,424 mg/L, with pH values ranging from 2.9 to 7.4. Most pH values were less than 5. Zinc concentrations in leachate ranged from 0.5 to 1,231 mg/L, iron concentrations ranged from 0.2 to 6,282 mg/L, and lead concentrations ranged from 0.06 to 3.8 mg/L.

The zinc concentration in leachates from the soil samples with low sulphur contents (<0.5 %) ranged from 0.013 mg/L to 128 mg/L. The leachates from the samples with higher sulphur contents ranged from about 10 mg/L to about 1,231 mg/L and showed a good correlation with the sulphur content especially at higher sulphur grades. This would suggest that additional soluble zinc was likely released from the tailings present in the samples. The zinc concentrations in the leachates from the background samples ranged from 0.008 mg/L to 0.166 mg/L.

Attenuation coefficients ( $K_d$ ) were estimated from the leach extraction tests and the estimated 'free' zinc contents of the samples, as shown in Table 3.6, results are sorted in order of increasing total carbon content. The results suggest attenuation coefficients typically between 4 and 10.

A comparison between the solute concentrations in the porewater extraction and the leach extraction is shown in Table 3.7. The table shows the concentrations ratios for zinc, sulphate and sodium. As shown, the natural soil sample for which a porewater extraction was achieved showed a similar sulphate and sodium dilution ratio, which corresponds to a dilution ratio for a sample with an initial moisture content of about 50 % (by wt). However, the zinc dilution is substantially greater

indicating that not all the zinc was extracted by the leach extraction test. Rather, a substantial amount of the zinc was retained in the sample.

In contrast, the ratios for the tailings samples were similar for all three parameters shown. The dilution ratio indicates an initial sample moisture content of about 15 to 20 % (by wt).

**Table 3.6 Estimated  $K_d$ -Values**

Sample ID			Description	T-Carbon (%)	T-Sulphur (%)	$K_d$ (L/kg)
Drillhole	From (m)	To (m)				
NA-05-10	12.9	13.5	Soil	0.11	0.03	474
NA-05-3	6.63	7.35	Soil	0.12	0.03	9.2
NA-05-2	8.8	13.3	Soil	0.14	0.18	81
NA-05-6	6.7	7.3	Soil	0.22	0.15	5.3
NA-05-3	6.4	6.6	Tailings/Soil	0.94	2.12	6.4
NA-05-3	6.6	6.63	Soil	1.00	0.18	11
NA-05-5	9	9.1	Tailings/Soil	1.99	0.53	5.8
NA-05-6	7.3	7.8	Tailings/Soil	2.00	1.85	3.6
NA-05-4A	5.85	5.95	Tailings/Soil	2.02	0.66	103.3
NA-05-12	6	6.4	Tailings/Soil	4.76	1.56	23.0
NA-05-7	2.4	2.6	Tailings/Soil	5.16	3.03	5.8
NA-05-5	8.9	9	Tailings/Soil	6.26	1.46	6.0
NA-05-12	5.9	6	Tailings/Soil	8.65	11.24	6.2
NA-05-7	2.2	2.4	Tailings/Soil	15.98	7.46	13.6

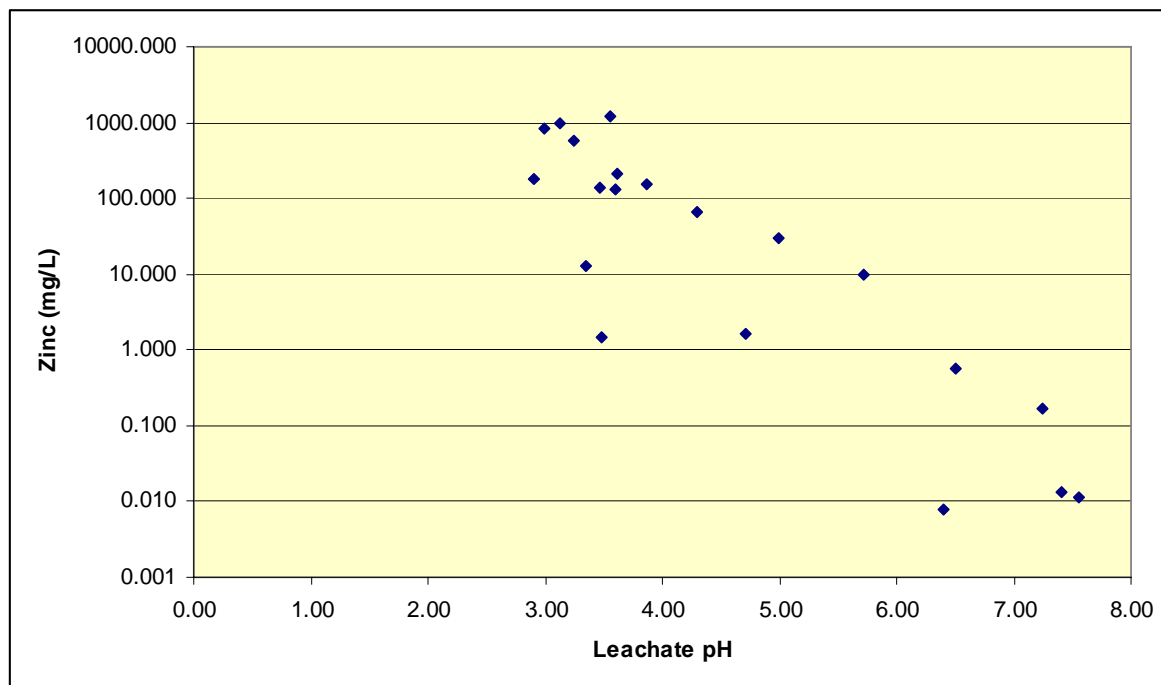
**Table 3.7 Summary of Solute Ratios in Porewater and Leach Extraction Eluate**

Parameter	Soil Sample NA-05-8 7.4-8.8 m	Tailings Sample NA-05-2 8.7-8.8 m	Tailings Sample NA-05-7 2.0-2.2 m	Tailings Sample NA-05-10 11.8-12.0 m
Zn(PW)/Zn(LE)	224	18.1	18.2	21.0
SO <sub>4</sub> (PW)/SO <sub>4</sub> (LE)	6.5	20.7	17.8	23.7
Na(PW)/Na(LE)	6.9	23.9	16.3	22.5

The above results suggest that, for the natural soil samples, a direct correlation between the leach extraction test results and the porewater concentration may not exist for zinc.

The results for the leach extraction tests completed on the natural soils indicated a correlation between the zinc concentration in the leach extraction leachate and zinc content of the solids. However, it is also noted that there is a strong correlation between the zinc correlation and the leachate pH, as shown in Figure 3-7. Most of the samples had acidified, presumably as a result of the ingress of oxygen to the leach extraction tests (or during the initial sampling) leading to oxidation of dissolved ferrous iron resulting in the precipitation of ferric hydroxide. It is therefore not possible to determine whether the zinc release is occurring from the tailings that are present in the samples

(through oxidation, acidification), and/or being released from the organic carbon due to the declining pH.



**Figure 3-7 Correlation between Zinc Concentrations and pH in Shake Flask Leachates**

### 3.6 Mineralogy

Mineralogical evaluation of eight samples was carried out by Dr. John Jambor of Leslie Research and Consulting. Hand specimens were initially examined, following by preparation of polished thin sections and subsequent examination by optical and scanning electron microscope. Selected grains and particles were subjected to electron microprobe analysis to determine the zinc concentration of the target phases. The mineralogical report is appended in Appendix D.

The following is a summary of the mineralogical findings:

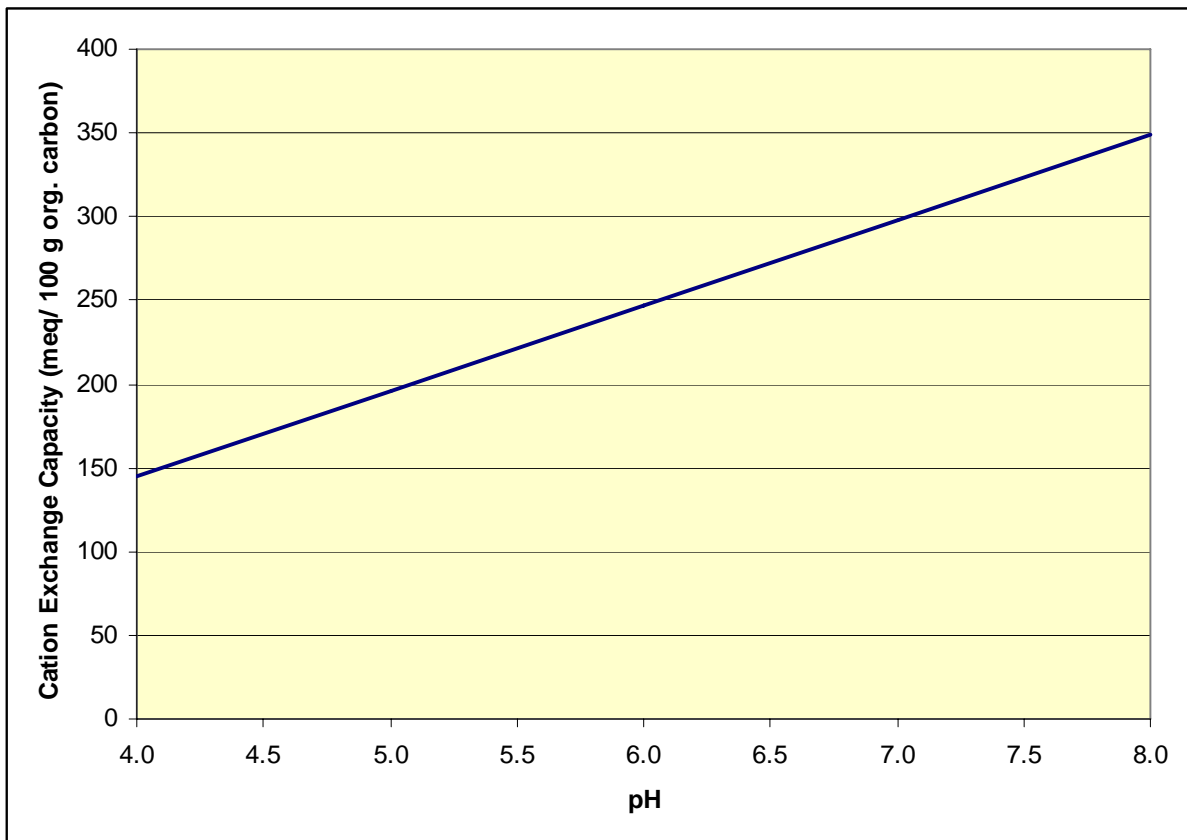
- no authigenic (secondary) sulphides were observed in the soils;
- most samples contained primary tailings sulphide grains;
- negligible formation of oxy-hydroxide rims on primary sulphide grains was observed;
- oxy-hydroxide phases were quantitatively insignificant;
- few primary carbonates (mostly siderite), and no secondary carbonates, were observed; and
- carbonaceous (organic) matter was common, and microprobe analyses indicated up to 0.6% Zn by weight.

Based on the earlier discussion of the distribution of lead and zinc, it is somewhat surprising that no secondary sulphide minerals were observed. It may be possible that the secondary zinc sulphide minerals had oxidized prior to the assessment. The presence of primary sulphides (i.e. tailings contamination) is consistent with the analytical results. On the whole, the results confirm the association of zinc with organic carbon. The analytical results are somewhat lower (about 10 times) than the calculated estimates, but the microprobe covers only a small area of the sample.

### 3.7 Comparison with Literature Values

As shown in Table 3.4, it is estimated that zinc loading on the organic matter is on average between 8 and 9 % (wt/wt). This equates to a loading of about 246 to 277 meq per 100 g of organic matter.

Typical cation exchange capacities reported for soil organic carbon is in the range of 150 to 400 meq per 100 g organic carbon (Appelo and Postma, 1993). A pH-dependent estimate of cation exchange capacity for soil organic carbon (Scheffer & Schachtschabel, 2002) suggests a linear correlation as shown in Figure 3-8. At a neutral pH the cation exchange capacity is very similar to that calculated for the Rose Creek soil organic carbon presented herein. As shown in the figure, the exchange capacity decreases from about 300 to about 150 meq per 100 g organic carbon for a decrease in pH from 7 to 4.



**Figure 3-8 pH Dependency of Cation Exchange Capacity of Soil Organic Carbon (Scheffer & Schachtschabel, 2002)**



## **4 Organic Carbon Distribution**

### **4.1 Introduction**

The results from the laboratory testing program indicated that zinc is being attenuated by the organic matter in the soils underlying the tailings. Therefore, based on the observed zinc association with the organic matter, the distribution and abundance of organic matter can be used to infer the overall metal attenuation that can be expected for these soils. In the following sections, the available drill logs for subsoils underlying the tailings are used to estimate the distribution of organic matter.

### **4.2 Approach**

To estimate the distribution of organic carbon in the soils below the tailings, available borehole logs were examined for records of thickness of organic matter present at the base of the Rose Creek tailings, and for notations of organic materials within the underlying stratigraphy. The mapped distribution of alluvial and terrace terrain units were also evaluated along with the borehole logs to assess whether the geomorphology could be used as a guide to surface and subsurface organic content. The known footprint of borrow areas excavated during construction were taken into consideration when evaluating borehole logs. Where surface organics were noted, the thickness was manually plotted adjacent to the borehole collar on a plan of the impoundment footprint. In addition, any reference to organic material at depth was noted.

### **4.3 Information Sources**

Logs for boreholes within the tailings footprint were available from the following drilling programs:

- Golder 1979
- Golder 1980
- Robertson Geoconsultants (RGC) 1996
- Gartner Lee 2001
- Gartner Lee 2003
- Klohn Crippen 2005
- SRK 2005
- Robertson Geoconsultants (RGC) 2005

Notations regarding organic content of soils in the logs from the above drilling campaigns varied in degree of description, from no mention of organic material to detailed descriptions of organic matter abundance and distribution and accompanying laboratory test results.

A plan of borrow areas within the tailings impoundment footprint was developed previously from a series of historic aerial photographs, which provided snapshots of the development history of the

dikes and dams. The surface organic materials were removed in these areas at the time of construction. It is likely that the organic material at the original ground surface beneath the airstrip was also removed, in accordance with good construction practices; lack of surface organics identified in drillhole NA-05-2 suggests that stripping was in fact carried out. Figure 4-1 shows the footprint of these borrow areas and the airstrip.

## **4.4 Results and Discussion**

### **4.4.1 Correlation between Organic Matter and Terrain Units**

Two borehole transects across the Rose Creek valley were drilled under the supervision of Golder Associates in 1979 and 1980 along the present alignments of the Intermediate Dam and the Cross Valley Dam. The presence and thickness of the surface organic layer is recorded in many of the borehole logs, and gives the impression that the logs from these campaigns provide reliable descriptions of the surface organic layer.

Terrain mapping carried out by Klohn Crippen in support of dam stability assessments in 2004 and 2005 indicated that two geomorphologic units (a glacial terrace and an alluvial unit bordering the original Rose Creek channel) underlie the tailings impoundment. The 1979 and 1980 drilling transects sampled both of these units, as shown in Figure 4-2.

The logs from the 1979 and 1980 boreholes show a wide distribution range of surface organics, with no identifiable correlation of thickness of surface organics between adjacent boreholes or with the mapped terrain units. On this basis, there appears to be no justification for inferring different distributions of surface organics for the two geomorphologic units.

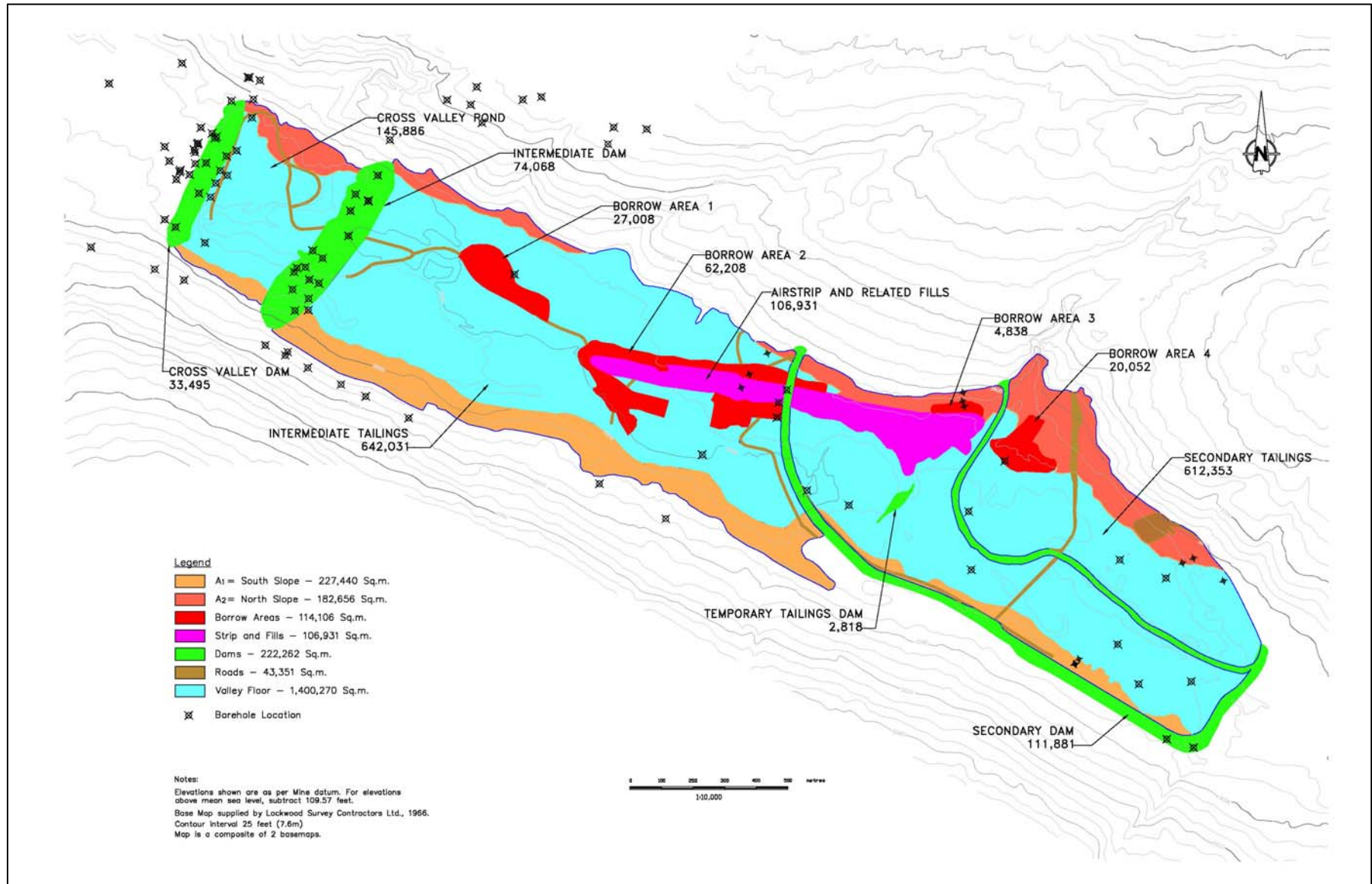
### **4.4.2 Distribution of Organic Matter in Borehole Logs**

For boreholes where organic material was identified, annotations were incorporated onto a plan of the impoundment, as shown in Figure 4.3. As indicated, the thickness of surface organic material ranges from zero to approximately 3 m, and this thickness does not appear to be systematically distributed. As such, it appears that the thickness of surface organics across the tailings impoundment footprint is best approximated by an average value, with no thickness attributed to the borrow areas identified from aerial photographs.

Logs from the SRK 2005 assessment are considered the most reliable with regard to accurate depiction of organic content of surface and shallow subsurface soils as determination of the organic content of the soils was a specific objective of this investigation, and as the borehole logs are complimented by laboratory test results. Information from these logs was given the greatest weight in a local area, and was supplemented by information from other boreholes in areas not addressed by the SRK 2005 investigation.

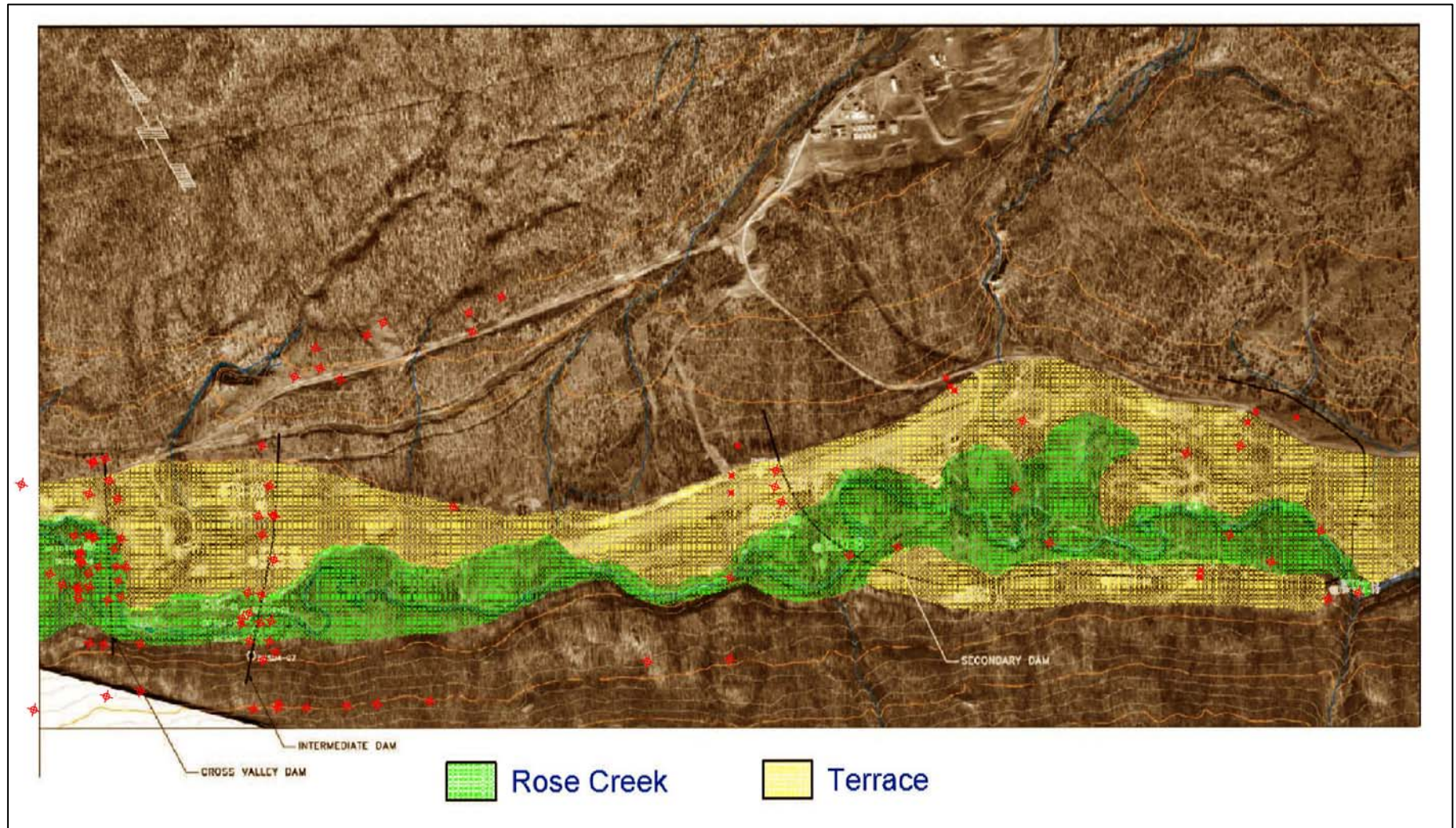
The average thickness of surface organic matter is estimated to be on the order of 0.2 to 0.3 m. This material is compressed due to the overlying tailings, and has a very high organic content and little incorporated mineral material.

Apart from the SRK 2005 records, borehole logs made rare mention of subsurface organic material, and comments were limited to observations of twigs and roots. However, the SRK 2005 drilling and related laboratory testing showed that mineral soils to 3 m below the surface organics can have appreciable organic content. Organic rich silt layers were identified, and organic material was also noted in sand and gravel units. SRK 2005 boreholes were terminated within 5 m of the base of tailings, and no information is available from this program for materials at greater depth. An estimate of average mineral soil organic content for the impoundment area could be derived from the available laboratory test results.



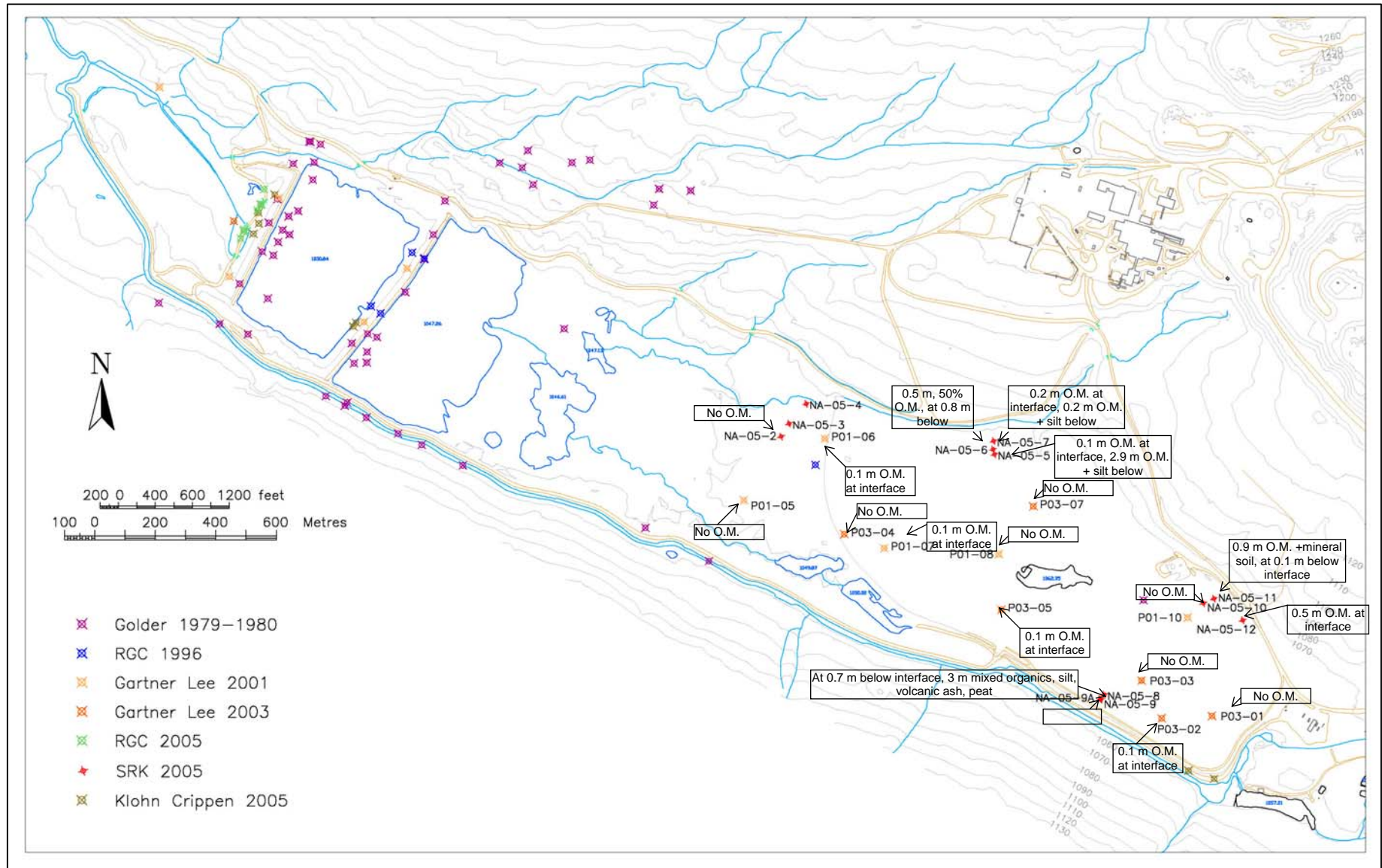
**Figure 4-1 Delineation of Borrow Areas in the Rose Creek Tailings Area**





**Figure 4-2 Delineation of Geomorphological Units in the Rose Creek Tailings Area**





### Figure 4-3 Recorded Occurrence of Organic Matter

## 5 Summary and Conclusions

Migration of tailings into the underlying soils was visually observed in the drill cores. Smearing of tailings into the underlying soil material may also have occurred during drilling. Primary pyrite, with lesser sphalerite, galena, pyrrhotite, and chalcopyrite were observed in 7 of 8 soil samples examined in this section. The sulphur contents of the soils samples tested, along with mineralogical observations, indicate that tailings material was present in most samples.

The contamination of the underlying samples with tailings has somewhat confounded the interpretation of the results. However, the static test work and the mineralogical observations indicate that zinc attenuation is not occurring by neutralization or secondary mineralization mechanisms.

The distilled water leach results indicate that high concentrations were present in the porewater and/or highly soluble solids are present in some samples. Sulphate concentrations up to 2.6 weight % suggest that secondary sulphate minerals may be present, as has been observed in the near-surface tailings as part of other studies. This observation was not corroborated by mineralogical evidence.

Mineralogical observations and correlations in the chemical analyses suggest that organic material is the most significant attenuating phase and a good correlation is observed between total carbon content and total zinc content of the soils underlying the tailings deposit. Zinc on the organic carbon of the soils typically reach 8 to 9 % by weight. These estimates corresponded well with cation exchange capacities reported in the literature.

Static test results further indicate that there are significant amounts of total and organic carbon underlying the Rose Creek Tailings. The distribution of the organic carbon does not however appear to be well correlated with the geomorphologic units. However, drill results indicated that soils to 3 m below the surface organics can have appreciable organic content. Organic rich silt layers were identified, and organic material was also noted in sand and gravel units.

## 6 Recommendations

Key questions that need to be answered to address the potential effects of attenuation on limiting zinc concentrations in the Rose Creek aquifer below the tailings include:

- What is the capacity of the various soils to attenuate zinc, on a mass basis (leading to an assessment of the areal removal capacity of the underlying soils)?
- What is the rate of zinc removal by the soils (i.e. how quickly is equilibrium reached)?
- Are the attenuation processes reversible? Could changing conditions (such as a decline in the pH of pore fluids) lead to remobilization of attenuated zinc?

Microprobe analyses indicate that the organic carbon can absorb 0.6 % by weight zinc, whereas interpretation of the analytical results suggest that it may be between 8 and 9 %. Clearly this represents a wide range and should be refined, however, the upper end of the range is supported by values reported in the literature and may therefore be used to infer the potential significance of zinc attenuation by organic carbon.

As discussed before, the results suggest an average total carbon content in the underlying soils of about 3.24 %. The depth of the organic matter below the tailings has not been defined. However, assuming that the average carbon content applies to the first 1 m of soil below the tailings (area of about 196 ha), then it can be shown that the soils may attenuate about 10,000 tonnes of zinc. At the estimated current loadings of about 200 tonnes per year, this capacity is sufficient to limit the mobility of zinc for about 50 years and is consistent with the lack of zinc in the underlying aquifer. Note that this calculation does not include the attenuation capacity of the aquifer or any organic matter that may be present at depths greater than 1 m.

The rate of attenuation has not been determined, however, the current absence of zinc in the Rose Creek aquifer would suggest that the rate of attenuation is rapid.

There is no clear evidence to indicate whether or not the association of zinc with the organic carbon is reversible. However, the lack of secondary mineral precipitates and the fact that sorption processes generally are reversible would suggest that the zinc association with the organic carbon is likely reversible. Furthermore, a pH dependence is reported in the literature which indicates that the cation exchange capacity will decrease as pH decreases, which suggests that zinc will be released from the organics should the pH in the underlying soils become acidic. Additional testing to verify this would be valuable.

The observations and investigations to date indicate that the underlying soil samples have been compromised primarily through the presence of tailings (either as a result of migration of tailings solids into the underlying soils, or as a result of smearing during drilling), and probably due to

exposure (albeit briefly so) to atmospheric conditions prior to vacuum sealing for shipping. These factors combined likely make the samples unsuitable for use in further testing. It is therefore recommended that the currently available information, i.e. estimated range of zinc sorption, be utilized to estimate the overall significant of attenuation processes in the aquifer.

Should it become necessary to assess the reversibility of the attenuation mechanism, alternate methods for obtaining undisturbed and uncontaminated soil samples from below the tailings or elsewhere should be investigated. Elution tests can then be undertaken to assess zinc desorption rates.

This report, “**Anvil Range Mining Complex, Rose Creek Tailings Deposit, Assessment of Zinc Attenuation**”, has been prepared by SRK Consulting (Canada) Inc.

**Prepared by**

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John Chapman, P.Eng.

**Reviewed by**

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Cam Scott, P.Eng.

## 7 References

Appelo C. A. J. and Postma D. (1993) *Geochemistry, Groundwater and Pollution*. Balkema.

Scheffer and Schachtschabel et al. (2002) *Lehrbuch der Bodenkunde*. Ferdinand Enke, ISBN 3-8274-1324-9, 491 S. Stuttgart.

## **Appendix A**

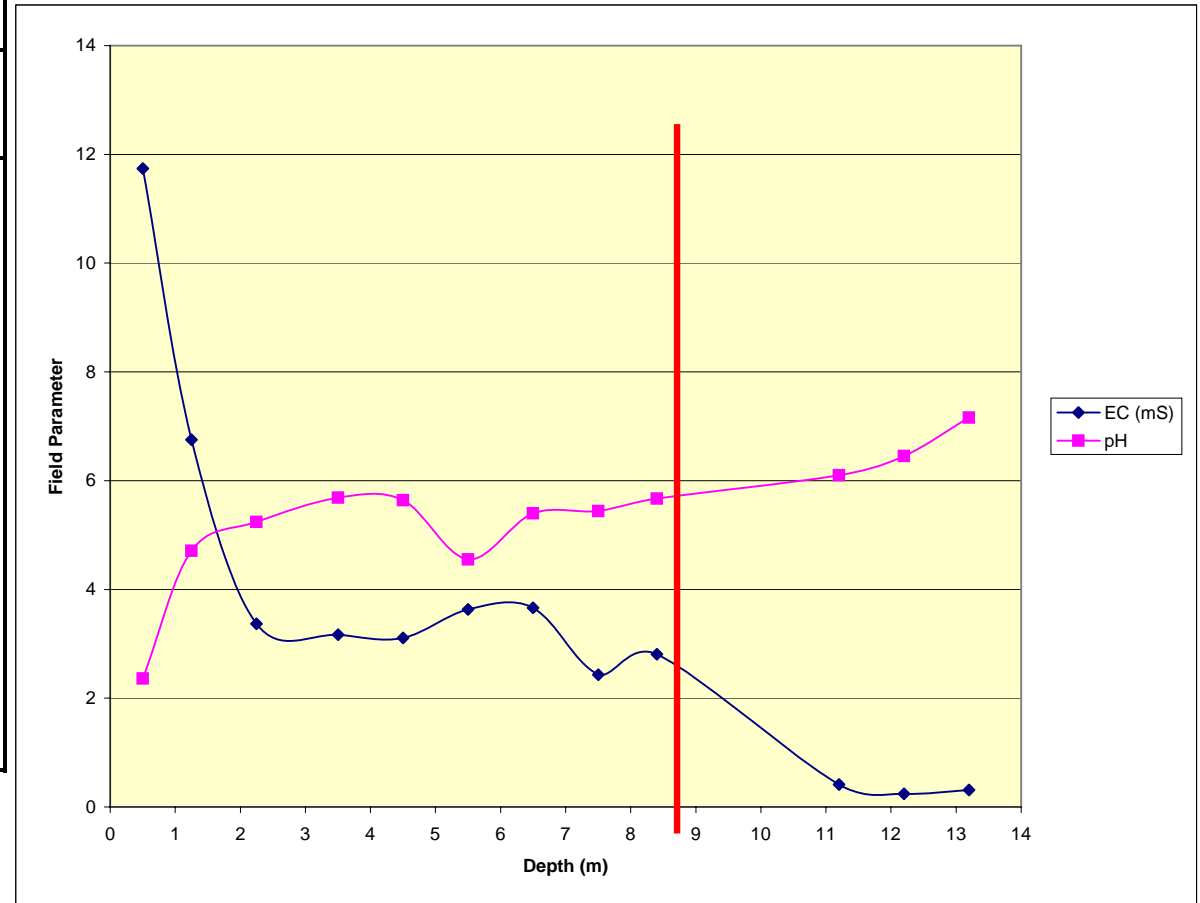
### **Drill Logs and Field Parameters**

<b>Borehole:</b>		<b>NA-05-1</b>
<b>Tailings Impoundment:</b>		<b>Background (Upstream of Original Impoundment)</b>
<b>From depth (m)</b>	<b>To depth (m)</b>	<b>Field Description</b>
0	0.1	Surface organics- moss and roots
0.1	0.3	Orange stained gravelly silt, cryoturbated- mixed with fine grained organic (black) and volcanic ash (creamy white). Laminations of organics ~1mm thick parallel to
0.3	0.6	Orangey-brown stained sandy subrounded gravel directly below orange staining in above sample, slightly moist
0.6	3.2	Orangey-brown stained sandy subrounded boulder/ cobble gravel, boulders and cobbles reduced to powder by drill bit
3.2	3.6	Light brown gravelly sand, slightly moist, subangular to subrounded.
3.6	4.3	Olive brown gravelly sand silt (till), contains orange stained hairline cracks and fissures, and rare oxidized clasts to 2 m.
4.3	9	Olive brown to black till, dry, very dense.

<b>Borehole:</b>		<b>NA-05-2</b>
<b>Tailings Impoundment:</b>		<b>Intermediate Impoundment</b>
<b>From depth (m)</b>	<b>To depth (m)</b>	<b>Field Description</b>
0	0.3	Mixed orange fine tailings sand, yellow and gray surface silt and dark brown cemented sand particles
0.3	0.9	Orangey brown medium to fine tailings sand with 20% cemented clasts of same colour and grain size. Cemented clasts showing brighter orange on broken faces. Contains isolated pods of moist olive brown silt.
0.9	1.4	Yellowish brown material as above, no silt pods observed.
1.4	1.7	Dark grey moist medium tailings sand, little to no silt
1.7	1.8	Dark grey moist tailings silt layer with 30% fine sand
1.8	3.6	Dark yellowish grey moist fine tailings sand with trace silt.
3.6	4.3	Yellowish grey wet medium to fine tailings sand with 20-30% silt
4.3	6	Yellowish grey wet medium to fine tailings sand, trace silt
6	6.5	Yellowish grey wet medium to fine tailings sand with 20-30% silt
6.5	7.5	Yellowish grey wet coarse to fine tailings sand, trace silt
7.5	8.8	Yellowish grey wet medium to fine tailings sand with 20-30% silt
8.8		<b>Contact with original ground</b>
8.8	13.3	Orange gravelly coarse sand, wet, clean. Gravel subangular to subrounded
13.3	13.7	Orange gravelly coarse sand, wet, clean. Gravel subangular to subrounded; contains 10% yellowish brown silt
13.7		EOH

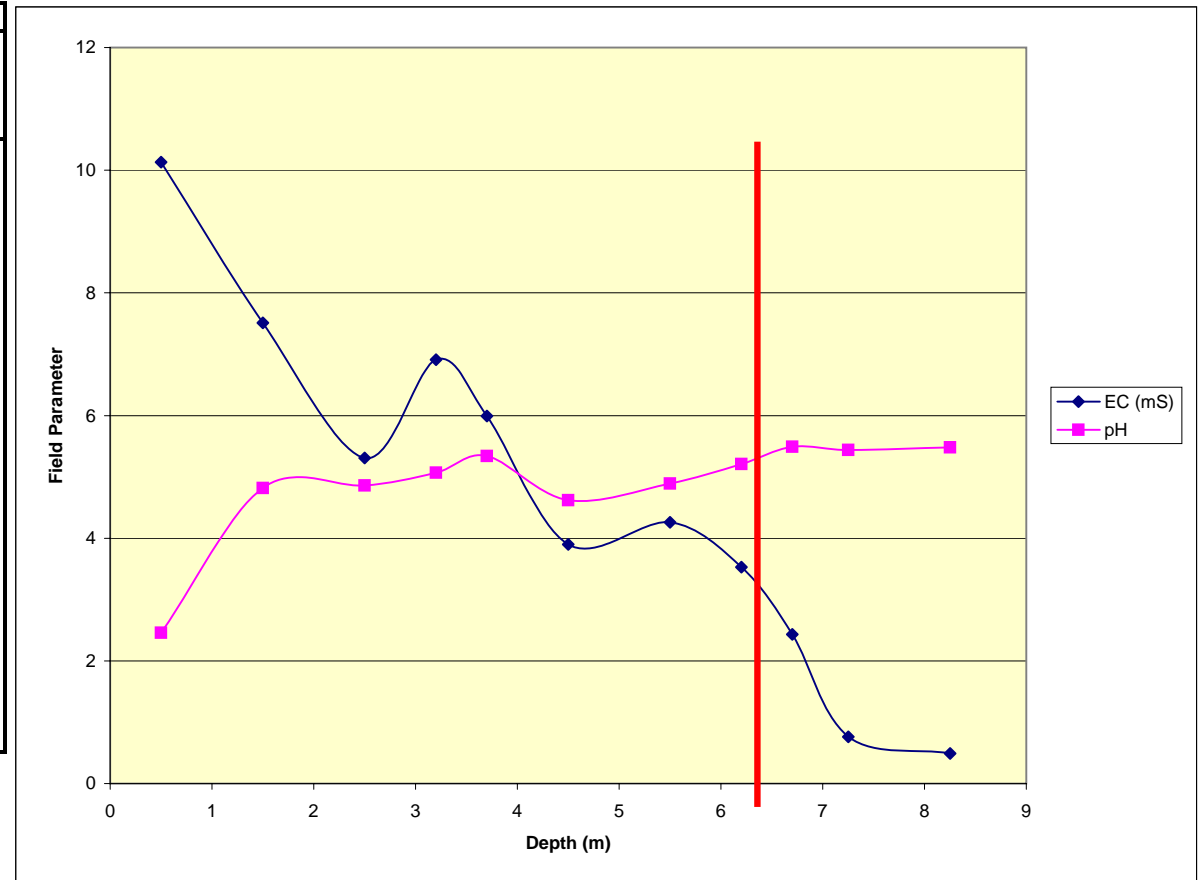


Contact Test Results			
Borehole: NA-05-2			
From depth (m)	To depth (m)	Contact EC (ms/cm)	Contact pH (s.u.)
0	1	11.74	2.36
1	1.5	6.75	4.71
1.5	3	3.37	5.24
3	4	3.17	5.69
4	5	3.11	5.64
5	6	3.63	4.55
6	7	3.66	5.4
7	8	2.43	5.44
8	8.8	2.81	5.67
10.7	11.7	0.41	6.1
11.7	12.7	0.24	6.45
12.7	13.7	0.31	7.16



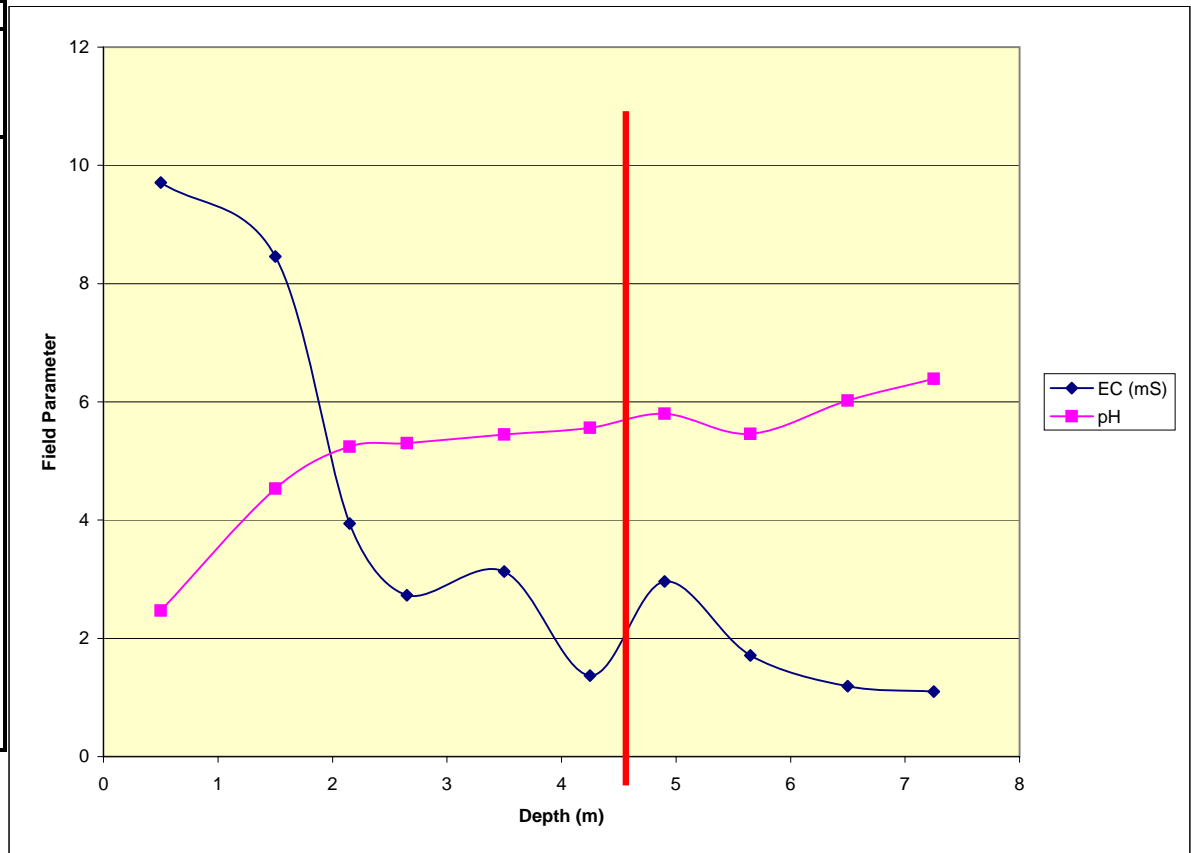
<b>Borehole:</b>		<b>NA-05-3</b>
<b>Tailings Impoundment:</b>		<b>Intermediate Impoundment</b>
<b>From depth (m)</b>	<b>To depth (m)</b>	<b>Field Description</b>
0	0.1	Orange medium tailings sand, slightly moist, generally low silt content. Discrete laminations of brownish yellow silt up to 1 cm
0.1	0.5	Orangey brown medium to fine tailings sand with clumps of olive brown slightly moist silt
0.5	0.8	Yellowish brown medium to fine tailings sand, slightly moist, with cemented layers up to 1 cm thick.
0.8	1	Orangey brown medium tailings sand, slightly moist, minor cemented clumps
1	1.2	Dark yellowish grey laminated silty tailings sand, 40% silt, moist
1.2	3.4	Dark yellowish grey medium to fine tailings sand, massive to laminated, moist. Water table at 3.4 m.
3.4	4.1	Dark yellowish grey medium to fine tailings sand, massive to laminated, wet.
4.1	5.2	Brassy brown wet medium tailings sand.
5.2	6.4	Wet tailings sand as from 3.4 - 4.1 m.
6.4		<b>Original ground interface</b>
6.4	6.5	Yellowish dark brown silty sand with gravel, wet, coarse. Contains a single piece of wete fibrous organic, stained a yellowish dark brown. Contains minor tailings.
6.5	6.6	Material as above, dark orangey brown in colour, no discrete organics observed, wet
6.6	6.63	Thin layer of slightly moist, very compact diamict. Contains visible flakes of muscovite in thematrix, along with distorted and discontinuous organic laminations ~1 nn thick. Also contains local orange staining around clasts and in discrete areas of the matrix. Matrix is olive brown silt; clasts are subangular to subrounded. May contain tailings and iron oxide contamination.
6.63	6.9	Orange stained sandy subrounded gravel, sand medium to coarse, very few fines.
6.9	7.3	Light orangey tan gravelly coarse sand, wet. Trace fines.
7.3	7.35	Intensely orange stained gravelly coarse sand. Wet. Orange staining and precipitate coating particles and filling interstices.
7.35	9	As from 6.9 to 7.3 m. Contains a single discrete 2 cm region of orange staining
9		EOH

Contact Test Results			
Borehole:		NA-05-3	
From depth (m)	To depth (m)	Contact EC (ms/cm)	Contact pH (s.u.)
0	1	10.13	2.46
1	2	7.51	4.82
2	3	5.31	4.86
3	3.4	6.91	5.07
3.4	4	5.99	5.34
4	5	3.9	4.62
5	6	4.26	4.89
6	6.4	3.53	5.21
6.4	7	2.43	5.49
7	7.5	0.76	5.44
7.5	9	0.49	5.48



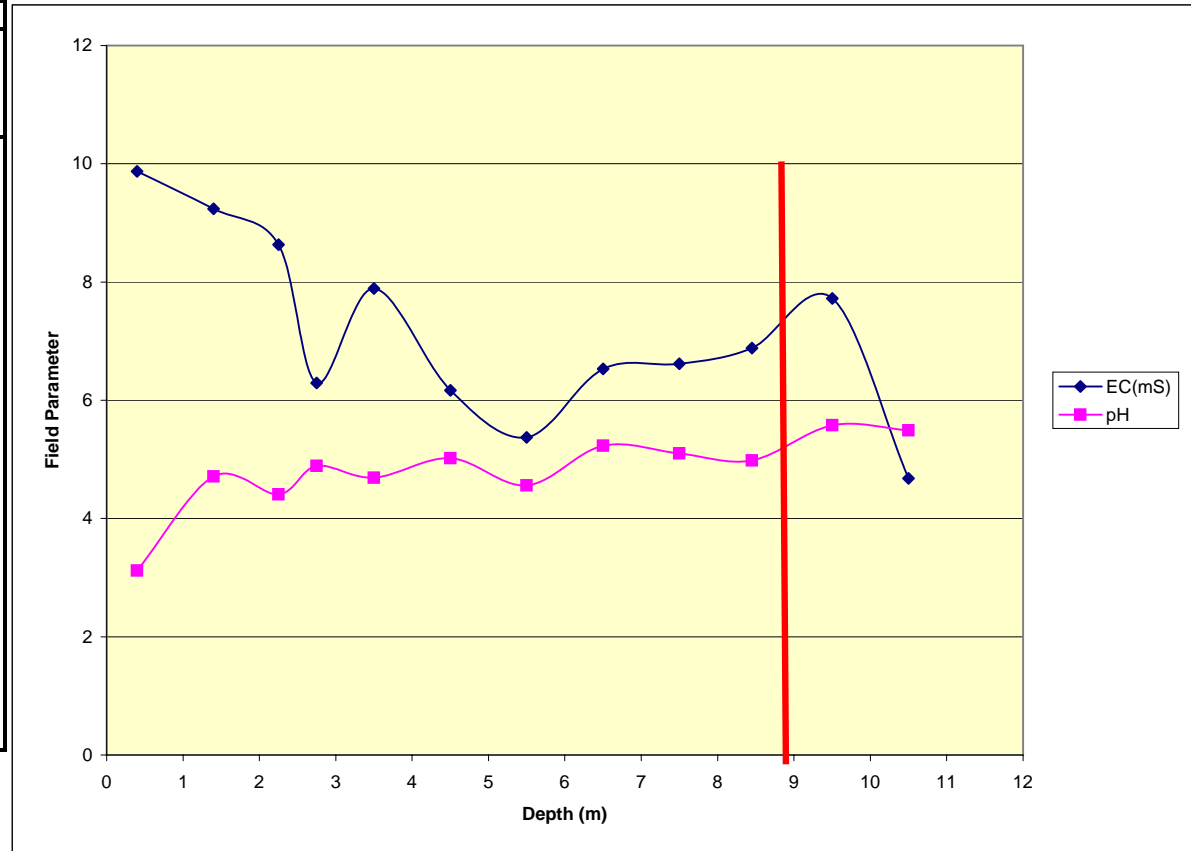
<b>Borehole:</b>		<b>NA-05-4</b>
<b>Tailings Impoundment:</b>		<b>Intermediate Impoundment</b>
<b>From depth (m)</b>	<b>To depth (m)</b>	<b>Field Description</b>
0	0.1	Surface crust, yellowish grey tailings silt with yellow fine to very fine tailings sand
0.1	0.3	Light orangey brown fine tailings sand layer immediately below the surface crust. No fines
0.3	0.7	Orangey brown fine tailings sand, slightly moist, no fines
0.7	1.3	Yellowish brown fine tailings sand, slightly moist, no fines
1.3	1.8	Yellowish grey silty fine tailings sand, moist, laminated with 1-2 cm light orangey brown layers
1.8	2	Yellowish brown to brownish orange fine tailings sand. Yellowish brown sand contains no silt; brownish orange fine sand contains 40% silt
2	2.3	Yellowish grey moist medium tailings sand. Water table at 2.3 m
2.3	3.3	Yellowish grey wet medium tailings sand
3.3	3.95	Yellowish grey wet fine tailings sand with 5% silt
3.95	4.5	As from 2.3 to 3.3 m
4.5		<b>Original ground interface</b>
4.5	4.7	Very dark brown to maroon brown organics at surface, fibrous, with roots. Grades to amorphous organic silt with root hairs at base
4.7	5.7	Mixed olive brown sandy silt with gravel and dark brown sandy silt with gravel. Colour contacts are irregular, undulating, and distorted
5.7	6.1	Mixed very dark brown organic silt and olive brown gravelly silt with sand. Contains isolated orange weathering coarse sand fragments
6.1	7.5	Olive brown gravelly sandy silt (TILL), moist, massive, contains rare laminations of dark brown organic matter.
7.5		EOH

Contact Test Results			
Borehole:		NA-05-4	
From depth (m)	To depth (m)	Contact EC (ms/cm)	Contact pH (s.u.)
0	1	9.71	2.47
1	2	8.46	4.53
2	2.3	3.94	5.24
2.3	3	2.73	5.3
3	4	3.13	5.45
4	4.5	1.37	5.56
4.5	5.3	2.96	5.8
5.3	6	1.71	5.46
6	7	1.19	6.02
7	7.5	1.1	6.39



<b>Borehole:</b>		<b>NA-05-5</b>
<b>Tailings Impoundment:</b>		<b>Secondary Impoundment</b>
<b>From depth (m)</b>	<b>To depth (m)</b>	<b>Field Description</b>
0	0.2	Orange medium sand, moist, massive
0.2	0.4	Dark yellowish brown medium sand, massive, moist. Contains rare cemented particles up to 1 cm.
0.4	1.3	Dark yellowish grey fine to medium sand, trace silt, massive to laminated, moist
1.3	2.1	Mottled yellowish grey and yellowish brown fine sand with 20% silt. Contains a discrete region at base of interval containing orange tan medium sand, fully
2.1	2.6	Yellowish brown to orangey brown fine sand, laminated, moist, little to no fines
2.6	3.2	Yellowish grey fine to very fine sand, moist, laminated, little to no silt. Contains orange weathered pocket at base of interval, irregular shape, contained within core.
3.2	6.6	Yellowish grey medium to coarse sand, moist, laminated, little to no fines
6.6	8.9	Brassy yellowish grey medium tailings sand, moist, laminated with greyer intervals. Twigs in base of brassy tailings
<b>8.9</b>		<b>Original ground surface</b>
8.9	9	Clean quartz-feldspar-mafic sand, moist, massive. NOT tailings
9	9.1	Very dark brown fibrous organics with amorphous organic matter matrix. Top 1 cm has grey inorganic silt matrix
9.1	10.9	Very dark brown silt with 5% coarse sand and fine gravel. Silt is a mix of amorphous organic matter and inorganic silt. Gravel is subangular, up to 1 cm
10.9	12	Mix of very dark brown organic silt as above, and olive brown silt with fine gravel and coarse sand. Mixture is irregular with wavy contacts
12	12.2	Orangey tan coarse sand and grit with 15% silt, moist
12.2	13	Olive brown silt with coarse sand and fine gravel, mixed with coarse sand as from 12 to 12.2. Contains a discrete pocket of very dark brown organic silt at 12.3 m
13	13.5	Very coarse sand as from 12 to 12.2, with 25% subrounded gravel
13.5		EOH
0		
0		
0		
0		
0		

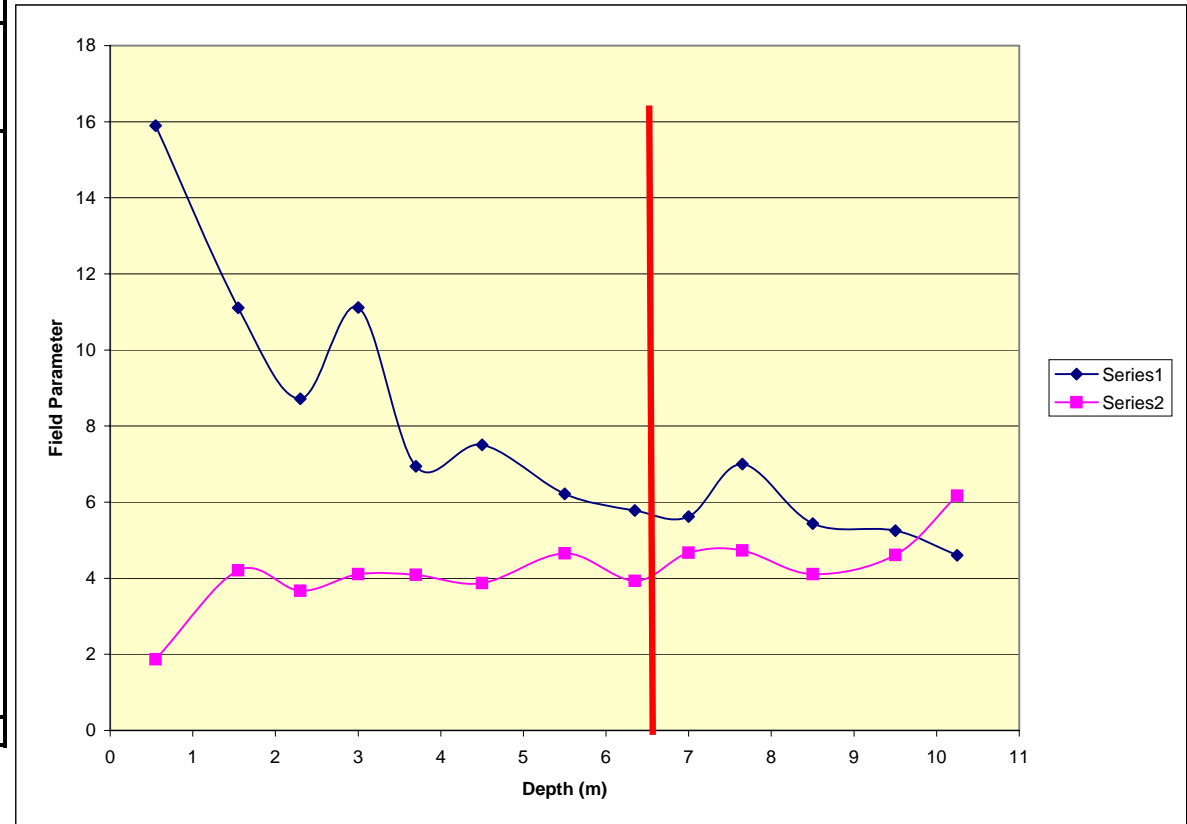
Contact Test Results			
Borehole:		NA-05-5	
From depth (m)	To depth (m)	Contact EC (ms/cm)	Contact pH (s.u.)
0	0.8	9.87	3.12
0.8	2	9.24	4.71
2	2.5	8.63	4.41
2.5	3	6.29	4.89
3	4	7.89	4.69
4	5	6.17	5.02
5	6	5.37	4.56
6	7	6.53	5.23
7	8	6.62	5.1
8	8.9	6.88	4.98
9	10	7.72	5.58
10	11	4.68	5.49



<b>Borehole:</b>		<b>NA-05-6</b>
<b>Tailings Impoundment:</b>		<b>Secondary Impoundment</b>
<b>From depth (m)</b>	<b>To depth (m)</b>	<b>Field Description</b>
0	0.1	Surface crust- light grey silt mixed with dark brown silt, 10% fine to very fine sand
0.1	0.2	Orange, yellow, and orangey brown medium to fine sand, mottled, few fines
0.2	0.4	Light grey and brassy fine to very fine sand with 25% silt, contorted layers up to 8 mm thick
0.4	0.6	Yellowish brown medium tailings sand, moist, few fines. Contains rare cemented dark gray stringers and rare subrounded gravel up to 0.8 cm
0.6	0.8	Yellowish orangey brown medium sand, slightly moist, contains rare cemented clasts of same, as well as up to 3% gravel
0.8	1	Yellowish to yellowish brown fine to very fine sand and silt, wavy to highly undulating, laminations contain discrete pods and laminations of grey silt, moist
1	1.1	Yellowish brown medium sand, moist, few fines
1.1	1.9	Dark grey tailings sand, laminated, contains laminations with 50% silt, otherwise few fines, moist
1.9	2	Dark grey fine sandy silt, laminated, wet
2	2.6	Orange to yellowish brown medium sand, moist
2.6	3.4	Dark grey and yellowish grey medium to fine sand, laminated, few fines, moist
3.4	4.3	Dark grey and yellowish grey coarse to medium sand, massive, moist. Contains isolated dark yellowish brown laminations near top of interval
4.3	4.4	Dark grey fine sand, 10% silt, moist to wet. Contains voids up to 3 mm, along with 1.5 cm wide stringers of light olive grey to rusty orange silt running subparallel to core axis
4.4	6.6	Sand as from 3.4 to 4.3
6.6		<b>Original ground surface. No organics present</b>
6.6	6.7	Dark grey hard sandy gravelly silt to silty gravelly silt, moist
6.7	7.3	Light orange gravelly medium to coarse sand with individual oxidized particles
7.3	7.8	Dark brown organic matter, amorphous with 5% fibres, with trace fine gravel and coarse sand particles, and with trace laminations of volcanic ash. Organic matter is mixed irregularly ~50/50% with light green to brown sandy gravelly silt. Subrounded gravel
7.8	8.4	Light olive green sandy gravelly silt, as above, mixed with greyish brown sandy gravelly silt. Mixture is irregularly laminated, but appears to be a single type of material with irregular colour variations.
8.4	9.8	Light olive brown sandy gravelly silt, as above.
9.8	10.5	Light olive brown sandy gravelly silt, as above, mixed with discrete pods of dark brown organic matter and orangey tan sandy gravelly silt. Mixture is irregularly laminated and contains isolated bright orange clasts up to 1 cm, and a single orange lamination at 10.1 m, very moist. Water table may have been intersected.
10.5		EOH

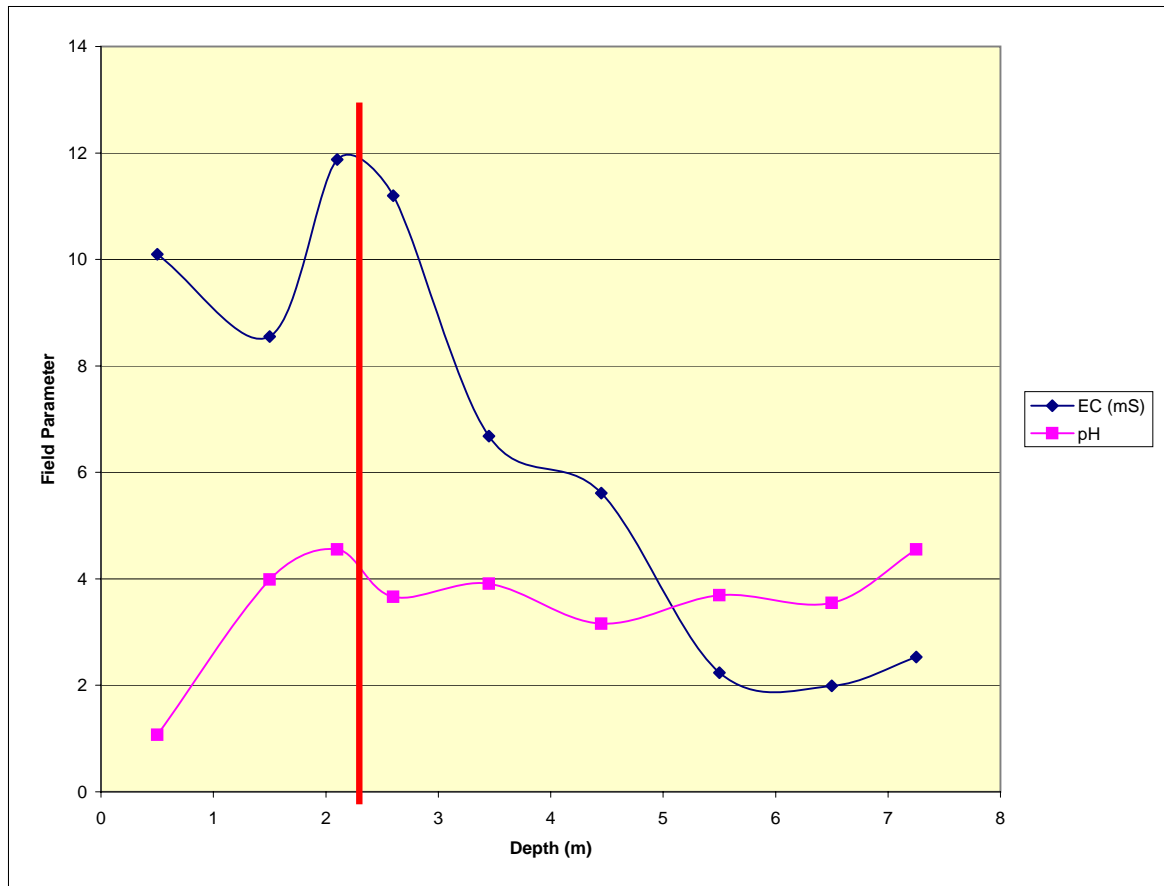


Contact Test Results			
Borehole:		NA-05-6	
From depth (m)	To depth (m)	Contact EC (ms/cm)	Contact pH (s.u.)
0	1.1	15.9	1.87
1.1	2	11.11	4.21
2	2.6	8.72	3.67
2.6	3.4	11.12	4.11
3.4	4	6.94	4.09
4	5	7.51	3.87
5	6	6.22	4.65
6	6.7	5.78	3.93
6.7	7.3	5.62	4.67
7.3	8	7	4.73
8	9	5.44	4.11
9	10	5.25	4.61
10	10.5	4.6	6.17



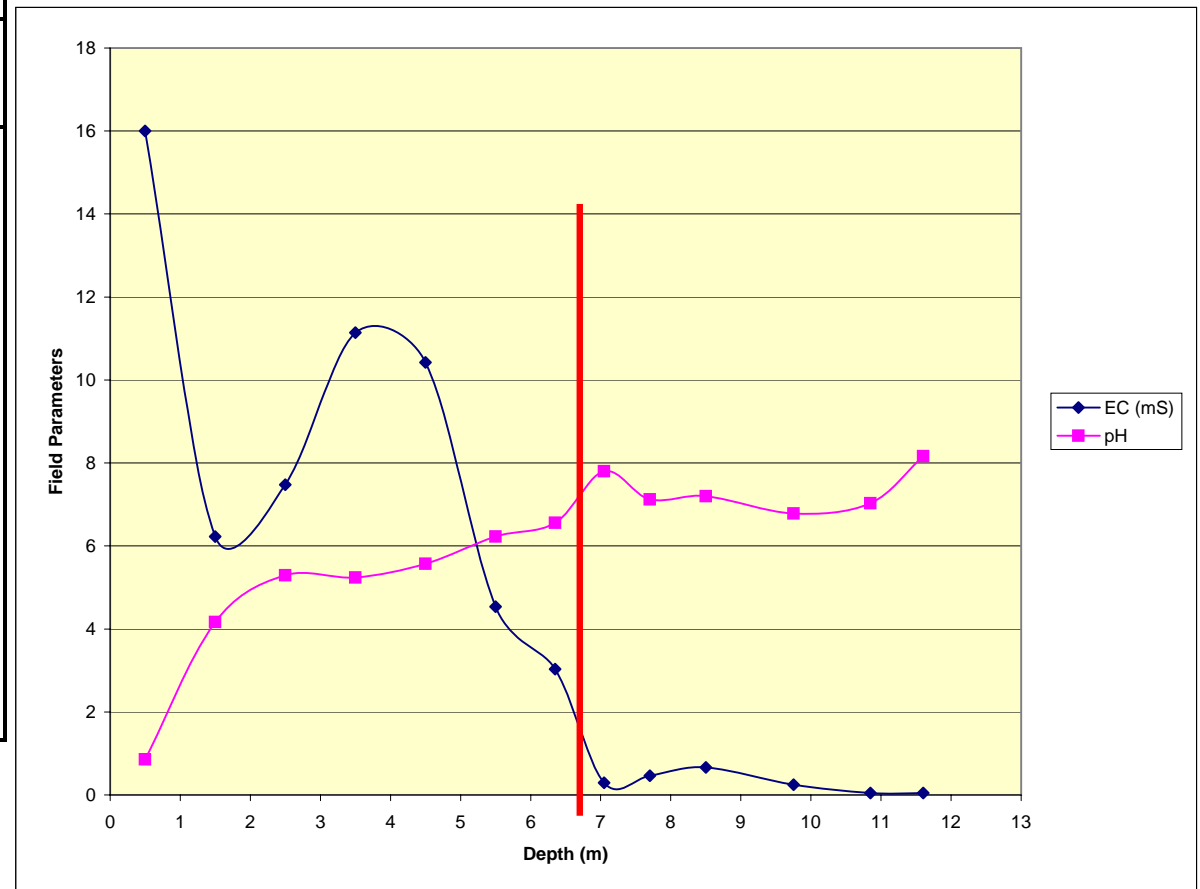
<b>Borehole:</b>		<b>NA-05-7</b>
<b>Tailings Impoundment:</b>		<b>Secondary Impoundment</b>
<b>From depth (m)</b>	<b>To depth (m)</b>	<b>Field Description</b>
0	0.1	Surface crust- yellow and grey tailings silt with fine tailings sand
0.1	0.3	Light orangey yellow coarse to medium tailings sand, slightly moist, few fines. Trace individual grains orange stained, with an orange stained layer at the base (medium sand)
0.3	1	Dark grey silty fine tailings sand, moist to wet, laminated, with 1 to 3 cm layers of dark yellowish brown fine sand on 10 to 15 cm intervals
1	1.5	Yellowish dark grey coarse tailings sand, moist, laminated, no fines
1.5	2	Yellowish dark brown coarse to medium tailings sand, moist, laminated, contains dark orange blebs 2 mm X 4 mm at top of interval
2	2.2	Dark grey wet medium to fine tailings sand, 10 to 15% silt, massive. Contains sticks and coarse organic matter.
2.2		Original ground surface
2.2	2.4	Very dark brown to black coarse fibrous organic matter with amorphous organic matter matrix
2.4	2.6	Very dark brown organic silt with grey laminations and rare dark orange blebs up to 1 mm
2.6	2.8	Moist yellowish tan sandy gravelly silt mixed with dark brown amorphous organic matter
2.8	3	Dark brown sandy gravelly silt mixed with dark brown amorphous organic matter
3	3.5	Olive brown gravelly sandy silt, massive
3.5	3.9	Olive brown sandy silty cobble gravel. Cobbles pulverized by sonic drill bit- leads to rock flour in recovered sample
3.9	5	Cobble gravel. Sample is dominated by cobble fragments and rock flour. Contains ~30% coarse sand, slightly moist
5	7.5	Yellowish tan gravelly silt with sand (TILL), massive, wet. Water table may be around 5.8 m- wetter from that point on
7.5		EOH

Contact Test Results			
Borehole:		NA-05-7	
From depth (m)	To depth (m)	Contact EC (ms/cm)	Contact pH (s.u.)
0	1	10.1	1.07
1	2	8.55	3.99
2	2.2	11.88	4.55
2.2	3	11.2	3.66
3	3.9	6.68	3.91
3.9	5	5.61	3.16
5	6	2.24	3.69
6	7	1.99	3.55
7	7.5	2.53	4.55



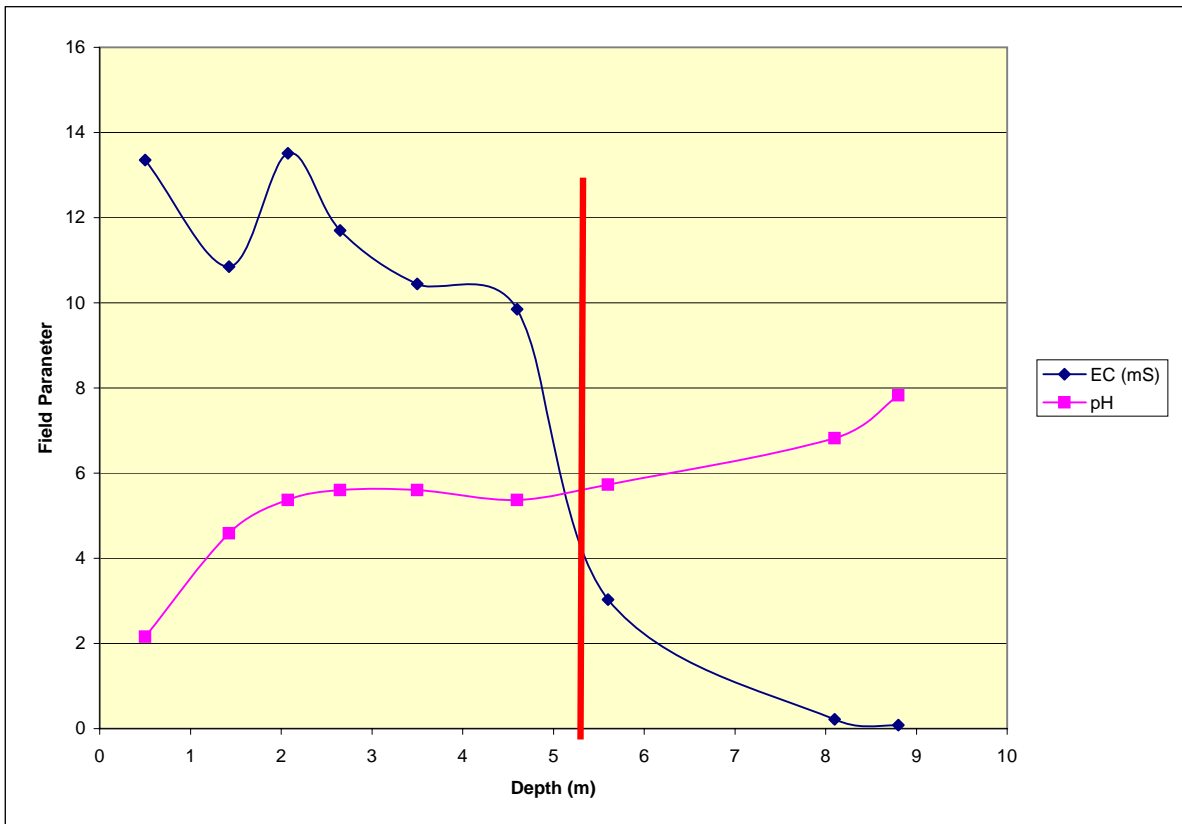
<b>Borehole:</b>		<b>NA-05-8</b>
<b>Tailings Impoundment:</b>		<b>Secondary Impoundment</b>
<b>From depth (m)</b>	<b>To depth (m)</b>	<b>Field Description</b>
0	0.2	Grayish light yellow fine to very fine tailings sand, moist, with 5% silt, with rare stringers of cream and grey coloured silt
0.2	0.5	Yellowish grey fine to very fine tailings sand, moist to wet, 20% silt
0.5	1	Yellowish to orangish dark brown fine tailings sand, moist, laminated, weakly cemented, with up to 20% silt
1	2.1	Dark grey with lesser yellowish grey fine to very fine sand, moist, massive to laminated, trace to 25% silt variation on laminations
2.1		Water table
2.1	2.3	Dark gray fine to very fine sand with trace to 40% silt content, wet
2.3	3.8	Dark grey silt, very wet, with trace fine sand, appears massive
3.8	6.6	Yellowish grey silt, very wet, with trace fine sand, appears massive
6.6	6.7	Yellowish grey medium sand, moist to wet, massive
6.7		<b>Original ground surface</b>
6.7	7.4	Brown gravelly sandy silt, slightly moist, massive, very hard, contains isolated oxidized orange sand grains and isolated gravel clasts
7.4	8.8	Dark chocolate brown gravelly silt with sand, moist to wet, organic smell. Contains blebs of brownish cream volcanic ash, of very dark brown organic silt, and of olive green silt, along with isolated oxidized orange clasts
8.8	9.6	Dark chocolate brown silt with trace gravel and traces of volcanic ash, moist. Fibrous organics distributed throughout (<1%), bottom of unit had a 1 cm diameter twig
9.6	10.2	Dark chocolate brown gravelly silt, moist, with 2% fibrous organics as small twigs and roots
10.2	10.5	Very dark brown to blackpeat, slightly moist, with isolated pods of volcanic ash and subrounded gravel at base
10.5	11	Light yellowish brown sandy cobble gravel with silt, wet, massive, with orange staining on clasts
11	11.6	Tan sandy silty cobble gravel, wet, massive, isolated clasts are fully weathered to sand/silt
11.6	12	Orangey brown gravelly coarse sand, wet, massive. Clasts are stained orange
12		EOH

Contact Test Results			
Borehole:		NA-05-8	
From depth (m)	To depth (m)	Contact EC (ms/cm)	Contact pH (s.u.)
0	1	16	0.86
1	2	6.23	4.17
2	3	7.48	5.29
3	4	11.14	5.24
4	5	10.42	5.57
5	6	4.54	6.23
6	6.7	3.03	6.56
6.7	7.4	0.29	7.8
7.4	8	0.46	7.12
8	9	0.66	7.2
9	10.5	0.25	6.78
10.5	11.2	0.05	7.03
11.2	12	0.05	8.16



<b>Borehole:</b>		<b>NA-05-9</b>
<b>Tailings Impoundment:</b>		<b>Secondary Impoundment</b>
<b>From depth (m)</b>	<b>To depth (m)</b>	<b>Field Description</b>
0	0.55	Light grey silty fine tailings sand (surface material) moist, laminated
0.55	0.65	Mixed yellowish brown and light grey cemented layer of fine to medium tailings sand, slightly moist to dry. Light grey is medium sand with open framework and small clear ice blue crystals
0.65	0.8	Orangey brown fine tailings sand, slightly moist, no fines
0.8	1	Grey silty fine tailings sand with orangish brown and yellowish brown mottles, moist, massive
1	1.6	Grey fine tailings sand, slightly moist, massive, no fines
1.6	1.7	Yellowish brown layer of fine tailings sand, slightly moist, massive, no fines
1.7	1.8	As from 1.0 to 1.6
1.8	2.3	Grey massive tailings silt, wet, no sand
2.3	2.7	As from 1.0 to 1.6
2.7	4	As from 1.8 to 2.3
4	4.7	Grey to yellowish grey tailings silt, massive to laminated, wet, no sand, one 4 cm interval of orangish brown staining
4.7	5.2	Brassy yellowish grey to yellowish brown fine tailings sand with 10% silt, very moist, massive
5.2		<b>Original ground</b>
5.2	5.3	Dark brown coarse sandy angular gravel with black and orange staining on particles and in sandy zones around gravel particles, trace silt, slightly moist. No organic material was observed
5.3	5.6	Olive brown to brown sandy gravel, slightly moist, orange staining on 30% of particles
5.6		Water table
5.6	6	Olive brown fine sandy gravel with 3% silt, wet, massive
6	7.5	Lost- cobble in bit
7.5	9	Tan coarse sandy gravel with 0 to 10% silt, wet, massive
9	10.5	Lost- cobble in bit
10.5		EOH

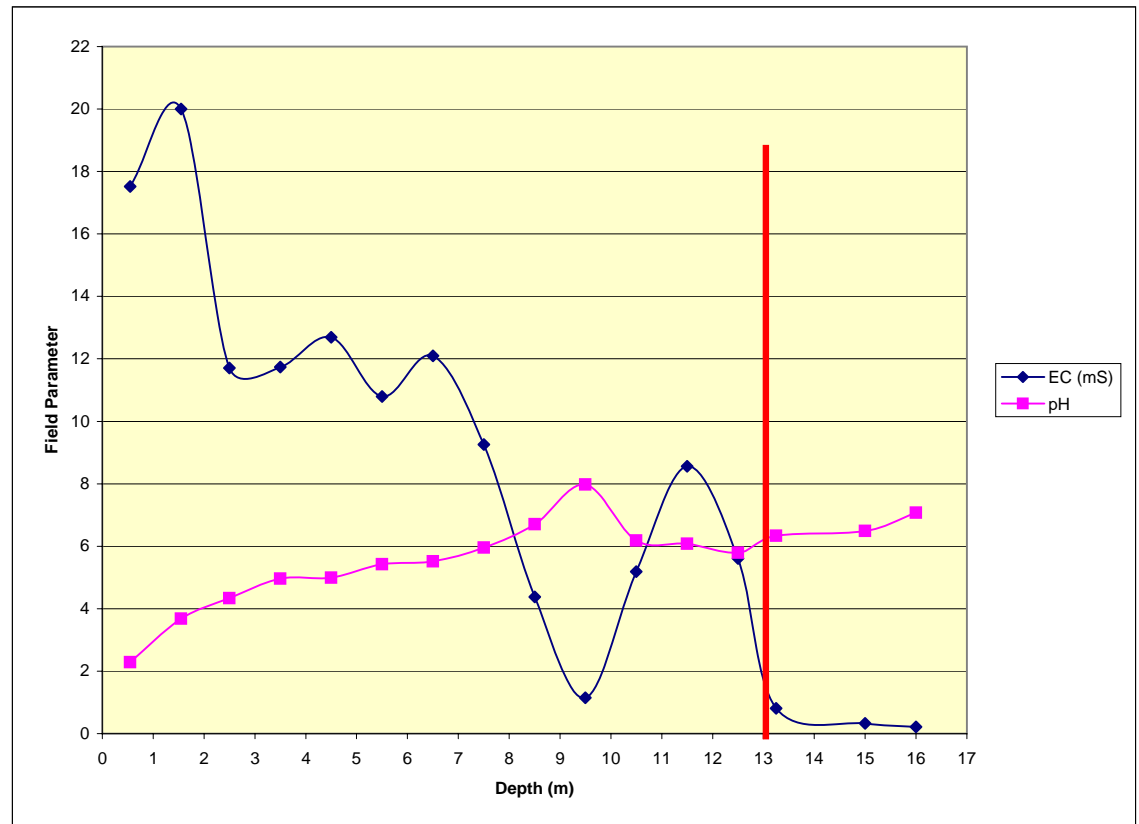
Contact Test Results			
Borehole:		NA-05-9	
From depth (m)	To depth (m)	Contact EC (ms/cm)	Contact pH (s.u.)
0	1	13.35	2.16
1	1.85	10.85	4.59
1.85	2.3	13.51	5.37
2.3	3	11.7	5.6
3	4	10.44	5.6
4	5.2	9.85	5.37
5.2	6	3.03	5.73
7.6	8.6	0.22	6.82
8.6	9	0.08	7.83



<b>Borehole:</b>		<b>NA-05-10</b>
<b>Tailings Impoundment:</b>		<b>Original</b>
<b>From depth (m)</b>	<b>To depth (m)</b>	<b>Field Description</b>
0	0.3	Yellowish grey to brownish orange fine tailings sand, massive, slightly moist
0.3	0.65	Brownish orange medium to fine tailings sand, trace fines, with rare stringers of greyish orange sand, moist
0.65	1.1	Gradation from orangey brown at top to brownish orange at base of interval. Material is laminated silt and fine tailings sand, silt layers cemented, slightly moist to
1.1	1.4	Mixed yellowish grey and yellowish brown silty fine tailings sand, irregular colour boundaries, slightly moist
1.4	1.5	Orangey brown fine tailings sand, with isolated cemented clumps to 1 cm, moist
1.5	2	Grey fine tailings sand with lenses of yellowish grey fine sandy silt
2	2.7	Gradation from orangey brown fine sandy silt at top through yellowish dark brown fine sand with no fines to yellowish grey fine sand at base of interval. All material is tailings, slightly moist, with weakly cemented silt laminations
2.7	5.6	Yellowish grey fine tailings sand, slightly moist, trace to 10% silt
5.6	5.85	Dark grey silt tailings, wet, appears massive.
5.85	6	Yellowish dark grey laminated fine tailings sand, few fines, moist
6	6.4	As from 5.6 - 5.85 m
6.4	7.5	Yellowish dark grey fine tailings sand with trace to 5% fines and brassy patches at bottom of interval, slightly moist
7.5	7.8	As from 5.6 - 5.85 m
7.8	7.9	Pale yellowish grey layer of fine tailings sand with orange-stained laminations at top and base of interval, slightly moist
7.9	8.8	Tailings sand as from 6.4 - 7.5 m
8.8	9.1	Dark grey silty tailings sand, wet
9.1	11.5	Yellowish dark brown medium to fine tailings sand, trace to 5% silt, massive, slightly moist
11.5	12.7	Yellowish dark brown silty tailings sand, wet
12.7		Original ground
12.7	12.9	Mixed silty tailings sand and sandy gravel, slightly moist
12.9	13.5	Tan sandy silty gravel, wet
13.5	16.5	Orangey brown gravelly coarse sand, massive, wet
16.5		EOH

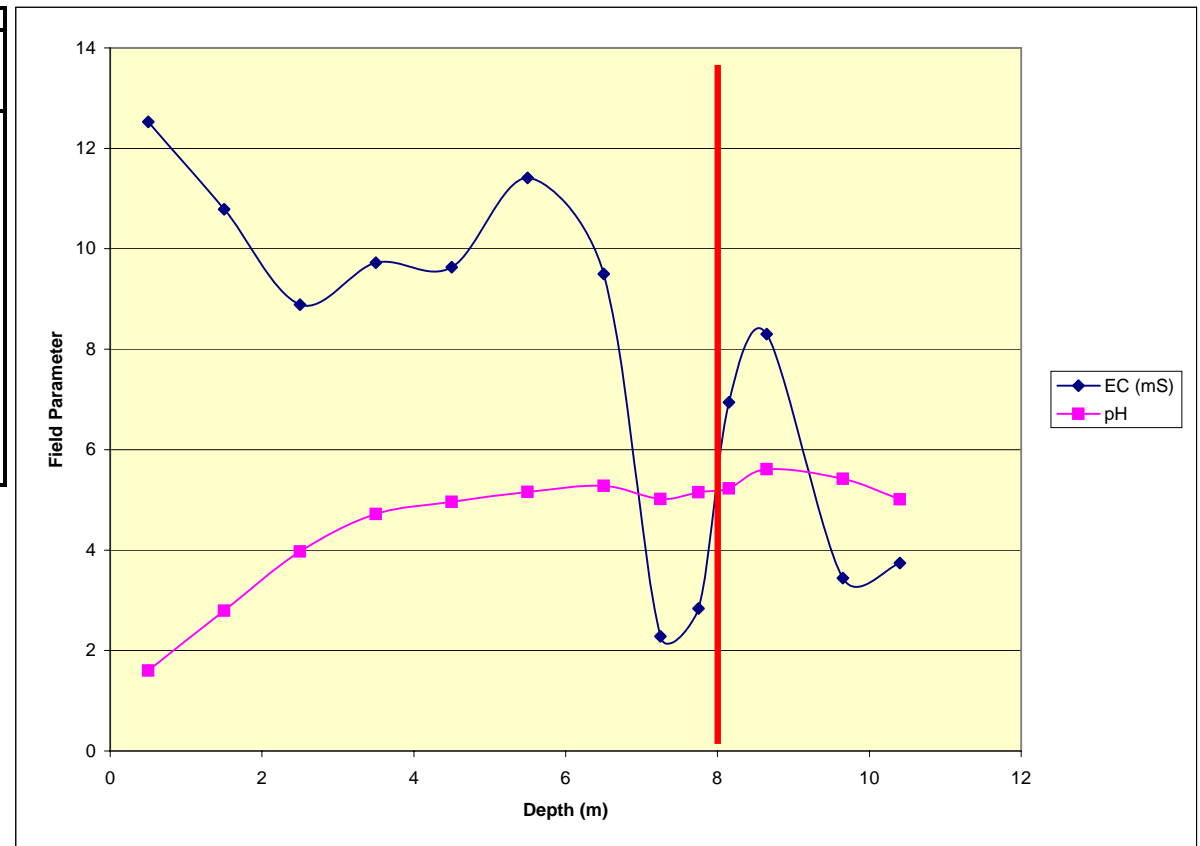


Contact Test Results			
Borehole:		NA-05-10	
From depth (m)	To depth (m)	Contact EC (ms/cm)	Contact pH (s.u.)
0	1.1	17.52	2.29
1.1	2	20	3.68
2	3	11.71	4.34
3	4	11.74	4.96
4	5	12.69	4.99
5	6	10.79	5.42
6	7	12.1	5.52
7	8	9.26	5.96
8	9	4.38	6.7
9	10	1.15	7.98
10	11	5.19	6.18
11	12	8.56	6.08
12	13	5.61	5.79
13	13.5	0.81	6.34
14.5	15.5	0.33	6.49
15.5	16.5	0.22	7.07



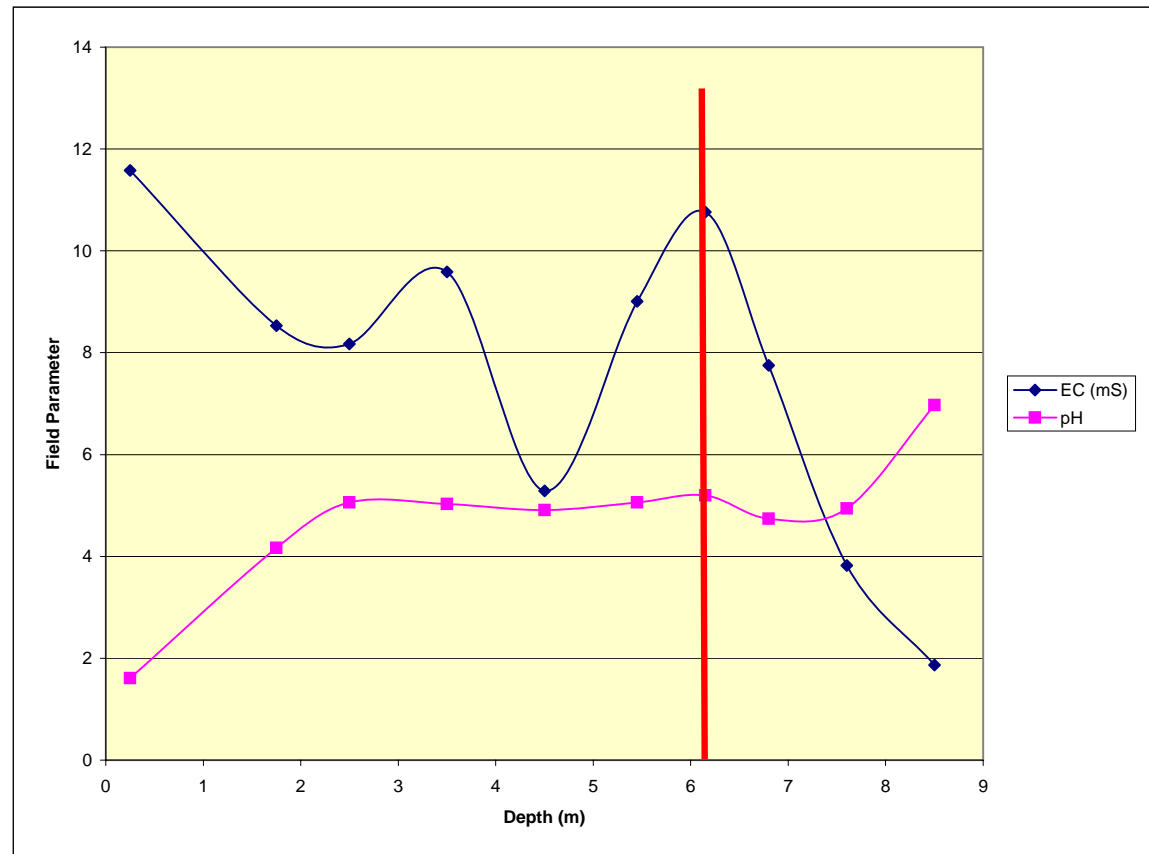
<b>Borehole:</b>		<b>NA-05-11</b>
<b>Tailings Impoundment:</b>		<b>Original</b>
<b>From depth (m)</b>	<b>To depth (m)</b>	<b>Field Description</b>
0	0.1	Orangey tan and yellowish grey medium to fine tailings sand and silt, moist
0.1	0.5	Light yellowish grey fine tailings sand, massive, slightly moist
0.5	0.9	Orangey brown to brownish orange medium to fine tailings sand, trace fines, slightly moist
0.9	1	Grey fine tailings sand with 5% silt, slightly moist
1	2.3	Dark brown to yellowish dark brown to orangish dark brown fine bedded tailings sand, trace to no fines, slightly moist
2.3	2.5	Light yellowish grey fine tailings sand, trace fines, laminated, slightly moist
2.5	2.6	Weakly cemented zone of fine tailings sand and 10% silt, moist, with several layers of colour variation: dark brown (2 cm) over orange (1 cm) over pale yellowish light grey (6 cm) over orange (1 cm); moist
2.6	2.8	Yellowish brownish grey laminated fine tailings sand and silt, moist
2.8	3	Yellowish grey medium tailings sand, massive, slightly moist
3	3.1	Yellowish dark brown medium tailings sand, massive, slightly moist
3.1	3.2	Similar to 2.5 to 2.6 m
3.2	4.2	Yellowish dark grey fine to very fine tailings sand and silt, laminated, wet
4.2	5	Yellowish dark grey fine sand, few fines, laminated, slightly moist
5	6	Dark grey tailings silt, with a single bed of yellowish dark grey fine tailings sand from 5.3 to 5.34 m, wet
6	7	Grey to yellowish grey medium tailings sand, slightly moist, massive to bedded, trace to 5% silt, slightly moist
7	7.5	Yellowish dark brown medium tailings sand, few fines, massive, slightly moist
7.5	8	Grey medium tailings sand, trace fines, massive, slightly moist
8		Original ground
8	8.1	Tan to dark brown till (gravelly silty sand), very hard, slightly moist,
8.1	8.2	Dark brown zone of amorphous organic material and sandy gravel, slightly moist
8.2	8.3	Dark brown zone of amorphous organic material with flecks of volcanic ash and trace gravel, slightly moist
8.3	8.7	Mixed dark brown zone of amorphous organic material and volcanic ash (brownish cream), appears cryoturbated. 50% ash. Slightly moist
8.7	9	Dark brown silt mixed with amorphous organic matter. Contains trace angular gravel and coarse sand, slightly moist
9	10.3	Olive brown till (silt with gravel and sand), hard, moist
10.3	10.5	Orangey brown gravelly sand, trace fines, wet
10.5		EOH

Contact Test Results			
Borehole:		NA-05-11	
From depth (m)	To depth (m)	Contact EC (ms/cm)	Contact pH (s.u.)
0	1	12.53	1.6
1	2	10.79	2.79
2	3	8.89	3.97
3	4	9.72	4.72
4	5	9.63	4.96
5	6	11.41	5.16
6	7	9.5	5.28
7	7.5	2.28	5.02
7.5	8	2.84	5.15
8	8.3	6.94	5.23
8.3	9	8.3	5.61
9	10.3	3.44	5.42
10.3	10.5	3.74	5.01



<b>Borehole:</b>		<b>NA-05-12</b>
<b>Tailings Impoundment:</b>		<b>Original</b>
<b>From depth (m)</b>	<b>To depth (m)</b>	<b>Field Description</b>
0	0.4	Pale yellowish grey fine tailings sand with silty sand lenses, compact at base, moist
0.4	1.5	Loss- drillers indicated bit was plugged with compact material
1.5	1.7	Grey medium tailings sand, massive, no fines, moist
1.7	2	Mixed yellowish brown and yellowish grey medium sand, massive, moist
2	3.4	Dark grey fine sandy silt, laminated, wet
3.4	4	Yellowish dark brown fine to medium sand containing isolated twig fragments, grass, and clasts of very dark brown amorphous organic matter, moist
4	5.9	Yellowish dark grey to brassy dark grey fine sand, trace silt, massive to laminated, moist
5.9		Original ground
5.9	6	Very dark brown amorphous organic matter, contains 5% volcanic ash as thin stringers, and 1% fibrous organics (twigs and grass). Tailings have migrated into the
6	6.4	Mixed very dark brown amorphous organic matter as above, and olive brown to olive green till (sandy silt with trace gravel), irregular contacts between two
6.4	7.2	Orangey olive brown gravelly sandy silt with inclusions of very dark brown organic matter and local bright orange-stained pockets of matrix, moist, lower contact
7.2	9	Brownish orange-stained coarse sandy gravel, dry to slightly moist, gravel subangular to subrounded and up to small cobble size. Sonic bit pulverized larger rocks
9		EOH

Contact Test Results			
Borehole:		NA-05-12	
From depth (m)	To depth (m)	Contact EC (ms/cm)	Contact pH (s.u.)
0	0.5	11.58	1.61
1.5	2	8.53	4.17
2	3	8.17	5.06
3	4	9.59	5.03
4	5	5.29	4.91
5	5.9	9.01	5.06
5.9	6.4	10.76	5.2
6.4	7.2	7.75	4.74
7.2	8	3.82	4.94
8	9	1.87	6.97



## **Appendix B**

### **Laboratory Testing Program Design and Methods**

## Memorandum

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<b>To:</b>	File	<b>Date:</b>	October 10, 2005
<b>cc:</b>		<b>From:</b>	John Chapman Dylan MacGregor
<b>Subject:</b>	Anvil Range – Rose Creek Tailings Attenuation Testing Program	<b>Project #:</b>	1CD003 – Task 22(h)

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### 1 Introduction

The water and load balance for the Rose Creek aquifer indicated that zinc concentrations in the aquifer are substantially lower than expected. Potential mechanisms that may be contributing to the lower zinc concentrations include:

- Adsorption or absorption by organic soils underlying the tailings;
- Co-precipitation with iron and/or manganese at or near the tailings-soil interface;
- Attenuation in the aquifer itself by adsorption to mineral soils.

Some of the mechanisms have the potential to be irreversible, that is, they could permanently remove zinc from solution. Other mechanisms, or future changes in geochemical conditions, could lead to zinc being released either gradually or rapidly.

The primary objectives of the attenuation testing program are to: i) identify the mechanisms, and ii) quantify the potential short and long term effects these mechanisms may have on zinc mobility

Tailings and soils samples obtained during the recent drilling program have been vacuum sealed and are maintained in cold storage. The next step in the proposed program is to complete the laboratory analytical and testing program.

The purpose of this memorandum is to review the field data and to develop a detailed outline for the proposed laboratory testing program.

### 2 Field Program Results

A total of 11 drill holes (NA-05-2 to NA-05-12) were completed in the Rose Creek Tailings Deposit and one drill hole (NA-05-1) at a control site immediately upstream of the Original Tailings Impoundment. The coordinates for the drill holes are provided in Table 1. The last column in the table also shows the depth from surface at which the tailings – original ground contact was encountered.

**Table 1 Drill Hole Location Coordinates**

Drill Hole	Location	GPS Easting	GPS Northing	GPS Collar Altitude (ft)	Contact Depth (m)
NA-05-1	Background	583818	6912531	3434	n/a
NA-05-2	Intermediate Impoundment	581876	6913511	3483	8.8
NA-05-3	Intermediate Impoundment	581902	6913554	3732	6.4
NA-05-4	Intermediate Impoundment	581959	6913620	3729	4.5
NA-05-5	Secondary Impoundment (N)	582582	6913452	3811	8.9
NA-05-6	Secondary Impoundment (N)	582577	6913468	3820	6.6
NA-05-7	Secondary Impoundment (N)	582579	6913496	3728	2.2
NA-05-8	Secondary Impoundment (S)	582945	6912651	3720	6.7
NA-05-9	Secondary Impoundment (S)	582934	6912635	3720	5.2
NA-05-9A	Original Impoundment	582931	6912636	3713	12.7
NA-05-10	Original Impoundment	583273	6912956	3758	8.0
NA-05-11	Original Impoundment	583308	6912971	3761	5.9
NA-05-12	Original Impoundment	583403	6912899	3734	8.8

Notes: Grid UTM

Datum: NAD27 / Canada

(N) – north side of valley; (S) south side of valley

The drill logs together with the field paste pH and conductivity measurements, completed for discrete core intervals, are provided in Attachment A. Plots showing the paste pH and paste conductivity changes with depth have been prepared and are included in the attachment. The approximate tailings – original soil contact is also shown on each of the plots. The field parameters are briefly discussed below.

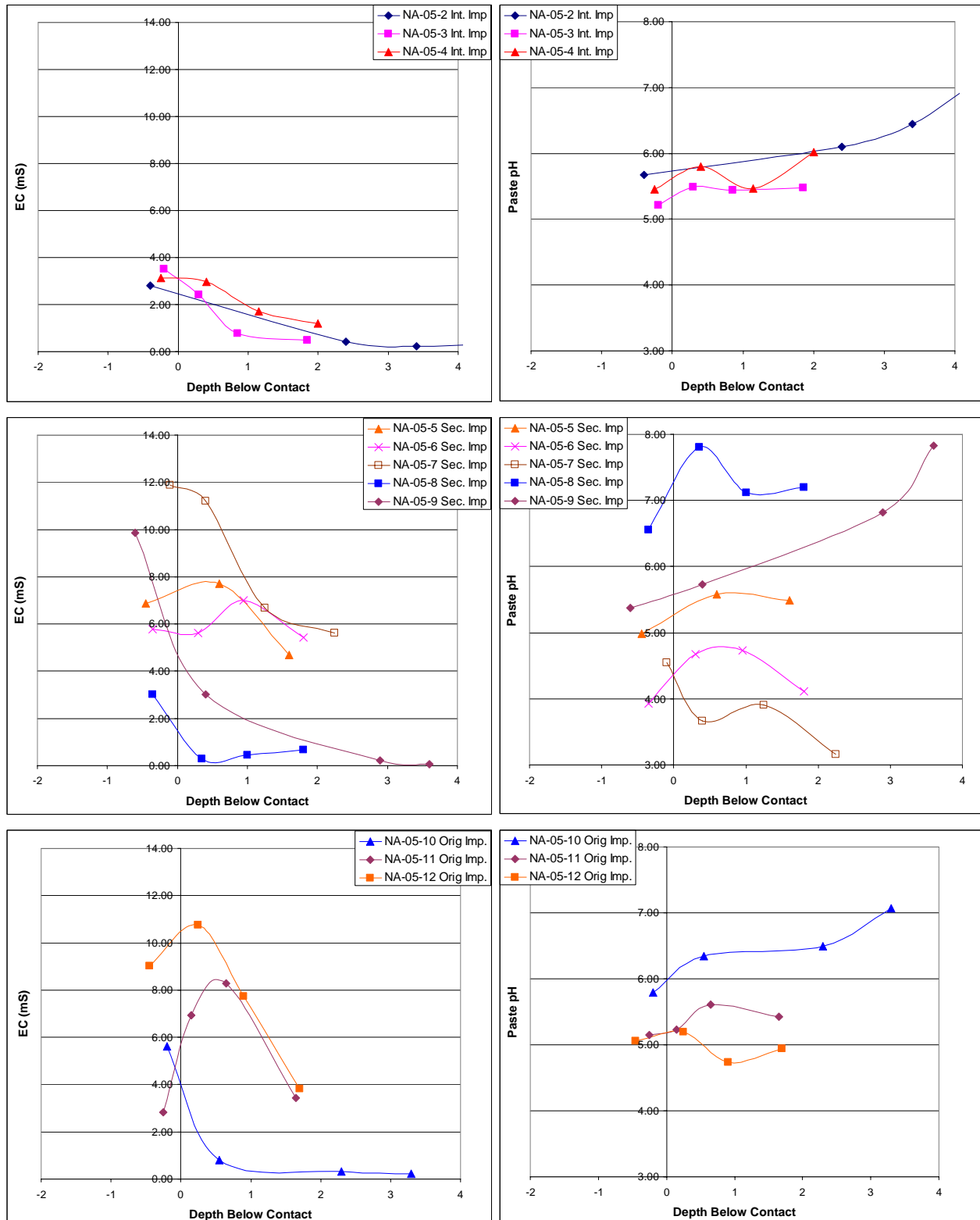
## 2.1 Paste Parameters

Plots comparing the paste parameter transitions across the tailings – original ground contact are shown in Figure 1. The plots illustrate the conditions respectively at the Intermediate, Secondary and Original Impoundments, and can be summarized as follows:

**Intermediate Impoundment.** The paste conductivity in the tailings above the contact is marginally elevated above a gypsum saturated solution, but decreases to low levels approximately 2 to 3 m below the contact. The paste pH values in the tailings are between 5 and 6. Below the contact the paste pH for NA-05-2, for which the deepest contact was encountered, the pH in general was higher than for the other two drill holes, with a circum neutral pH. The EC-pH results indicate that a marginally elevated conductivity front was encountered at this location. The breakthrough of the front has not fully progressed across the contact at NA-05-2, whereas, the front has modified the properties of the underlying soils for at NA-05-3 and -4. The results indicate that neutralization and precipitation reactions are occurring within the soils.

**Second Impoundment.** For this impoundment drill hole locations were targeted to obtain samples from both the south and the north side of the valley. On the north side samples were obtained from Drill Holes NA-05-5, -6 and -7. The conductivity is elevated in the tailings and in the underlying soils across the contact. The elevated conductivities in the soils suggest that they contain porewater with elevated metal concentrations.





**Figure 1 Changes in Paste Parameters Across the Soil Contact**

As indicated by the paste pH values for these holes, the tailings have acidified down to the contact. The underlying soils also appear to have been acidified.

It is noted that the paste pH values of the soils of drill hole NA-05-7, at a contact of 2.2 m below surface were below that of the tailings immediately above the contact, while the conductivity decreased across the contact. The lower pH may be a result of the oxidation of dissolved ferrous iron in the porewater of the soils, and precipitation of ferrihydrite, during the field measurements. At the greater contact depth of 8.9 m in drill hole NA-05-5, the pH increases marginally across the contact.

The results for drill holes located on the south side of the valley indicate that breakthrough conditions are straddled by drill holes NA-05-8 and -9. Drill hole NA-05-9, with a contact depth of 5.2 m, indicated elevated conductivity values to the contact and marginally beyond the contact; at depth below the contact the conductivity decreased to very low values. The results for Drill hole NA-05-8, with a contact depth of 6.2 m, are slightly elevated within the tailings above the contact, but decreases to low values immediately below the contact. Similarly, the pH is acidic above and below the contact in drill hole NA-05-9 whereas it is circum neutral in the tailings and marginally alkaline below the contact for drill hole NA-05-8. These results are consistent with neutralization and precipitation reactions occurring within the underlying soils.

**Original Impoundment.** The results for the three drill holes completed in the original impoundment (NA-05-10, 11 and -12) were divergent. Drill hole NA-05-10, with a contact depth of 12.7 m below surface, the paste conductivity decreased across the contact and the pH increased across the contact. This is consistent with neutralization and precipitation reactions within the underlying soils. In drill hole NA-05-11 with a contact depth of 8 m, the pH increased marginally across the contact, however the conductivity first increased substantially and then decreased. The results suggest that a high TDS front has passed from the tailings into the underlying soils and is progressing downwards. The results for NA-05-12, with a contact depth of 5.9 had a similar profile to that observed for NA-05-11, except that conductivity in the tailings was higher and pH in the underlying soil was marginally lower. The results for NA-05-11 and -12 are indicative of a front of elevated conductivity porewater having passed through the contact and is now located within the underlying soils.

## 2.2 Soil Characteristics

A simplified representation of the drill logs for the soils immediately below the contact is provided in Table 2. The green shading signifies the presence of organics in the core interval. The grey shading represents till. The orange boundaries and diagonal broken lines signify the presence of orange staining within that core interval.

It is noted that orange staining (presumably iron oxy-hydroxides) was pervasive throughout the background soil drill core. It appears to be a natural occurrence as the drill hole was sited on undisturbed soil well upstream of the tailings deposit. Although at varying depths within the 3 m zone below the contact, zones of orange staining were detected in all but one drill hole (NA-05-5). Orange staining was however detected in drill hole NA-05-5 at a depth of about 3.3 m below the contact.

Table 2 Summary of Soil Profiles below the Soil-Tailings Contact

Depth below Contact		Background	Intermediate Impoundment			Second Impoundment					Original Impoundment		
(m)		NA-05-01	NA-05-02	NA-05-03	NA-05-04	NA-05-05	NA-05-06	NA-05-07	NA-05-08	NA-05-09	NA-05-10	NA-05-11	NA-05-12
Contact Depth (m)			8.8	6.4	4.5	8.9	6.6	2.2	6.7	5.2	12.7	8.0	5.9
0.0	0.1	Surface organics		silty sand with gravel, minor tailings.	Very dark brown to maroon brown organics at surface. Fibrous, with roots. Amorphous organic silt with root hairs at base	Clean quartz-feldspar-mafic sand, moist, massive.	Dark grey hard sandy gravelly silt, moist to silty gravelly silt, moist	Dibrown to black coarse fibrous organic matter with amorphous organic matter matrix		Dark brown coarse sandy angular gravel with orange staining	Mixed silty tailings sand and sandy gravel, slightly moist	Tan to dark brown till (gravelly silty sand), very hard	volcanic ash, 1% fibrous organics (twigs and grass).
0.1	0.2					Dibrown fibrous organics with amorphous organic matter matrix. Top 1 cm has grey inorganic silt.						Dark brown zone of amorphous organic material and sandy gravel, slightly moist	
0.2	0.3	Orange stained gravelly silt, fine grained organic (black) and volcanic ash (creamy white)		and discontinuous organic laminations, tailings and iron								Dark brown amorphous organic material with flecks of volcanic ash and trace gravel, slightly moist	Mixed Dibrown amorphous organic matter as above, and olive brown to olive green till (sandy silt with trace gravel), irregular contacts between two materials, slightly moist
0.3	0.4		Orange stained sandy gravel, sand medium to coarse, very few fines.	Light orange tan gravelly coarse sand, wet. Trace fines			Light orange gravelly medium to coarse sand with individual oxidized particles	Dibrown organic silt with grey laminations and are dark orange to tan up to 1 mm	Brown gravelly sandy silt, slightly moist, massive, very hard, contains isolated oxidized orange sand grains and isolated gravel clasts	Olive brown to brown sandy gravel, slightly moist, orange staining of 30% of particles			
0.4	0.5							Most yellowish tan sandy gravelly silt mixed with dibrown amorphous organic matter					
0.5	0.6	Orange-brown stained sandy subrounded gravel						Dark brown sandy gravelly silt mixed with dark brown amorphous organic matter		Olive brown fine sandy gravel with 3% silt, wet, massive	Tan sandy silty gravel, wet	Mixed dark brown zone of amorphous organic material and volcanic ash (brownish cream), appears cryoturbated, 50% ash. Slightly moist	
0.6	0.7												
0.7	0.8			Intensely orange stained gravelly coarse sand, wet. Orange staining and precipitate coating particles and filling interstices.	Mixed olive brown sandy silt with gravel and dark brown sandy silt with gravel. Colour contacts are irregular, undulating, and distorted								
0.8	0.9						Dark brown organic matter, amorphous with 5% fibres, with trace fine gravel and coarse sand particles, and with trace laminations of volcanic ash. Organic matter is mixed irregularly ~50/50% with light green to brown sandy gravelly silt. Subrounded gravel					Dark brown silt mixed with amorphous organic matter. Contains trace angular gravel and coarse sand, slightly moist	Orange olive brown gravelly sandy silt with incursions of very dark brown organic matter and local bright orange stained pockets of matrix, moist, lower contact additional
0.9	1.0												
1.0	1.1					Very dark brown silt with 5% coarse sand and fine gravel. Silt is a mix of amorphous organic matter and inorganic silt. Gravel is subangular, up to 1 cm		Olive brown gravelly sandy silt, massive					
1.1	1.2												
1.2	1.3												
1.3	1.4												
1.4	1.5		Orange gravelly coarse sand, wet, clean. Grains subangular to subrounded		Mixed very dark brown organic silt and olive brown gravelly silt with sand. Contains isolated orange weathering coarse sand fragments		Light olive green sandy gravelly silt, as above, mixed with greyish brown sandy gravelly silt. Mixture is irregularly laminated, but appears to be a single type of material with irregular colour variations.		Olive brown sandy silty cobble gravel. Cobbles pulverized by zone drill bit, leads to rock flour in recovered sample				
1.5	1.6												
1.6	1.7												
1.7	1.8												
1.8	1.9	Orange-brown stained sandy subrounded boulder/cobble gravel, boulders and cobbles reduced to powder by drill bit		As from 6.9 to 7.9 m. Contains a single discrete 2 cm region of orange staining						??? Core Lost- cobble in bit		Olive brown till (silt with gravel and sand), hard, moist	
1.9	2.0												
2.0	2.1												
2.1	2.2												
2.2	2.3												
2.3	2.4							Cobble gravel. Sample is dominated by cobble fragments and rock flour. Contains ~30% coarse sand, slightly moist					
2.4	2.5					Mix of very dark brown organic silt as above, and olive brown silt with fine gravel and coarse sand. Mixture is irregular with heavy contacts							
2.5	2.6												
2.6	2.7												
2.7	2.8												
2.8	2.9												
2.9	3.0							Yellowish tan gravelly silt with sand (TLL), massive, wet		Tan coarse sandy gravel with 0 to 10% silt, wet, massive			Brownish orange stained coarse sandy gravel, diff to slightly moist, gravel subangular to subrounded and up to small cobble size.

Notes: Green shading indicates presence of organics; grey indicates till; orange broken line indicates the presence of orange staining; blue line + triangle indicates the water table

Zones containing organics, present as amorphous matter and/or as fibrous matter, were detected in most drill holes. The thickness of the layers however varied significantly from location to location, ranging from a few centimeters to several meters. The layers do not appear to be continuous but rather appear as discreet zones.

## **2.3 Processes affecting Water Quality**

Potential processes that may be in effect were hypothesized from the observed pH and conductivity trends across and immediately below the tailings – soil contact, and considering the drill log observations. The hypothesized processes are summarized below in Table 3. The processes have been superimposed on the drill hole logs shown in Table 2.

As noted in the earlier discussions, the paste parameters suggest that in some locations (e.g. in the Original Impoundment) a high TDS front has passed across the contact, typically indicating a lower TDS in the tailings than in the underlying soils. Another phenomenon is the observed decrease in pH in the soils to below that measured in the tailings. Two possible explanations exist. First, it may be possible that dissolved ferrous iron present in the porewater may have oxidized during core recovery and testing to form ferrihydrite and cause the pH to decrease. The second explanation is that organic matter present in the soils may be releasing organic acids which cause the change in pH. In a number of cases it appears that downward trends in pH coincide with organics zones (e.g. NA-05-7, -8, -12), or occur immediately below zones that contain organic matter (e.g. NA-05-11). It would seem that the latter explanation is more likely.

In many cases it is not possible at present to distinguish amongst possible processes. As shown in the table, in many cases porewater quality is likely affected by a combination of processes. However, these hypotheses can be used to target specific samples for selected tests.

## **3 Proposed testing Program**

### **3.1 Sample Selection**

The original proposal identified the following analytical and testing procedures for the tailings and soils samples:

- Elemental analysis of solids
- Pore water extraction and analysis
- Sequential / Selective Leach Extractions
- Column testing if warranted

The proposed program included a mineralogical assessment comprising:

- Petrographic assessment (optical microscopy)
- SEM – Microprobe analysis
- XRD

Table 3 Hypothesized Processes Affecting Percolate from Tailings

Depth below Contact		Background	Intermediate Impoundment				Second Impoundment					Original Impoundment		
(m)		NA-05-01	NA-05-02	NA-05-03	NA-05-04		NA-05-05	NA-05-06	NA-05-07	NA-05-08	NA-05-09	NA-05-10	NA-05-11	NA-05-12
Contact Depth (m)			8.8	6.4	4.5		8.9	6.6	2.2	6.7	5.2	12.7	8.0	5.9
0.0	0.1			Neutralization / Precipitation	neutralization/precipitation/sorption		?? (TDS front??)		Sorption / organic acid (Fe ppt?)		Neutralization / precipitation (Sorption)	(Tailings) Neutralization/precipitation	TDS front ??	TDS front ?
0.1	0.2						Neutralization ??						Neutralization / DESORPTION(?)	
0.2	0.3			Sorption					Sorption / organic acid (Fe ppt?)				Sorption	
0.3	0.4								Sorption / organic acid (Fe ppt?)	Neutralization / precipitation / (Sorption?)				DESORPTION??
0.4	0.5													
0.5	0.6													
0.6	0.7								Sorption / organic acid (Fe ppt?)					
0.7	0.8				organic acid / (Fe precipitation)									
0.8	0.9													
0.9	1.0													
1.0	1.1													
1.1	1.2													
1.2	1.3													
1.3	1.4													
1.4	1.5													
1.5	1.6													
1.6	1.7													
1.7	1.8													
1.8	1.9													
1.9	2.0													
2.0	2.1													
2.1	2.2													
2.2	2.3													
2.3	2.4													
2.4	2.5													
2.5	2.6													
2.6	2.7													
2.7	2.8													
2.8	2.9													
2.9	3.0													

Using the summary in Table 3, together with the drill logs, samples were selected for specific testing as shown in Table 4. Test methods are described in the next section.

The program will be scheduled in two stages. The first stage, comprising all but the sequential leach extractions and elution columns, will be carried out first. The results from the first stage will then be used to confirm that the sequential and elution tests are appropriate before proceeding.

## **3.2 Methods**

### **3.2.1 Sample Preparation**

Sample preparation will be undertaken in a glove box, isolated from the atmosphere with an overpressure of nitrogen and/or argon gas. Residual samples are to be resealed in airtight bags to prevent any oxygen ingress during subsequent storage.

Preparation of composite samples, where required, will entail splitting each of the core sections along its axis (lengthwise) and combining the core intervals accordingly. Where samples do not consist of intact core, the contents of the bag should be well mixed and split before compositing.

Sub-samples for each component of testing shall be split simultaneously, and sealed or prepared as necessary, to minimize sample handling and the risk of exposure to atmospheric conditions.

### **3.2.2 Paste Parameters**

Paste pH and conductivity measurements are to be undertaken on each interval of Drill Hole NA-05-1. The paste parameters shall be determined as follows:

1. Sieve a portion of the sample through a 2 mm screen
2. Place 60 g (wet weight) of the -2 mm fraction in a clean 200 to 250 ml container.
3. Add 60 ml of distilled water.
4. Stir continuously with clean spatula for 1 minute.
5. Let stand for 10 to 15 minutes to allow suspension to settle.
6. Measure conductivity and pH of the supernatant fluid.

### **3.2.3 Elemental Analyses**

All elemental analyses on solids and residues to be completed using a standard four acid digestion and ICP-AES/MS procedure. All elemental analyses of solutions to be completed by ICP-OES to low level detection limits (See Table 5).

**Table 4. Testing Program**

Location	Drill hole	Interval			Analysis and Testing									Mineralogy		
		From	To		Elemental analysis	Total Carbon	Inorganic Carbon	NP (Mod Sobek)	S(T); S(SO4)	Pore water analysis	Water LE	Sequential / Selective LE	Column testing	Petrographic (OM)	SEM – Microprobe	XRD
Background	NA-05-1	0	0.1	comp	x				x							
		0.1	0.3		x	x		x	x		x	XX				
		0.3	0.6		x						x	x				
		0.6	3.2		x						x					
		3.2	3.6		x			x	x		x					
		3.6	4.3		x											
		4.3	9		x											
Int. Imp.	NA-05-2	8.8	13.3		x		x	x	x	x		XX	x	x	x	x
Int. Imp.	NA-05-3	6.4	6.5	Comp	x		x	x	x	x		XX				
		6.5	6.6		x	x				x		x		x	x	x
		6.6	6.63	Comp	x		x	x	x	x		x				
		6.63	6.9		x		x	x	x	x		x				
		6.9	7.3		x		x	x	x	x		x				
Int. Imp.	NA-05-4	7.3	7.35													
		4.5	4.7		x	x	x	x	x		x	XX				
		4.7	5.7		x		x	x	x		x					
Sec. Imp-N	NA-05-5	5.7	6.1		x		x	x	x							
		8.9	9		x		x	x	x		x					
		9	9.1		x	x	x	x	x		x			x	x	x
Sec. Imp-N	NA-05-6	9.1	10.9		x	x	x	x	x			x	x	x	x	x
		6.6	6.7													
		6.7	7.3		x		x	x	x		x					
		7.3	7.8		x	x	x	x	x	x		XX	x	x	x	x
Sec. Imp-N	NA-05-7	7.8	8.4		x		x				x					
		2.2	2.4		x	x	x	x	x	x						
		2.4	2.6		x	x	x	x	x	x		x	x	x	x	x
Sec. Imp-S	NA-05-8	6.7	7.4		x		x				x					
		7.4	8.8		x	x	x	x		x		XX		x	x	x
Orig. Imp.	NA-05-10	12.7	12.9													
		12.9	13.5		x	x	x	x	x	x		x	x	x	x	x
		13.5	16.5		x		x		x			XX				
Orig. Imp.	NA-05-12	5.9	6		x	x	x	x	x		x					
		6	6.4		x	x	x	x	x			XX	x			
		6.4	7.2		x	x					x					
Tests					28	13	19	18	3	9	11	22	6	8	8	8

Note: XX signifies duplicate tests

**Table 5 ICP Detection Limits**

Element		Trace Level (ICP-OES)
Aluminum	Al	0.05
Antimony	Sb	0.05
Arsenic	As	0.05
Barium	Ba	0.001
Beryllium	Be	0.001
Bismuth	Bi	0.05
Boron	B	0.05
Cadmium	Cd	0.001
Calcium	Ca	0.05
Chromium	Cr	0.005
Cobalt	Co	0.005
Copper	Cu	0.01
Iron	Fe	0.03
Lead	Pb	0.03
Lithium	Li	0.01
Magnesium	Mg	0.05
Manganese	Mn	0.001
Mercury	Hg	--
Molybdenum	Mo	0.01
Nickel	Ni	0.005
Phosphorous	P	--
Potassium	K	1
Selenium	Se	0.02
Silicon	Si	--
Silver	Ag	0.01
Sodium	Na	--
Strontium	Sr	0.001
Sulphur	S	--
Thallium	Tl	0.03
Tin	Sn	0.02
Titanium	Ti	--
Uranium	U	0.5
Vanadium	V	0.03
Zinc	Zn	0.005

### 3.2.4 Pore Water Extractions

Porewater extractions shall be completed under anoxic conditions within a nitrogen or argon atmosphere. Extractions can be completed by either centrifuge or by pressure filtration. Once the porewater has been extracted it is to be preserved and submitted for elemental analysis by ICP-OES to Trace level detection limits.

### 3.2.5 Standard Water Leach Extraction Tests

Leach extractions shall be performed under an anoxic atmosphere using either nitrogen or argon. A distilled water to solids contact ratio of 3:1 (wet wt. solids) should be utilized.



The sample should be contacted with the solids for a period of 48 hours while being gently agitated.

At the end of the 48 hour period the solids should be allowed to settle, the supernatant decanted under anoxic conditions, routine parameters measured (EC, pH, alkalinity/acidity, redox), filtered, preserved and submitted for dissolved metals by ICP OES to Trace Levels.

### 3.2.6 Sequential Selective Leach extraction

The purpose of the selective extraction tests is to assess the speciation of zinc within the soils below the tailings. For this purpose samples have been selected to represent soils that have been subjected to elevated TDS/metals concentrations. Soil samples that do and do not contain organic matter were selected for testing. The test procedure is described below.

1. Place 3.0 g (equivalent to dry weight) of as-received material in a centrifuge tube. Weigh and record mass. Add 100 ml de-ionized water and agitate for 1 hr. Centrifuge for 30 minutes at 12 000 g. Remove supernatant by pipette and preserve for analysis. Record weight/volume of supernatant recovered. Analyze contained metals by ICP methods with appropriately low detection levels. Rinse residue with 8 ml de-ionized water, centrifuge and discard rinsate. Weigh and record mass. To prevent ferrous oxidation, this step is to be conducted under anoxic conditions. The centrifuge tube is to be sealed within an inert atmosphere prior to centrifuging. The Supernatant is to be recovered in an inert atmosphere, as does the rinse step.
2. Add 24 ml of 1 M  $\text{NH}_4$ -acetate, adjusted to pH 4.5 with HOAc, to residue from de-ionized water extraction. Record weight. Agitate for 2 hours. Adjust weight to initial weight by adding deionized water as required. Centrifuge, remove supernatant and record weight/volume of supernatant recovered. Submit for analysis. Rinse residue with de-ionized water as above. Weigh and record mass of residue.
3. Add 60 ml of 0.2 M  $\text{NH}_4$ -oxalate, adjusted to pH 3.0 using 0.2 M oxalic acid ( $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ ), to residue from  $\text{NH}_4$ -acetate extraction. Record weight. Agitate in complete darkness for 1 hour. Adjust weight to initial weight as necessary by adding distilled water. Centrifuge, record weight/volume of supernatant recovered and analyze supernatant,. Rinse with de-ionized water as above. Weigh and record mass of residue.
4. Add 60 ml of 0.2 M  $\text{NH}_4$ -oxalate, adjusted to pH 3.0 using 0.2 M oxalic acid ( $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ ), to residue from initial 0.2 M  $\text{NH}_4$ -oxalate extraction. Record weight. Heat for 2 hours in a water bath at 80° C, and occasionally agitate. Adjust weight to initial weight by adding deionized water as required. Centrifuge, remove and record weight/volume of supernatant recovered. Analyze supernatant, and rinse residue with de-ionized water as above. Weigh and record mass.
5. Add 24 ml of 30%  $\text{H}_2\text{O}_2$  to residue from final 0.2 M  $\text{NH}_4$ -oxalate extraction. Record weight. Heat to 85° C in water bath for 1 hour, with occasional agitation. Adjust weight to initial weight by adding deionised water as required. Centrifuge, remove and record weight/volume of supernatant recovered. Analyze supernatant, and rinse residue with deionized water as above. Weigh and record mass.
6. Add 60 ml of 0.2 M  $\text{KClO}_3$  and 10 ml of 0.2 M HCl to residue from peroxide extraction, record weight and agitate for 1 hour. Adjust weight to initial weight with

deionized water as required. Quantitatively transfer contents of vial to appropriate flask, add 10 ml of 4 M HNO<sub>3</sub>, record weight and boil for 1 hr, adding deionized water as required to prevent drying. Adjust weight to previous weight as required with deionized water. Quantitatively transfer contents back into centrifuge tube. Centrifuge, remove and record weight / volume of supernatant. Analyze supernatant, and rinse with deionized water as above. Weigh and record mass.

7. Submit final residue for a standard 'four acid' digestion - ICP MS procedure.

### 3.2.7 Mineralogical characterization

Mineralogical assessment of the soil solids is expected to provide valuable insight into the mechanisms of zinc retention in the soils underlying the tailings. In particular, identification of secondary mineral phases will help guide the interpretation of selective extraction results, and may point to previously unrecognized solid phases that are contributing to zinc retention. Three types of examination are planned, as follows.

1. Petrographic assessment. Optical microscopic techniques will be used to identify individual grains for further examination, and to assess sample mineralogy at the optical level. Weathering rims and secondary mineral formation on primary mineral grains may be identified at this stage.
2. SEM and electron microprobe. The scanning electron microscope provides detail on surface textures, coatings, and grain size, and has sufficient resolution that individual grains can be targeted for investigation by electron microprobe. The microprobe will provide quantitative determinations of zinc content in the selected grains.
3. XRD. Submission of selected samples for scanning by an x-ray diffractometer will provide bulk mineralogical characteristics of the sample and will potentially identify previously unrecognized mineral phases that may be contributing to zinc retention.

### 3.2.8 Column Tests – Elution

The purpose of the elution tests is to assess whether if attenuation is reversible. For this purpose samples have been selected to represent soils that have been subjected to elevated TDS/metals concentrations. Soil samples that do and do not contain organic matter were selected for testing. The test procedure is described below.

#### *Apparatus*

Prepare each column from using a PVC tube approximately 220 mm long with an internal diameter of 38 mm, and with removable head-plates each equipped with an inlet. A fine mesh distribution 'plate' (3 to 4 nylon fine mesh disks) is required at each end of the column as shown schematically in Figure 1, Attachment A. The internal volume of each column will be about 250 mL and should accommodate about 425 g of soil sample. The porevolume of the contained soil is estimated to be about 120 mL.

#### *Procedure*

The operational set-up of the column test is shown in Figure 2, Attachment A. The tests will be carried out using distilled de-aerated water. At the time of commencing the test, a sample of the water is to be submitted for analysis for ICP-OES, pH conductivity, acidity and redox.

The column shall be assembled in a glove box in an inert atmosphere. The proposed procedure for the preparation of the column is as follows:

1. Seal the base plate of the column in place.
2. Place the nylon disks at the bottom of the column, and weigh the apparatus.
3. In an inert atmosphere, fill column with soil to the top of the column, ensuring that an even compacted fill density is achieved. Weigh the apparatus and subtract the column weight to obtain the soil charge.
4. Seal the top of the column in place, and pressure test.
5. Attach the top outlet of the column to an air trap and displace the pore gases with nitrogen.
6. Flood the column with de-aerated distilled water to prime the column. Measure the volume of water used to saturate the column (by weight or by volume injected).
7. Allow conditions to equilibrate for 24 hours.
8. Commence water displacement, passing approximately **60 mL of water** through the column over a **24 hour** period. Working in an anoxic environment, measure pH and redox for **each 120 mL** or one pore volume displaced (i.e. combine every 2 days to represent one displacement, seal and place in cold storage for analysis if required at a later date (filter the sample if tailings solids are present in the sample)).
9. Submit the **first** and then every **third** displacement for ICP analysis, alkalinity and acidity as appropriate (i.e. displacements 1, 4, 7, 10 and 12).
10. Continue test for 20 days or 10 pore volume displacements have been completed. Maintain the column under sealed conditions until the results from the first 10 pore volumes have been reviewed. At that time a decision will be made to continue or to terminate the test.

## ATTACHMENT A

### Column Test Set-up Illustrations

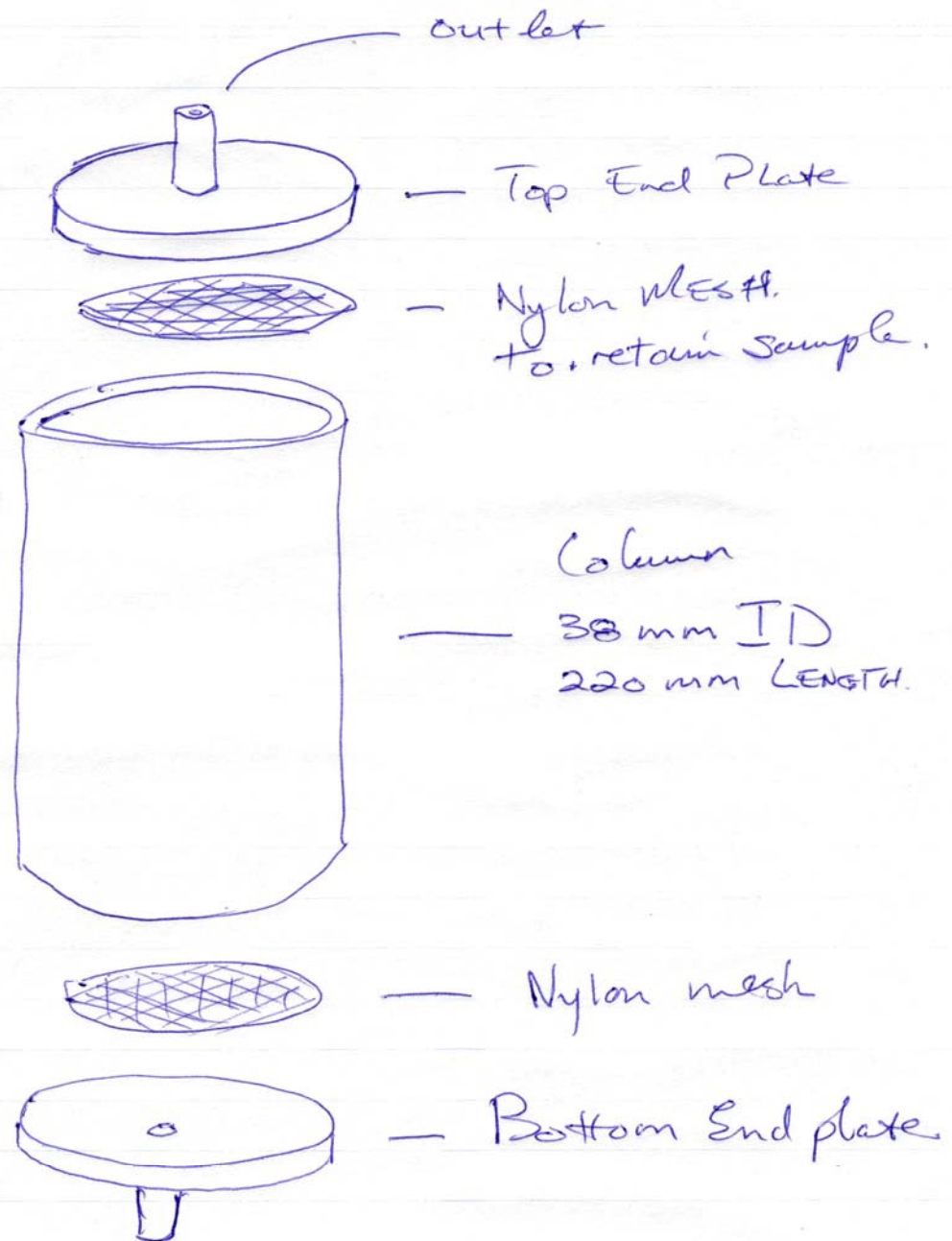


Figure 1 Column Schematic.

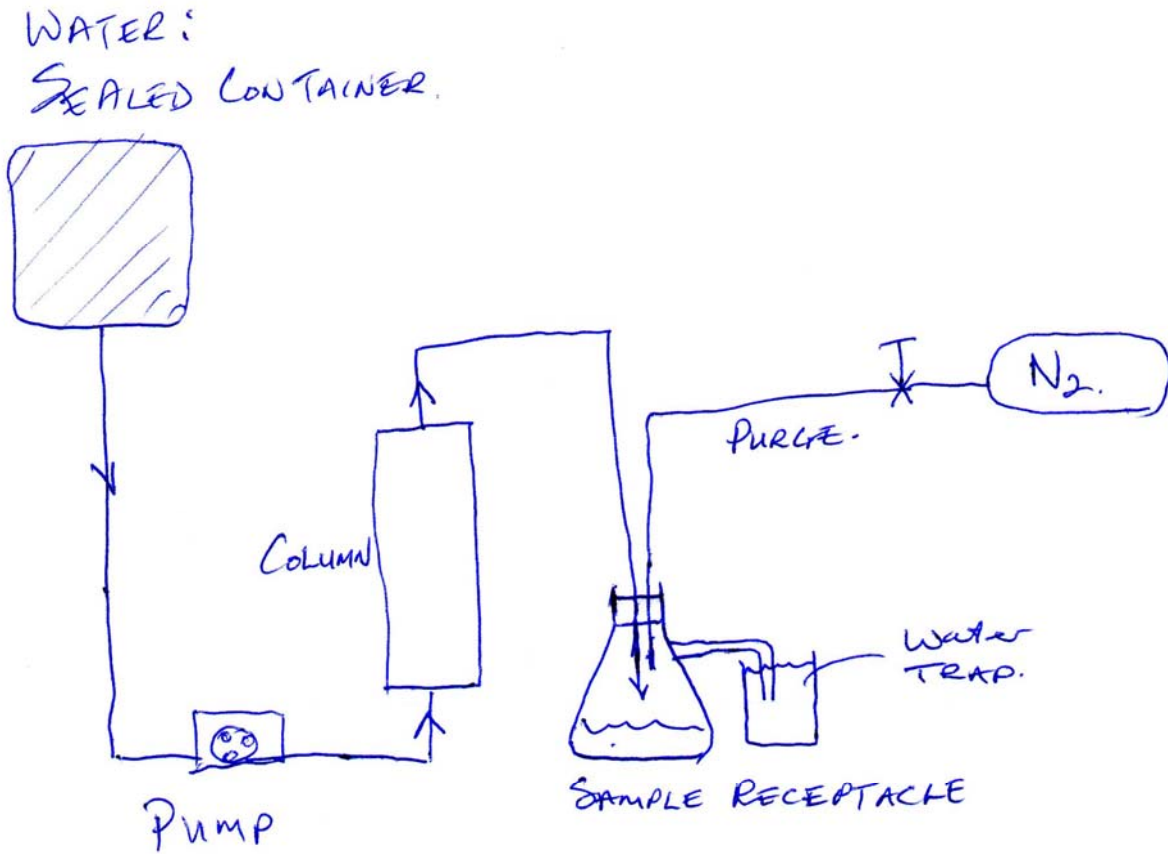


Figure 2. Operational Column SET-UP.

## **Appendix C**

### **Laboratory Test Results**

Table 1: ABA Results for Faro Tailings Samples - December, 2005

Sample			Paste pH	Total Carbon (Wt.%)	CO2 (Wt.%)	CaCO3 Equiv. (Kg CaCO3/Tonne)	Total Sulphur (Wt.%)	Sulphate Sulphur (Wt.%)	Sulphide Sulphur* (Wt.%)	Maximum Potential Acidity** (Kg CaCO3/Tonne)	Neutralization Potential (Kg CaCO3/Tonne)	Net Neutralization Potential (Kg CaCO3/Tonne)	Fizz	
Hole	From	To												
NA-05-1	0	0.1		4.28			0.05	0.03	0.02	0.6				
	0.1	0.6		5.67	0.46		0.02	0.03	-0.01	-0.3	12.3	12.6	none	
	0.6	3.2												
	3.2	3.6												
	3.6	4.3		7.21	0.46		0.02	0.03	-0.01	-0.3	101.0	101.3	none	
	4.3	9												
NA-05-2	8.8	13.3	6.33	0.14	0.04	0.9	0.18	0.04	0.14	4.4	30.8	26.4	none	
NA-05-3	6.4	6.6	5.42	0.94	0.41	9.3	2.12	0.20	1.92	60.0	23.4	-36.6	none	
	6.6	6.63		1.00			0.18		0.18	5.6				
	6.63	7.35	5.07	0.12	0.01	0.2	0.03	0.09	-0.06	-1.9	25.9	27.8	none	
NA-05-4A	5.7	5.85	4.82	6.99	0.30	6.8	2.21	0.26	1.95	60.9	-29.6	-90.5	none	
	5.85	5.95	4.89	2.02	0.10	2.3	0.66	0.13	0.53	16.6	1.2	-15.4	none	
	7.5	7.7	5.00	7.83	0.04	0.9	0.30	0.27	0.03	0.9	-19.7	-20.6	none	
NA-05-5	8.9	9	3.14	6.26			1.46	0.72	0.74	23.1	-136.7	-159.8	none	
	9	9.1	3.42	1.99	0.08		0.53	0.29	0.24	7.5	-20.9	-28.4	none	
	9.1	10.9		2.31	0.07	1.6	0.45	0.34	0.11	3.4				
NA-05-6	6.7	7.3	3.82	0.22	0.08	1.8	0.15	0.16	-0.01	-0.3	-11.1	-10.8	none	
	7.3	7.8	3.12	2.00	0.02	0.5	1.85	0.47	1.38	43.1	-56.7	-99.8	none	
	8.6	8.9			0.02									
NA-05-7	2.2	2.4	2.87	15.98	0.37	8.4	7.46	2.64	4.82	150.6	-450.7	-601.3	none	
	2.4	2.6	2.94	5.16	0.15	3.4	3.03	1.47	1.56	48.8	-234.4	-283.2	none	
NA-05-8	6.7	7.4			0.43	9.8								
	7.4	8.8	6.96	2.22	0.15	3.4	1.70		1.70	53.1	22.2	-30.9	none	
NA-05-10	12.9	13.5	6.95	0.11	0.02	0.5	0.03	0.03	0.00	0.0	16.6	16.6	none	
	13.5	16.5		0.12	0.03	0.7	0.02	0.03	-0.01	-0.3				
NA-05-12	5.9	6	2.85	8.65	0.26	5.9	11.24	1.76	9.48	296.3	-296.2	-592.5	none	
	6	6.4	3.09	4.76	0.06	1.4	1.56	0.99	0.57	17.8	-157.4	-175.2	none	
	6.4	7.2		0.75		0.0	0.57		0.57	17.8				
Detection Limits				0.1		0.01		0.02	0.01					
Vizon Method Number				7160		7460.00	Calculation	7400.00	7410	Calculation	Calculation	7150	Calculation	7150

\*Based on difference between total sulphur and sulphate-sulphur

\*\*Based on sulphide-sulphur

NP method used: Mod. ABA method (1989)



**Table 3: Results of Trace Metals Analysis by Four Acid Digestion & ICP-MS Finish for Faro Tailings Samples,**

Sample	Class	Ag ppm	Al %	As ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cs ppm	Cu ppm	Fe %	Ga ppm	Ge ppm	Hf ppm
NA-05-1 0 - 0.1	Soil	0.76	6.36	15.1	1000	2.23	0.48	1.36	0.86	74.9	14.4	103	4.34	46.5	3.29	16.65	0.15	2.1
0.1 - 0.6	Soil	0.06	6.44	6.3	710	2.23	0.25	1.16	0.22	58.7	10.8	110	4.21	19.4	2.94	17.25	0.13	1.7
0.6 - 3.2	Soil	0.10	7.6	6.1	840	4.99	0.53	4.21	0.42	57.8	10.9	101	6.28	20.9	2.97	22.7	0.13	1.1
3.2 - 3.6	Soil	0.11	6.2	6.6	840	2.49	0.5	0.94	0.31	47.3	8.4	120	4.48	18.3	2.43	15.05	0.11	1.2
3.6 - 4.3	Soil	0.13	7.04	9.3	970	2.3	0.37	1.28	0.53	66.4	16.4	116	4.79	34.6	3.84	17.45	0.19	1.9
4.3 - 9.0	Soil	0.21	6.29	8.9	1140	2.1	0.22	2.13	0.8	62.4	15.2	132	4.77	33.8	3.32	16.55	0.16	1.8
NA-05-2 8.8 - 13.3	Soil	0.24	5.63	12.2	700	2.28	0.74	1.06	0.26	50.1	9.6	111	4.59	24.1	2.78	14.8	0.13	1.1
NA-05-3 6.4 - 6.6 Tailings/Soil	Soil	1.31	6.26	56	120	5.13	0.36	1.34	1.05	53.5	14.9	140	4.52	101.5	5.37	16.7	0.19	1.8
6.6 - 6.63	Soil	0.20	6.93	20.5	670	8.02	0.77	1.89	0.2	63.8	8.1	209	7.42	19.2	3.31	21.2	0.15	2.4
6.63 - 7.35	Soil	0.15	6.86	12.4	770	2.51	0.3	1.8	0.23	64.5	9.0	173	4.7	19.8	3.41	15.95	0.15	1.1
NA-05-4A 5.7 - 5.85 Tailings/Soil	Soil	0.88	5.52	42.1	160	2.08	0.26	1.34	13.65	59.7	22	108	3.83	334	4.66	14.7	0.18	1.8
5.85 - 5.95 Tailings/Soil	Soil	0.28	5.65	16.4	930	2.11	0.29	1.16	3.21	60	12	154	4.26	77.7	3.22	14.0	0.13	1.6
7.5 - 7.7	Soil	0.18	5.89	9.5	920	2.16	0.28	1.42	0.64	63.3	11.3	106	4.44	36.5	3.33	14.95	0.14	1.7
NA-05-5 8.9 - 9.0 Tailings/Soil	Soil	0.37	5.56	13.9	280	1.92	0.23	1.07	5.08	56.3	11.4	102	3.72	48.9	4.96	14.1	0.17	1.8
9.0 - 9.1 Tailings/Soil	Soil	0.16	6.44	9.0	880	2.18	0.26	1.34	0.61	65.5	11.1	158	4.33	27.1	3.91	16.2	0.17	1.9
9.1 - 10.9	Soil	0.13	5.88	7.0	860	1.88	0.24	1.18	0.35	65.5	11.4	131	3.79	24.4	3.57	14.45	0.16	1.7
NA-05-6 6.7 - 7.3	Soil	0.12	6.08	7.2	1050	2.48	0.42	0.88	0.43	68.8	10.6	101	4.38	22.2	2.89	15.3	0.15	1.3
7.3 - 7.8 Tailings/Soil	Soil	0.31	6.0	23.2	190	1.98	0.23	1.32	0.94	61.8	20.1	134	3.76	62.5	5.01	15.05	0.19	1.7
8.6 - 8.9	Soil	0.10	5.55	6.7	860	2.01	0.25	1.16	0.25	61.1	10.2	166	3.75	23.8	3.2	14.2	0.16	1.6
NA-05-7 2.2 - 2.4 Tailings/Soil	Soil	2.66	2.58	86.8	40	0.78	0.32	1.52	13.85	21.0	27.4	62	1.77	232	9.72	7.04	0.24	0.9
2.4 - 2.6 Tailings/Soil	Soil	0.73	5.59	28.2	80	1.32	0.18	1.94	1.56	41.3	15	110	2.25	75.5	6.62	13.25	0.21	2
NA-05-8 6.7 - 7.4 Tailings/Soil	Soil	2.02	6.15	141	140	2.02	0.45	1.56	3.49	56.3	51.1	118	4.12	311	10.05	15.95	0.32	1.2
7.4 - 8.8 Tailings/Soil	Soil	0.58	6.49	33.3	260	1.75	0.38	1.56	1.01	56.3	21.5	115	3.67	95.7	4.7	16.05	0.19	2.2
NA-05-10 12.9 - 13.5	Soil	0.08	6.62	4.4	700	3.1	0.63	1.36	0.18	56.9	8.7	117	7.48	22.9	2.54	18.2	0.14	1.6
13.5 - 16.5	Soil	0.14	5.67	6.8	750	2.49	0.28	1.04	0.25	46.7	8.2	111	4.17	17.2	2.32	13.45	0.12	1.1
NA-05-12 5.9 - 6.0 Tailings	Soil	2.63	2.84	91.7	20	0.62	0.24	0.81	4.26	14.35	36.3	41	0.95	287	12.2	7.46	0.3	1.3
6.0 - 6.4 Tailings/Soil	Soil	0.28	5.2	9.9	220	1.88	0.25	1.16	0.76	58.5	13.6	104	3.3	38.7	4.71	13.25	0.16	1.6
6.4 - 7.2 Tailings/Soil	Soil	0.12	6.55	9.8	900	2.4	0.4	1.08	0.42	67.7	13.6	138	4.61	27.5	4.21	16.85	0.18	2
Detection Limits		0.01	0.01	0.2	10	0.05	0.01	0.01	0.02	0.01	1	0.05	0.2	0.01	0.05	0.05	0.1	0.1

**Table 3: Results of Trace Metals**

Sample	Class	In ppm	K %	La ppm	Li ppm	Mg %	Mn ppm	Mo ppm	Na %	Nb ppm	Ni ppm	P ppm	Pb ppm	Rb ppm	Re ppm	S %	Sb ppm	Se ppm
NA-05-1 0 - 0.1	Soil	0.063	1.66	43.6	38.7	0.93	597	5.39	1.05	11.8	40.1	820	434	93.9	<0.002	0.06	1.78	3
0.1 - 0.6	Soil	0.049	1.9	29	48.1	0.72	748	6.53	1.38	8.7	23.6	570	33.6	102.5	<0.002	0.04	0.74	2
0.6 - 3.2	Soil	0.059	2.09	29.7	74.5	0.90	828	5.23	1.19	13.1	23.6	2220	23.2	121.5	<0.002	0.03	0.45	2
3.2 - 3.6	Soil	0.037	2.18	25	43.6	0.68	427	7.53	1.1	7.9	24.1	740	24.3	119	<0.002	0.01	0.86	2
3.6 - 4.3	Soil	0.048	1.94	36.6	44.7	1.28	582	4.64	0.87	13	54.2	930	19.0	102	<0.002	0.03	1.16	2
4.3 - 9.0	Soil	0.048	1.86	33.1	41.3	1.27	471	5.72	0.77	10.9	69.6	980	18.2	96.3	0.003	0.03	1.7	2
NA-05-2 8.8 - 13.3	Soil	0.043	1.85	25.9	48.7	0.70	346	6.32	1.01	8.2	23.7	1000	93.1	110	<0.002	0.25	1.07	2
NA-05-3 6.4 - 6.6	Tailings/Soil	0.102	1.77	26.5	46.2	0.79	554	7.96	1.17	8.9	23.3	640	590	101.5	<0.002	2.01	3.72	2
6.6 - 6.63	Soil	0.047	2.38	32	76.5	0.65	520	13.7	1.53	9.7	20.9	630	73.9	144.5	0.002	0.22	1.33	2
6.63 - 7.35	Soil	0.068	1.89	34.8	49.8	0.86	506	9.26	1.06	11.2	25.4	720	53	103	<0.002	0.16	0.85	2
NA-05-4A 5.7 - 5.85	Tailings/Soil	0.100	1.52	29.8	37.3	0.84	520	5.21	0.98	8.8	31.3	680	429	84.8	0.002	2.19	2.53	5
5.85 - 5.95	Tailings/Soil	0.056	1.68	31.5	38.2	0.82	383	7.97	0.91	8.7	31.4	640	109	96.7	<0.002	0.66	1.28	3
7.5 - 7.7	Soil	0.044	1.63	34.6	36.3	1.00	367	3.42	0.79	10.2	42.7	830	40.5	95.9	0.002	0.46	1.14	3
NA-05-5 8.9 - 9.0	Tailings/Soil	0.059	1.48	30.2	35.9	0.90	657	4.68	0.92	8.7	34.1	650	240	84.7	<0.002	1.62	1.58	4
9.0 - 9.1	Tailings/Soil	0.045	1.88	35.2	45.9	0.99	526	7.36	1.12	10.1	33.4	1800	65.7	109.5	<0.002	0.65	0.95	3
9.1 - 10.9	Soil	0.043	1.58	35.5	37.6	1.01	425	5.64	0.92	10.6	35.9	710	35.7	91.3	0.002	0.5	0.86	3
NA-05-6 6.7 - 7.3	Soil	0.045	2.18	35.4	39.8	0.60	379	5.11	0.99	8.7	27.2	520	73.4	126	<0.002	0.2	0.66	3
7.3 - 7.8	Tailings/Soil	0.068	1.56	32.7	36.4	1.12	521	5.67	0.93	10.4	42.4	690	139.5	89.5	<0.002	1.84	1.16	3
8.6 - 8.9	Soil	0.038	1.56	32.4	35.4	0.94	409	7.75	0.84	10	37.6	640	20	88.8	<0.002	0.28	0.78	2
NA-05-7 2.2 - 2.4	Tailings/Soil	0.142	0.66	10.1	13	0.37	616	4.79	0.52	3.3	14.8	540	1580	33.2	0.002	7.5	7.59	7
2.4 - 2.6	Tailings/Soil	0.066	1.34	20.6	25.4	0.83	596	6.27	1.24	6.8	19.4	620	414	59.1	<0.002	3.22	2.21	4
NA-05-8 6.7 - 7.4	Tailings/Soil	0.188	1.62	27.5	42.4	0.89	621	7.19	1.04	10.4	27.9	630	1110	91.9	<0.002	7.72	6.41	3
7.4 - 8.8	Tailings/Soil	0.071	1.65	30.4	36	1.06	607	5.97	1.22	9.6	42.5	830	284	81.1	<0.002	1.6	2.18	3
NA-05-10 12.9 - 13.5	Soil	0.039	2.64	27.7	61.8	0.77	358	7.72	1.41	8.4	22.7	630	553	151.5	<0.002	0.07	0.92	2
13.5 - 16.5	Soil	0.034	1.94	25.2	38	0.63	532	6.27	0.94	7.7	23.1	730	51.4	107.5	<0.002	0.04	0.93	2
NA-05-12 5.9 - 6.0	Tailings	0.185	0.77	5.9	10.9	0.34	512	4.6	0.82	2.6	9.7	460	2770	25.6	<0.002	>10.0	7.73	6
6.0 - 6.4	Tailings/Soil	0.042	1.4	30.9	31.9	0.86	329	4.35	0.86	9.1	38.2	750	138	78	<0.002	1.51	1.15	4
6.4 - 7.2	Tailings/Soil	0.047	1.82	37.5	44.9	1.05	479	6.28	0.98	11.6	46	710	37.7	107.5	<0.002	0.6	0.91	2
Detection Limits		0.005	0.01	0.5	0.2	0.01	5	0.05	0.01	0.1	0.2	10	0.5	0.1	0.002	0.01	0.05	1

**Table 3: Results of Trace Metals**

Sample	Class	Sn ppm	Sr ppm	Ta ppm	Te ppm	Th ppm	Ti %	Tl ppm	U ppm	V ppm	W ppm	Y ppm	Zn ppm	Zr ppm
NA-05-1 0 - 0.1	Soil	2.8	212	1.08	0.05	13.9	0.395	0.85	3.2	95	2.6	15.4	410	62.6
0.1 - 0.6	Soil	3	185	0.8	<0.05	11.7	0.302	0.6	2.2	82	1.4	12.2	117	50.9
0.6 - 3.2	Soil	10.5	214	1.81	<0.05	11.8	0.294	0.75	2.5	73	13.8	12.5	117	31.7
3.2 - 3.6	Soil	3.2	159	0.72	0.06	9.5	0.271	0.74	2.2	86	1.6	10.9	71	35.6
3.6 - 4.3	Soil	2.4	148	1.1	<0.05	12.3	0.432	0.66	2.3	140	1.5	15.3	108	56.7
4.3 - 9.0	Soil	2.3	165	0.96	<0.05	11.2	0.353	0.63	2.3	138	3	14.9	113	55.2
NA-05-2 8.8 - 13.3	Soil	3	168	0.7	<0.05	9.9	0.261	0.77	2.2	78	2.1	10.4	201	34
NA-05-3 6.4 - 6.6	Tailings/Soil	3.5	210	0.81	<0.05	11.6	0.29	1.34	2.2	78	1.9	11.3	1685	55.2
6.6 - 6.63	Soil	5.4	202	1.06	<0.05	16.6	0.273	1.06	3.6	66	3.2	11.4	784	71
6.63 - 7.35	Soil	3.3	237	2.19	<0.05	11.8	0.311	0.63	2.3	86	1.7	13.4	287	33.1
NA-05-4A 5.7 - 5.85	Tailings/Soil	2.5	192.5	0.79	<0.05	9.7	0.284	0.83	4.7	86	1.4	21.7	4210	55.7
5.85 - 5.95	Tailings/Soil	2.9	166.5	0.79	<0.05	10.5	0.28	0.66	2.5	90	1.9	13.5	1580	46.6
7.5 - 7.7	Soil	2.5	142.5	0.91	<0.05	11.9	0.315	0.59	6.3	99	1.7	15.3	2140	50.3
NA-05-5 8.9 - 9.0	Tailings/Soil	2.1	175	0.77	<0.05	9.6	0.282	0.68	3	83	1.4	12.9	5470	52.1
9.0 - 9.1	Tailings/Soil	2.5	188.5	0.91	<0.05	12.7	0.323	0.7	3.8	88	1.6	17.1	1415	56.2
9.1 - 10.9	Soil	2.2	174	0.94	<0.05	12	0.347	0.55	3.5	93	2.6	14.5	1265	49.5
NA-05-6 6.7 - 7.3	Soil	4.2	144.5	0.81	0.07	11.2	0.258	0.85	2.2	68	2.7	11.8	741	38.3
7.3 - 7.8	Tailings/Soil	2.3	184.5	0.85	<0.05	10.4	0.345	0.63	2.8	97	1.8	14	1350	53
8.6 - 8.9	Soil	2.5	158	0.9	<0.05	11.1	0.329	0.53	2.1	90	1.3	13.6	77	46.9
NA-05-7 2.2 - 2.4	Tailings/Soil	1.6	104.5	0.29	<0.05	2.9	0.116	2.16	2.1	37	1.5	8.3	1.62%	28.7
2.4 - 2.6	Tailings/Soil	1.6	293	0.58	<0.05	7.1	0.269	0.69	2.6	75	1.2	9.2	4440	64
NA-05-8 6.7 - 7.4	Tailings/Soil	4.1	204	0.91	<0.05	9.3	0.329	2.38	2.5	83	3.1	14.9	2880	34.6
7.4 - 8.8	Tailings/Soil	1.9	241	0.79	0.09	9.1	0.342	0.92	2.8	118	1.4	14.5	637	68.4
NA-05-10 12.9 - 13.5	Soil	4.6	225	0.93	<0.05	13.7	0.285	1.03	2.6	74	1.7	11.5	280	46.1
13.5 - 16.5	Soil	3	151.5	0.7	<0.05	8.9	0.267	0.64	1.7	81	2.5	9.8	95	32.6
NA-05-12 5.9 - 6.0	Tailings	1.6	136.5	0.23	<0.05	1.9	0.104	1.05	2.8	29	1.2	10.9	1.22%	40.6
6.0 - 6.4	Tailings/Soil	1.9	152.5	0.79	<0.05	9.8	0.299	0.52	4	87	2.1	12.8	4190	48.6
6.4 - 7.2	Tailings/Soil	2.8	164	1.04	<0.05	13.1	0.365	0.67	2.6	114	3.2	15.5	903	57
Detection Limits		0.2	0.20	0.05	0.05	0.20	0.01	0.02	0.10	1.00	0.10	0.10	2.00	0.50

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Table 5: Results of Pore water analysis for Faro Tailings Samples, Dec, 2005

Parameter	Units	Method	NA-05-2 8.7-8.8	NA-05-7 2.0-2.2	NA-05-8 7.5-8.0	NA-05-10 11.8-12.0
<b>Dissolved Metals</b>						
Ag Silver	mg/L	ICP-OES	<0.01	<0.5	<0.15	<0.5
Al Aluminium	mg/L	ICP-OES	0.77	28.1	0.84	<2.
As Arsenic	mg/L	ICP-OES	<0.05	<2.	<0.6	<2.
B Boron	mg/L	ICP-OES	1.08	5.6	<3	<5.
Ba Barium	mg/L	ICP-OES	0.01	1.01	0.28	0.49
Be Beryllium	mg/L	ICP-OES	<0.002	<0.1	<0.03	<0.1
Bi Bismuth	mg/L	ICP-OES	<0.1	<5.	<1.5	<5.
Ca Calcium	mg/L	ICP-OES	405	550	141	503
Cd Cadmium	mg/L	ICP-OES	<0.002	0.45	<0.03	<0.1
Co Cobalt	mg/L	ICP-OES	<0.01	<0.5	<0.15	<0.5
Cr Chromium	mg/L	ICP-OES	<0.01	<0.5	<0.15	<0.5
Cu Copper	mg/L	ICP-OES	<0.02	<1.	<0.3	<1.
Fe Iron	mg/L	ICP-OES	1683	44400	15.3	24800
K Potassium	mg/L	ICP-OES	58.1	<5.	13.7	<5.
Li Lithium	mg/L	ICP-OES	0.20	<1.	<0.3	1.6
Mg Magnesium	mg/L	ICP-OES	1263	675	17.3	963
Mn Manganese	mg/L	ICP-OES	249	533	4.90	444
Mo Molybdenum	mg/L	ICP-OES	<0.02	<1.	<0.3	<1.
Na Sodium	mg/L	ICP-OES	57.0	18.9	198	54.7
Ni Nickel	mg/L	ICP-OES	0.21	3.89	<0.15	<0.5
P Phosphorus	mg/L	ICP-OES	<0.07	<3.	<0.9	<3.
Pb Lead	mg/L	ICP-OES	2.71	9.4	<0.6	<2.
S Sulfur	mg/L	ICP-OES	3370	28628	216	19410
S-Sulphate	mg/L	calculated	10111	85883	647	58230
Sb Antimony	mg/L	ICP-OES	<0.05	<2.	<0.6	<2.
Se Selenium	mg/L	ICP-OES	<0.05	<2.	<0.6	<2.
Si Silicon	mg/L	ICP-OES	5.37	19.3	7.56	10.4
Sn Tin	mg/L	ICP-OES	0.07	<2.	<0.6	<2.
Sr Strontium	mg/L	ICP-OES	0.14	0.34	0.38	0.46
Ti Titanium	mg/L	ICP-OES	<0.02	<1.	<0.3	<1.
Tl Thallium	mg/L	ICP-OES	<0.05	<2.	<0.6	<2.
U Uranium	mg/L	ICP-OES	<1	183	<15	99
V Vanadium	mg/L	ICP-OES	0.26	5	<0.3	2
Zn Zinc	mg/L	ICP-OES	127	5628	2.94	6815
Water volume	mL		4.2	11.5	0.33	11.0

tailings samples

natural ground sample



**Table 4: Results of BCMEM Shakeflask for Faro Tailings Samples**

Key			Background Samples			Natural ground samples			Tailings samples				
Parameter	Units	Method	NA-05-1 0.1 - 0.6	NA-05-1 0.6 - 3.2	NA-05-1 3.6 - 4.3	NA-05-2 8.7-8.8	NA-05-2 8.8-13.3	NA-05-3 6.4-6.6	NA-05-3 6.6-6.63	NA-05-3 6.63-7.35	NA-05-4A 5.85 - 5.95	NA-05-5 8.9 - 9.0	NA-05-5 9.0 - 9.1
pH		meter	6.40	7.24	7.55	4.81	4.71	3.46	4.29	4.99	3.35	2.99	3.62
EC	umhos/cm	meter	29	125	68	946	296	1570	1351	698	2250	5390	3210
ORP	mV	meter	155	165	150	215	280	440	280	395	385	395	335
Sulphate	mg/L	Auto Turbidity	3	35	2	492	110	785	698	307	737	3630	2315
Acidity to 4.5	mg/L	titration	N/A	N/A	N/A	N/A	N/A	24	4.5	N/A	45	384	79
Acidity to 8.3	mg/L	titration	3	1	1	172	10	362	116	184	215	2758	1660
Alkalinity	mg/L	colorimetry	8	21	32	5	1	N/A	N/A	<1	N/A	N/A	N/A
<b>Dissolved Metals</b>													
Ag Silver	mg/L	ICP-OES	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	<0.025
Al Aluminium	mg/L	ICP-OES	0.42	0.08	0.21	<0.02	0.04	3.00	2.65	5.23	0.1	69.6	36.5
As Arsenic	mg/L	ICP-OES	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	<0.2	<0.1
B Boron	mg/L	ICP-OES	<0.05	<0.05	<0.05	<0.05	<0.05	0.1	15.6	0.23	<0.25	<0.5	<0.25
Ba Barium	mg/L	ICP-OES	0.010	0.042	0.033	0.016	0.040	0.020	0.033	0.032	0.05	0.01	0.02
Be Beryllium	mg/L	ICP-OES	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.001	0.003	<0.005	0.02	0.01
Bi Bismuth	mg/L	ICP-OES	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.5	<0.25
Ca Calcium	mg/L	ICP-OES	2.21	15.0	13.8	41.2	25.1	123	79.3	44.7	325	190	150
Cd Cadmium	mg/L	ICP-OES	<0.001	<0.001	<0.001	<0.001	0.001	0.027	0.005	0.010	<0.005	0.17	0.04
Co Cobalt	mg/L	ICP-OES	<0.005	<0.005	<0.005	<0.005	0.031	0.069	0.033	0.053	<0.025	0.16	0.25
Cr Chromium	mg/L	ICP-OES	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	<0.025
Cu Copper	mg/L	ICP-OES	<0.01	<0.01	<0.01	<0.01	0.02	0.23	0.02	0.15	<0.05	<0.1	0.10
Fe Iron	mg/L	ICP-OES	0.58	0.43	0.23	75.9	0.38	25.1	0.18	0.24	68.9	1036	528
K Potassium	mg/L	ICP-OES	1.34	3.07	2.04	3.79	3.62	2.36	26.0	11.9	9.88	0.6	<0.25
Li Lithium	mg/L	ICP-OES	<0.01	<0.01	<0.01	0.0	<0.01	0.12	0.31	0.1	<0.05	0.2	0.1
Mg Magnesium	mg/L	ICP-OES	0.38	1.82	1.20	56.4	6.81	42	42.3	19.7	70.8	173	97.7
Mn Manganese	mg/L	ICP-OES	0.022	0.059	0.005	14.5	2.77	25	28.0	10.6	7.54	80.3	51.1
Mo Molybdenum	mg/L	ICP-OES	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.1	<0.05
Na Sodium	mg/L	ICP-OES	1.71	3.01	1.08	2.38	3.53	5.0	42.7	6.20	14.1	4.4	4.5
Ni Nickel	mg/L	ICP-OES	<0.005	<0.005	<0.005	0.01	0.036	0.106	0.046	0.09	0.04	0.68	0.37
P Phosphorus	mg/L	ICP-OES	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.15	<0.3	<0.15
Pb Lead	mg/L	ICP-OES	<0.02	<0.02	<0.02	0.24	0.06	1.54	0.07	0.11	<0.1	1.5	<0.1
S Sulfur	mg/L	ICP-OES	1.24	11.6	1.16	163	37.2	263	232	104	413	1461	721
Sb Antimony	mg/L	ICP-OES	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	<0.2	<0.1
Se Selenium	mg/L	ICP-OES	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	<0.2	<0.1
Si Silicon	mg/L	ICP-OES	4.52	2.30	3.67	1.76	4.19	19.8	43.8	21.0	5.26	18.6	12.5
Sn Tin	mg/L	ICP-OES	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.1	<0.2	<0.1
Sr Strontium	mg/L	ICP-OES	0.010	0.055	0.040	0.08	0.14	0.270	0.273	0.22	0.63	0.28	0.27
Ti Titanium	mg/L	ICP-OES	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.1	<0.05
Tl Thallium	mg/L	ICP-OES	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	<0.2	<0.1
U Uranium	mg/L	ICP-OES	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2.5	<5.	<2.5
V Vanadium	mg/L	ICP-OES	<0.01	<0.01	<0.01	0.03	<0.01	0.02	0.02	0.01	<0.05	<0.1	<0.05
Zn Zinc	mg/L	ICP-OES	0.008	0.166	0.012	7.04	2	136	66.8	30	12.8	813	209
Sample wt.	g		250	250	250	250	250	250	40*	125	250	125	250
Water volume	mL		750	750	750	750	750	750	120	375	750	375	750

Table 4: Results of BCMEM Shakeflask for  
Key

Parameter	Units	Method	NA-05-6 6.7 - 7.3	NA-05-6 7.3-7.8	NA-05-6 8.6 - 8.9	NA-05-7 2.0-2.2	NA-05-7 2.2-2.4	NA-05-7 2.4-2.6	NA-05-8 6.6-6.7	NA-05-8 6.7 - 7.4	NA-05-8 7.4-8.8	NA-05-9 4.9-5.2	NA-05-10 11.8-12.0	NA-05-10 13.2-13.4
pH		meter	3.60	2.91	3.48	3.48	3.12	3.25	6.36	5.72	7.40	4.04	3.64	6.51
EC	umhos/cm	meter	1765	4340	2980	5640	11900	8820	538	873	356	2870	3250	304
ORP	mV	meter	345	560	340	310	340	330	210	230	175	250	295	185
Sulphate	mg/L	Auto Turbidity	983	3382	2183	5080	11424	7752	184	332	78	2284	2088	135
Acidity to 4.5	mg/L	titration	237	787	78	44	300	175	N/A	N/A	N/A	35	15	N/A
Acidity to 8.3	mg/L	titration	883	2362	983	3436	10075	6750	25	26	10	1550	2205	65
Alkalinity	mg/L	colorimetry	N/A	N/A	N/A	N/A	N/A	N/A	17	8	67	N/A	N/A	4
<b>Dissolved Metals</b>														
Ag Silver	mg/L	ICP-OES	<0.025	<0.025	<0.05	<0.025	<0.025	<0.025	<0.005	<0.005	<0.005	<0.025	<0.025	<0.005
Al Aluminium	mg/L	ICP-OES	67.1	169	22.3	<0.1	6.13	14.48	<0.02	0.11	0.38	<0.1	0.22	<0.02
As Arsenic	mg/L	ICP-OES	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02
B Boron	mg/L	ICP-OES	<0.25	<0.25	<0.5	0.30	0.89	0.99	<0.05	<0.05	0.08	<0.25	<0.25	<0.05
Ba Barium	mg/L	ICP-OES	0.02	0.021	0.03	<0.005	<0.005	<0.005	0.048	0.05	0.089	0.005	<0.005	0.073
Be Beryllium	mg/L	ICP-OES	0.01	0.033	0.01	<0.005	<0.005	<0.005	<0.001	<0.001	<0.001	<0.005	<0.005	<0.001
Bi Bismuth	mg/L	ICP-OES	<0.25	<0.25	<0.5	<0.25	0.269	<0.25	<0.05	<0.05	<0.05	<0.25	<0.25	<0.05
Ca Calcium	mg/L	ICP-OES	49.3	417	324	483	475	458.5	33.44	94.4	29.6	56.4	65.5	25.8
Cd Cadmium	mg/L	ICP-OES	0.03	0.072	0.01	<0.005	<0.005	0.036	0.016	0.02	<0.001	0.021	<0.005	<0.001
Co Cobalt	mg/L	ICP-OES	0.11	0.524	0.15	<0.025	<0.025	<0.025	0.009	0.04	<0.005	<0.025	<0.025	0.007
Cr Chromium	mg/L	ICP-OES	<0.025	0.063	<0.05	<0.025	<0.025	<0.025	<0.005	<0.005	<0.005	<0.025	<0.025	<0.005
Cu Copper	mg/L	ICP-OES	0.39	0.82	0.10	<0.05	<0.05	<0.05	<0.01	0.02	<0.01	<0.05	<0.05	<0.01
Fe Iron	mg/L	ICP-OES	162	215	448	1827	6283	4407	1.21	1.38	0.59	830	936	0.36
K Potassium	mg/L	ICP-OES	4.4	0.97	3.3	2.88	5.36	5.82	5.78	10.5	4.96	6.83	4.35	7.44
Li Lithium	mg/L	ICP-OES	0.2	0.15	<0.1	<0.05	<0.05	<0.05	0.01	0.0	<0.01	0.07	0.06	0.03
Mg Magnesium	mg/L	ICP-OES	46.7	110	85.0	29.1	113	100	14.0	8.28	3.49	79.1	47.3	10.9
Mn Manganese	mg/L	ICP-OES	17.2	47	28.5	32.1	65.4	55.9	6.66	4.6	0.98	42.0	29.3	1.22
Mo Molybdenum	mg/L	ICP-OES	<0.05	<0.05	<0.1	<0.05	<0.05	<0.05	<0.01	<0.01	<0.01	<0.05	<0.05	<0.01
Na Sodium	mg/L	ICP-OES	3.3	5.4	6.5	1.2	5.36	10.50	32.9	46.4	28.7	3.5	2.44	5.95
Ni Nickel	mg/L	ICP-OES	0.18	0.619	0.35	0.158	0.234	0.12	0.014	0.04	<0.005	0.088	0.04	<0.005
P Phosphorus	mg/L	ICP-OES	<0.15	<0.15	<0.3	<0.15	<0.15	<0.15	<0.03	<0.03	<0.03	<0.15	<0.15	<0.03
Pb Lead	mg/L	ICP-OES	<0.1	0.10	<0.2	<0.1	2.48	2.94	3.81	0.75	<0.02	2.57	2.94	<0.02
S Sulfur	mg/L	ICP-OES	379	1035	668	1607	3825	2784	104	130	33.0	725	818	45.4
Sb Antimony	mg/L	ICP-OES	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02
Se Selenium	mg/L	ICP-OES	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02
Si Silicon	mg/L	ICP-OES	26.2	43.2	24.3	3.85	5.46	9.87	5.11	7.14	5.90	4.29	3.01	2.71
Sn Tin	mg/L	ICP-OES	<0.1	0.16	<0.2	0.14	0.13	0.16	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02
Sr Strontium	mg/L	ICP-OES	0.14	1.049	1.04	0.237	0.58	0.853	0.119	0.317	0.093	0.034	0.052	0.053
Ti Titanium	mg/L	ICP-OES	<0.05	<0.05	<0.1	<0.05	<0.05	<0.05	<0.01	<0.01	0.01	<0.05	<0.05	<0.01
Tl Thallium	mg/L	ICP-OES	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02
U Uranium	mg/L	ICP-OES	<2.5	<2.5	<5	<10	<30	<20	<0.5	<0.5	<0.5	<5	<4	<0.5
V Vanadium	mg/L	ICP-OES	<0.05	0.08	<0.1	0.21	0.52	0.38	<0.01	<0.01	<0.01	0.10	0.10	<0.01
Zn Zinc	mg/L	ICP-OES	128	176	1.45	309	980	564	8.20	9.99	0.013	166	325	0.566
Sample wt.	g		250	250	250	250	150*	150*	250	250	250	250	250	250
Water volume	mL		750	750	750	750	450	450	750	750	750	750	750	750

**Table 4: Results of BCMEM Shakeflask for**  
Key

Parameter	Units	Method	NA-05-12 5.9 - 6.0	NA-05-12 6.4 - 7.2
pH		meter	3.55	3.87
EC	umhos/cm	meter	10220	5060
ORP	mV	meter	320	260
Sulphate	mg/L	Auto Turbidity	8596	4426
Acidity to 4.5	mg/L	titration	52	28
Acidity to 8.3	mg/L	titration	9850	3025
Alkalinity	mg/L	colorimetry	N/A	N/A
<b>Dissolved Metals</b>				
Ag Silver	mg/L	ICP-OES	<0.05	<0.05
Al Aluminium	mg/L	ICP-OES	20.2	7.5
As Arsenic	mg/L	ICP-OES	<0.2	<0.2
B Boron	mg/L	ICP-OES	0.9	<0.5
Ba Barium	mg/L	ICP-OES	<0.01	0.02
Be Beryllium	mg/L	ICP-OES	<0.01	<0.01
Bi Bismuth	mg/L	ICP-OES	<0.5	<0.5
Ca Calcium	mg/L	ICP-OES	241	298
Cd Cadmium	mg/L	ICP-OES	<0.01	0.02
Co Cobalt	mg/L	ICP-OES	0.07	0.24
Cr Chromium	mg/L	ICP-OES	<0.05	<0.05
Cu Copper	mg/L	ICP-OES	<0.1	<0.1
Fe Iron	mg/L	ICP-OES	4247	1675
K Potassium	mg/L	ICP-OES	0.7	3.5
Li Lithium	mg/L	ICP-OES	<0.1	0.1
Mg Magnesium	mg/L	ICP-OES	106	93.6
Mn Manganese	mg/L	ICP-OES	43.7	28.6
Mo Molybdenum	mg/L	ICP-OES	<0.1	<0.1
Na Sodium	mg/L	ICP-OES	4.6	16.1
Ni Nickel	mg/L	ICP-OES	0.25	0.41
P Phosphorus	mg/L	ICP-OES	<0.3	<0.3
Pb Lead	mg/L	ICP-OES	2.5	<0.2
S Sulfur	mg/L	ICP-OES	3396	1365
Sb Antimony	mg/L	ICP-OES	<0.2	<0.2
Se Selenium	mg/L	ICP-OES	<0.2	<0.2
Si Silicon	mg/L	ICP-OES	9.2	13.9
Sn Tin	mg/L	ICP-OES	<0.2	<0.2
Sr Strontium	mg/L	ICP-OES	0.09	0.77
Ti Titanium	mg/L	ICP-OES	<0.1	<0.1
Tl Thallium	mg/L	ICP-OES	<0.2	<0.2
U Uranium	mg/L	ICP-OES	18	7
V Vanadium	mg/L	ICP-OES	<0.1	<0.1
Zn Zinc	mg/L	ICP-OES	1231	156
Sample wt.	g		250	250
Water volume	mL		750	750

**Appendix D**  
**Mineralogical Assessment**



# **MINERALOGICAL EXAMINATION FOR Zn ATTENUATION IN SONIC DRILL SAMPLES, FARO MINE, YUKON**

Prepared for: **SRK Consulting**  
Vancouver, B.C.

**February 2006**



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## EXECUTIVE SUMMARY

Eight samples of sediments recovered by sonic drilling near the tailings containment facility at the Faro mine, Yukon, were examined by optical and scanning electron microscopy to determine the manner in which the attenuation of dissolved Zn is occurring at the site. Seven of the examined samples contain variable amounts of tailings sulfides, predominantly pyrite. The seven also contain small amounts of primary sphalerite, which is undoubtedly the source-mineral responsible for the dissolved Zn that occurs in the aqueous outflow at the drill site. No secondary sulfides, i.e., those that might form *in situ* in a reductive environment, and no well-defined particulate accumulations of secondary Fe oxyhydroxides were observed in the sediments. Oxidation of the tailings sulfide minerals, including pyrrhotite, is negligible, thus eliminating sulfide-associated Fe-oxyhydroxide rims and pseudomorphs as quantitatively significant potential sinks for Zn. Siliceous and carbonaceous organic particles are present in some of the samples, and are at their highest abundance in sample NA-05-07. The siliceous particles are Zn-free, but most of the carbonaceous organic matter is Zn-bearing. Sequestration of Zn by sorption to carbonaceous matter is concluded to be the principal Zn-attenuation mechanism. Sorption of Zn by particles of *in-situ* Fe oxyhydroxide has also occurred, but the overall amount of such sorption is limited by the sparseness of the oxyhydroxides. Electron-microprobe analysis to obtain the magnitude of the Zn incorporation in the carbonaceous material indicates that the content is up to about 0.6 wt% Zn.

## INTRODUCTION

Eight samples of soil-like material recovered by sonic drilling at the Faro mine, Yukon, were received by LRC in late November, 2005. The samples had been double-bagged and vacuum sealed under argon gas, primarily to prevent the oxidation of unstable ferrous iron minerals that might be present.

Previous geochemical studies of the drilled site had indicated that sulfate passes through the drilled assemblage into an underlying aquifer; however, unlike sulfate, dissolved Zn is attenuated either by a thin peat layer along the base of the tailings, or within the aquifer itself. The primary objective of the mineralogical examination was to determine the solid-phase sinks for Zn so that the attenuating mechanisms could be better understood.

## METHODS

The contents of the sample bags were megascopically examined, then were cut open and a large portion of each was removed and allowed to dry at ambient temperatures so that sections for optical microscopy could be prepared. The material was monitored in order to observe whether oxidation, as manifested by ochreous discoloration, or the formation of precipitates was occurring during the drying stage. Two of the dried samples were screened, and all others were partly hand-picked prior to the submission for optical sections. The hand-picking involved only the removal of relatively large pebbles; details for each sample are given farther below. The material selected for mineralogical examination was submitted to Vancouver Petrographics Ltd for the preparation of standard  $26 \times 46$  mm polished thin-sections mounted on glass slides. To minimize the dissolution of soluble minerals that might be present, it was specified that no water be used for lubrication during section preparation. The sections were received by LRC on December 14, 2005.

The optical sections were examined microscopically in transmitted and reflected light. Areas selected for subsequent examination were marked on the surface of the polished thin-sections, and photomicrographs were taken to provide the general coordinates of the area and to speed the subsequent location of the specific grains to be examined by microbeam analysis. The scanning electron microscope (SEM) that was used is a Philips XL-30 instrument with a coupled

Princeton Gamma Tech energy-dispersion analyzer; energy-dispersion spectroscopic (EDS) analyses were obtained at 20 kV. The microprobe is a Cameca instrument with four spectrometers, and was operated in the wavelength-dispersion mode. Both microbeam units are housed in the Department of Earth and Ocean Sciences at the University of British Columbia, Vancouver.

## RESULTS OF OPTICAL MICROSCOPY

As was noted in the preceding section, the approach used in this study was to microscopically examine each polished thin-section, marking on it the locations of particles that might merit further examination by SEM. Grains of sphalerite are common in the samples, thus indicating the primary-mineral source of the dissolved Zn, but oxidation products associated with the sulfide minerals were observed to be rare. Examination of all of the particles of Fe oxyhydroxide and organic carbon that were observed in the sections is impractical, and such a procedure would be unnecessary if secondary sulfides or obvious accumulations of secondary Fe oxyhydroxides, i.e., those that might have formed *in situ*, had been encountered. However, no secondary sulfides and only rare particles of possibly secondary Fe oxyhydroxides were observed. The approach, therefore, was to assess each section in terms of its potential to sequester substantial amounts of the microscopically unrevealed secondary Zn, and to concentrate the SEM–EDS investigations on the sections that were deemed to have the highest potential. By default, the conclusion was that the sections richest in organic carbon have the best potential.

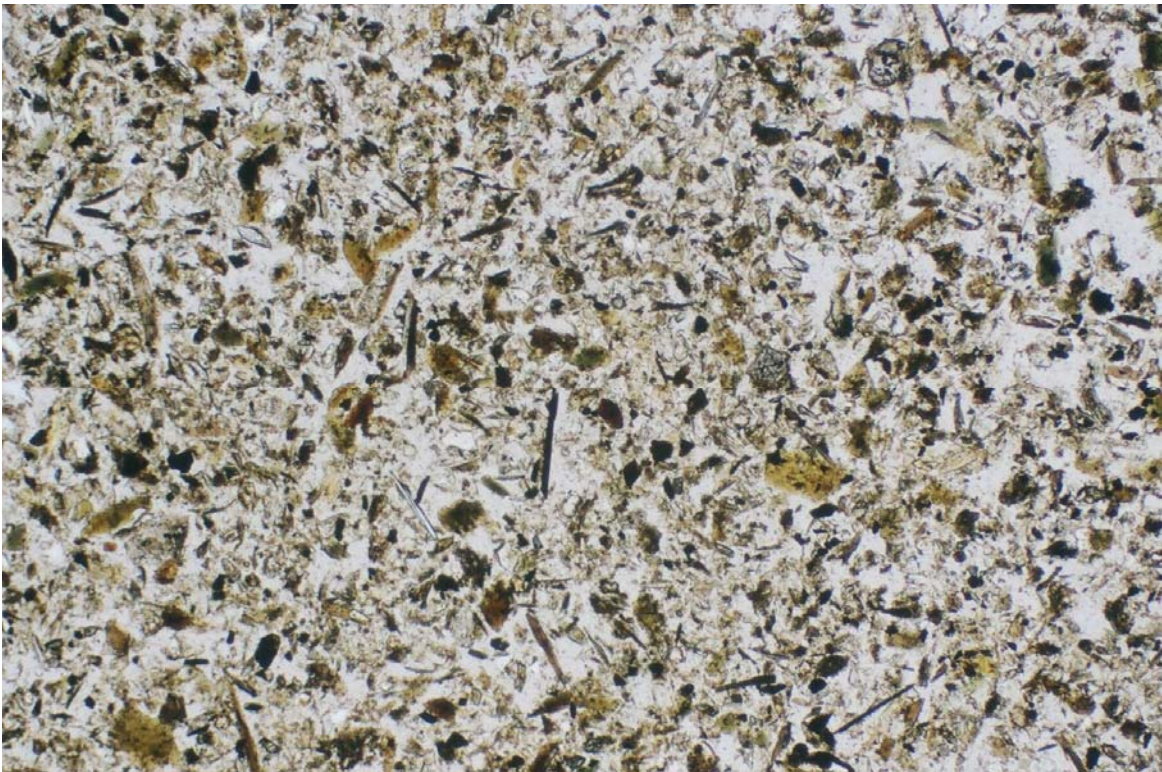
### ***Sample NA-05-02*** (8.8–13.3)

The as-received sample consisted largely of coarse grit, with a small amount (probably <1%) of mud-like material adhering to the inner surface of the plastic sample bag. The material was brownish, but not ochreous, and was unconsolidated. Pebbles within the grit are up to 1 × 1½ × 2 cm. It was concluded that secondary minerals, if present, would occur within the fines; consequently, the bulk sample was gently screened and the fraction passing 60 mesh (250 µm) was used for the preparation of the polished thin-section.

The optical section is megascopically slightly brownish and numerous sulfide grains are visible. Transmitted-light microscopy revealed that the assemblage consists largely of quartz, feldspars, and biotite, and that abundant biotite accounts for the brownish colour of the section (Fig. 1). Numerous other minerals, such as amphibole, muscovite, titanite, chlorite, rutile, and zircon occur sparingly, and only a trace amount of carbonate is present. SEM–EDS analysis of one of the carbonate grains (Fig. 2) indicated that it is siderite containing small amounts of Ca and Mg. The freshness of the biotite grains indicates that little if any AMD-related alteration has occurred, and particles of secondary-type Fe oxyhydroxides, or discoloration of the rims of silicate minerals by Fe oxyhydroxides, were not observed.

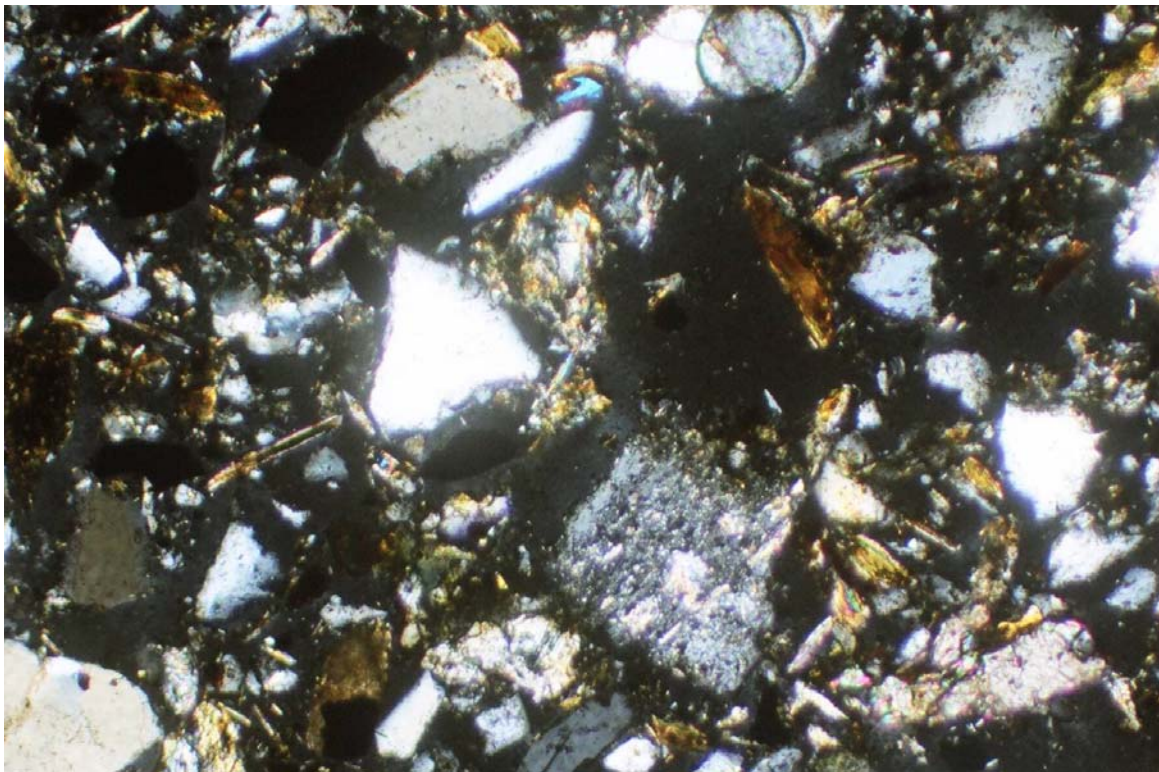
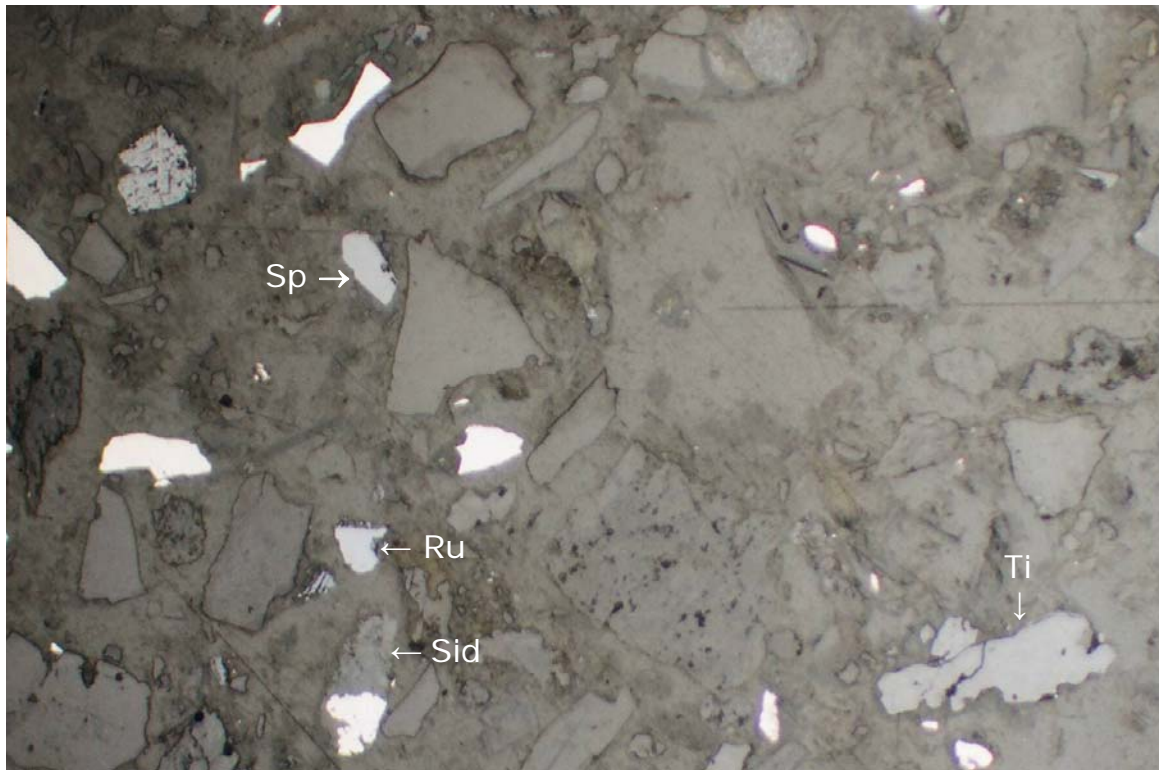
The principal sulfide mineral is pyrite, which occurs as liberated grains up to 100  $\mu\text{m}$  across and which shows no signs of oxidation. As an order of magnitude the total sulfide content was estimated to be about 0.7%, with pyrite making up >95% of the total. Others identified are sphalerite, marcasite, pyrrhotite, and chalcopyrite, among which sphalerite is the most abundant and chalcopyrite is the sparsest. SEM–EDS analysis indicated that the sphalerite has a low content of Fe.

Pyrrhotite is the sulfide mineral that is the most susceptible to oxidation, and the resulting rims or pseudomorphs of Fe oxyhydroxides commonly sequester heavy metals from the associated pore waters. However, all except one of the several grains of pyrrhotite observed in the sample are fresh, and the alteration rim on the exception is relatively thin (Fig. 3). SEM–EDS analysis of the rim did not detect the presence of Zn. The organic content of the sample is low, and the overall features suggested that the sample is not a priority candidate in terms of its potential for appreciable attenuation of dissolved Zn.

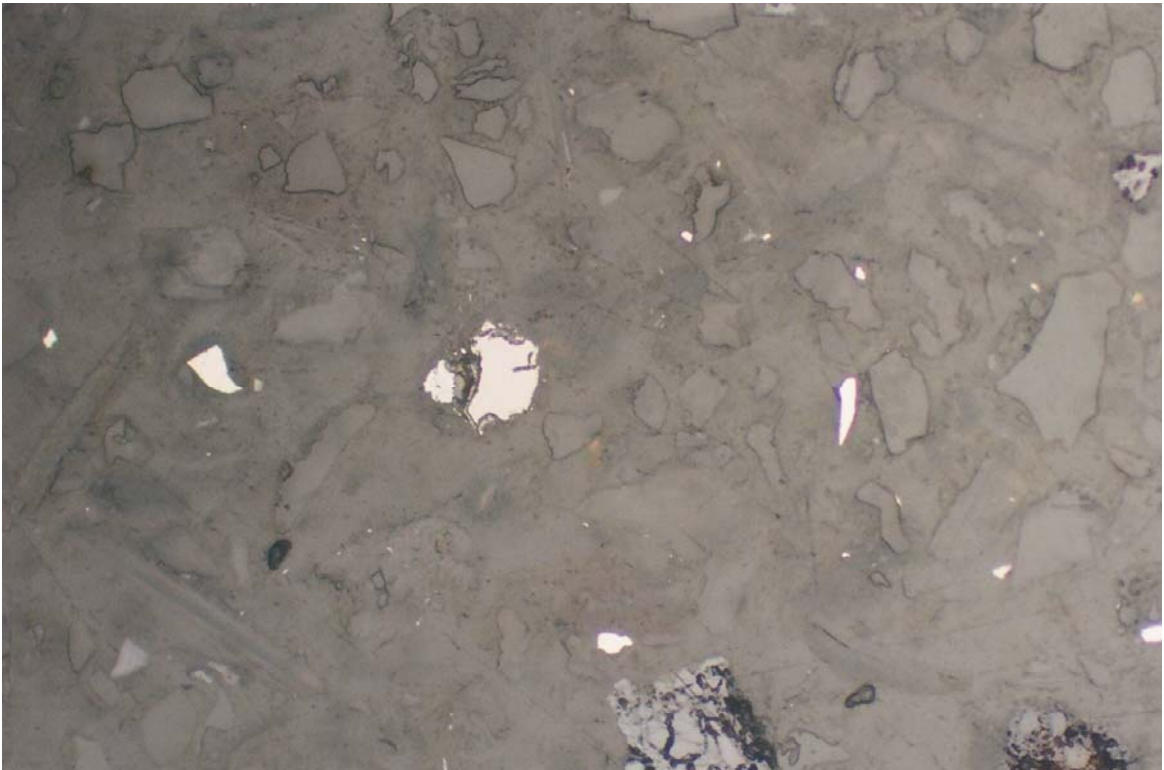


**Figure 1.** Overview of NA-05-02 in plain reflected light (top) and the same field in plain transmitted light (bottom), width of field 5.2 mm. The white grains in the upper photo are pyrite. The brownish and dark lath- or needle-like grains in the lower photo are biotite.





**Figure 2.** NA-05-02 in plain reflected light (top) and the same field in transmitted light with crossed polarizers (bottom), width of field 1.3 mm. The white grains in the upper photo are pyrite; labelled grains are **Ti** titanite, **Sid** siderite, **Ru** rutile, and **Sp** sphalerite. The white-to-grey rains in the lower photo are quartz and feldspar, and the brightly coloured shreds and laths are biotite.



**Figure 3.** NA-05-02 in plain reflected light, width of field 0.625 mm. The white grains are pyrite, and in the upper photo, above centre is a grey grain of unaltered sphalerite with associated chalcopyrite. At the centre of the lower photo is pyrrhotite that has a narrow rim of Fe oxyhydroxide.



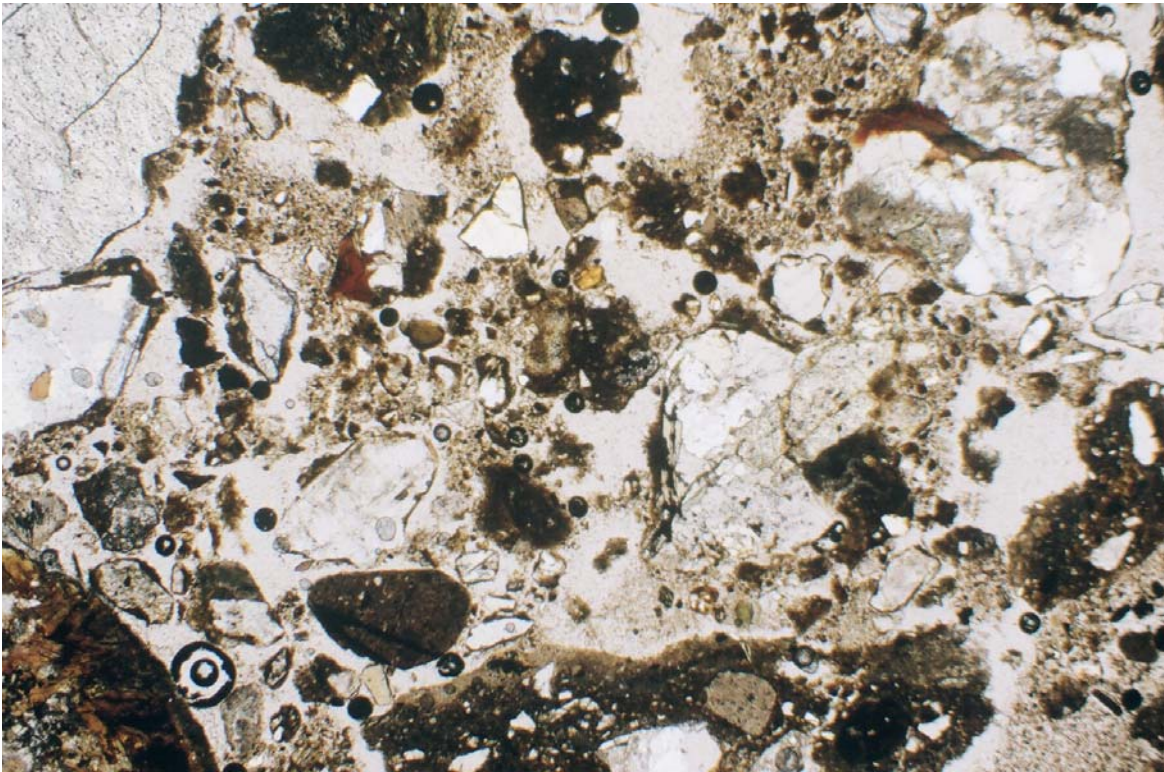
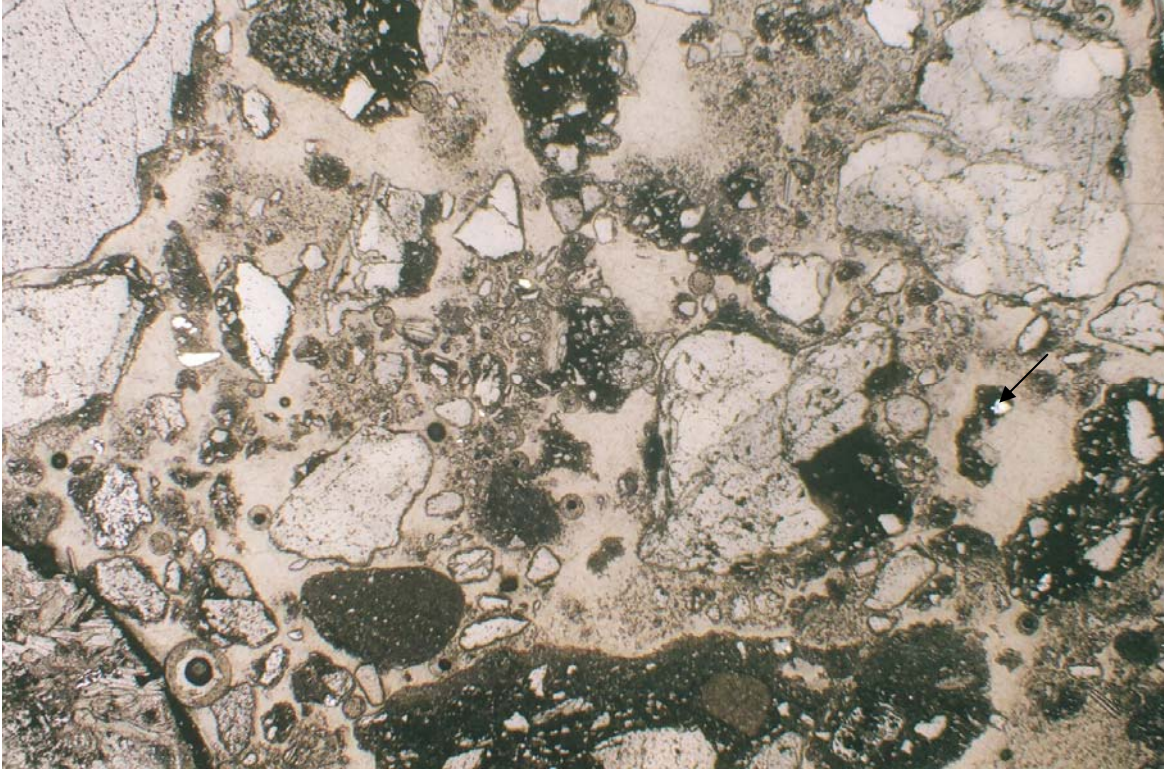
***Sample NA-05-3*** (6.6–6.63 m)

The as-received sample was dark brown and non-ochreous. A few pebbles, up to  $\frac{1}{2} \times 1 \times 1\frac{1}{2}$  cm, were noted to be present. These were removed by hand-picking, but no other treatment, such as screening, was done.

The polished thin-section megascopically shows the material to be poorly sorted, with angular particles up to 3 mm across and with disseminated sulfides occurring sparingly amidst the fines. Transmitted-light microscopy revealed that the larger particles are lithic and have diverse lithologies, but most are granitoid rocks. None of the rocks is calcareous, and no carbonate grains were observed among the fines.

All of the lithic particles are sulfide-barren, and the sulfide grains observed megascopically are indeed within the fines as liberated grains (Fig. 4). The largest grain is about 250  $\mu\text{m}$  across and is unaltered pyrite. Trace amounts of chalcopyrite and sphalerite occur as intergrowths with pyrite or attachments to it, but pyrite is predominant and the total sulfide content was estimated to be  $<0.1\%$ . Although nearly all of the pyrite is fresh, two grains have well-developed Fe-oxyhydroxide rims whose optical character is like that of goethite (Fig. 5). SEM–EDS examination of the rims showed that they are relatively pure Fe oxyhydroxide in which Zn is not detectable (Fig. 6).

Most of the Fe oxyhydroxide in the section occurs within the lithic particles. Such oxyhydroxide is quantitatively and kinetically considered to be an inferior candidate, relative to fresh precipitates, for the sorption of appreciable amounts of heavy metals; the sample was therefore rated accordingly. The high proportion of coarse lithic fragments in the sample suggests that, if further work is undertaken, it would be advantageous to screen the sample to obtain a concentrate of the fines.

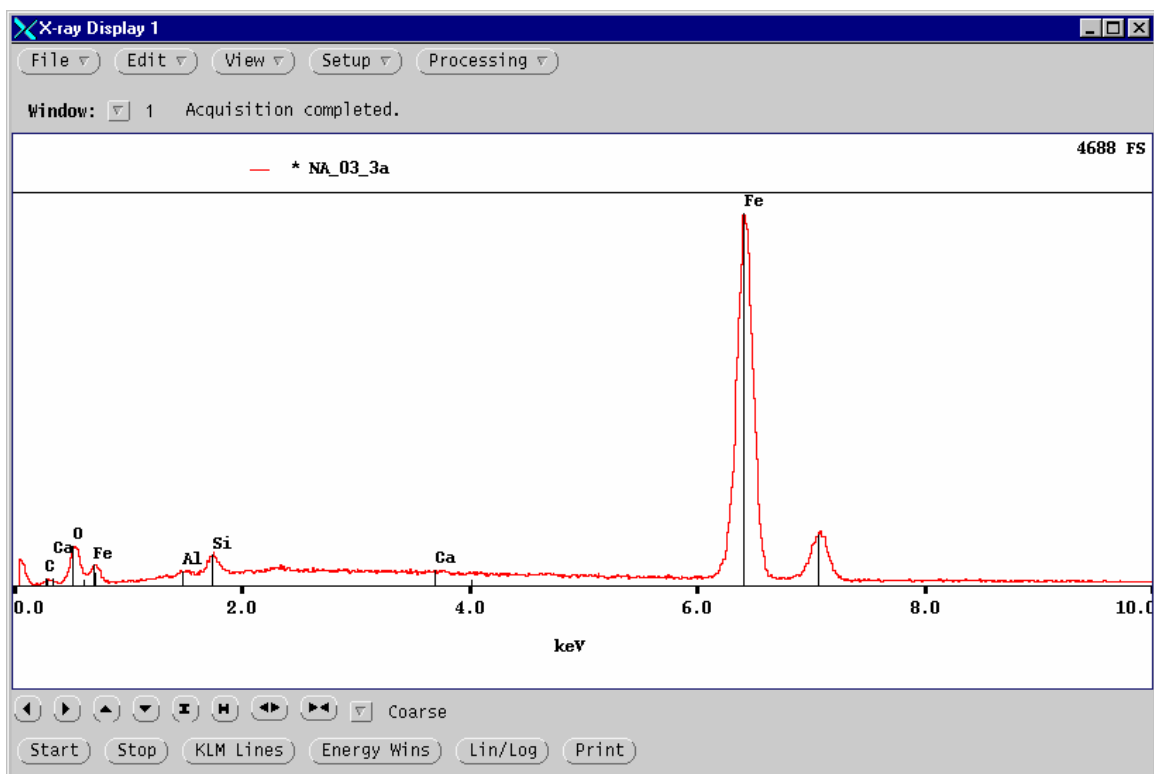


**Figure 4.** Overview of NA-05-03 in plain reflected light (top) and the same field in plain transmitted light (bottom), width of field 5.2 mm, showing the high proportion of lithic particles and the sparseness of sulfides (white grains). The arrow (upper photo, right) points to the pyrite of Figure 5 (upper photo). Much of the opacity is a polishing artifact, as is evident along the base of the lower photo.





**Figure 5.** The two oxidized pyrite grains observed in NA-05-03, shown in reflected light, width of field 0.625 mm. A core of residual pyrite is enclosed within goethite-like Fe oxyhydroxide. EDS spectra of the rims on both grains gave similar results (Fig. 6).



**Figure 6.** EDS spectrum of the Fe-oxyhydroxide rim shown in the lower photo of Figure 5. A similar spectrum was obtained for the rim in the upper photo.

***Sample NA-05-5 (9–9.1 m)***

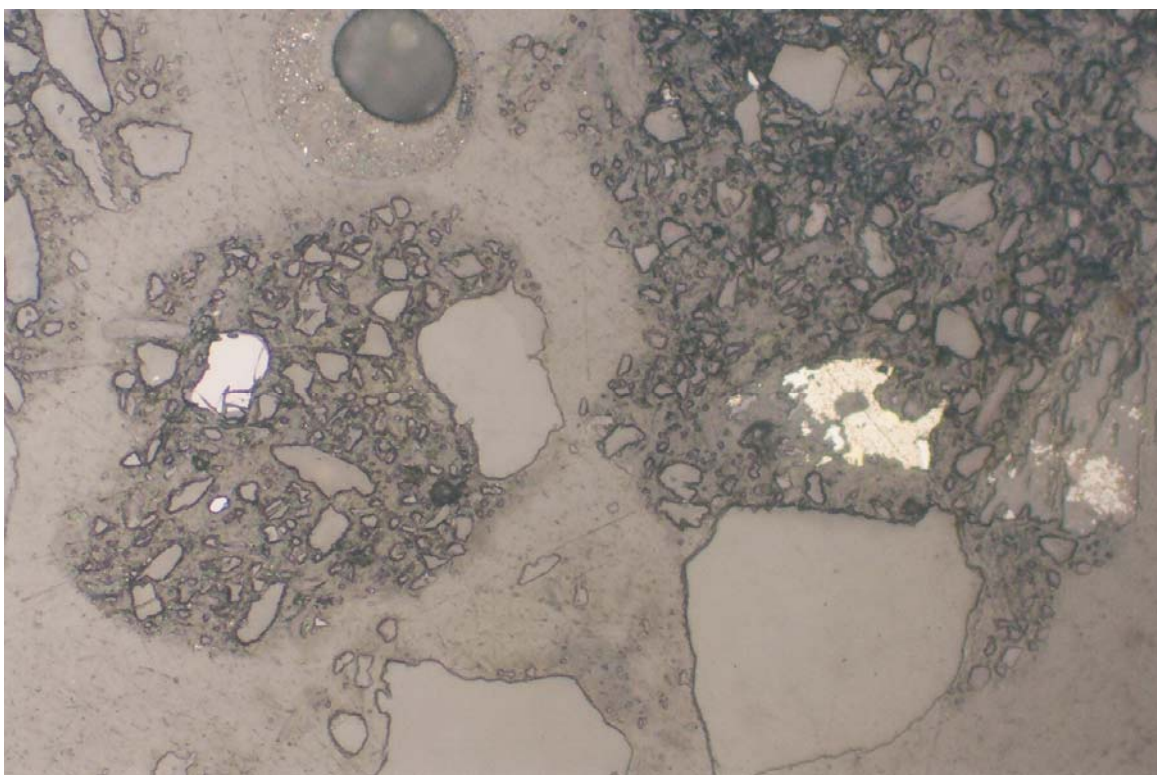
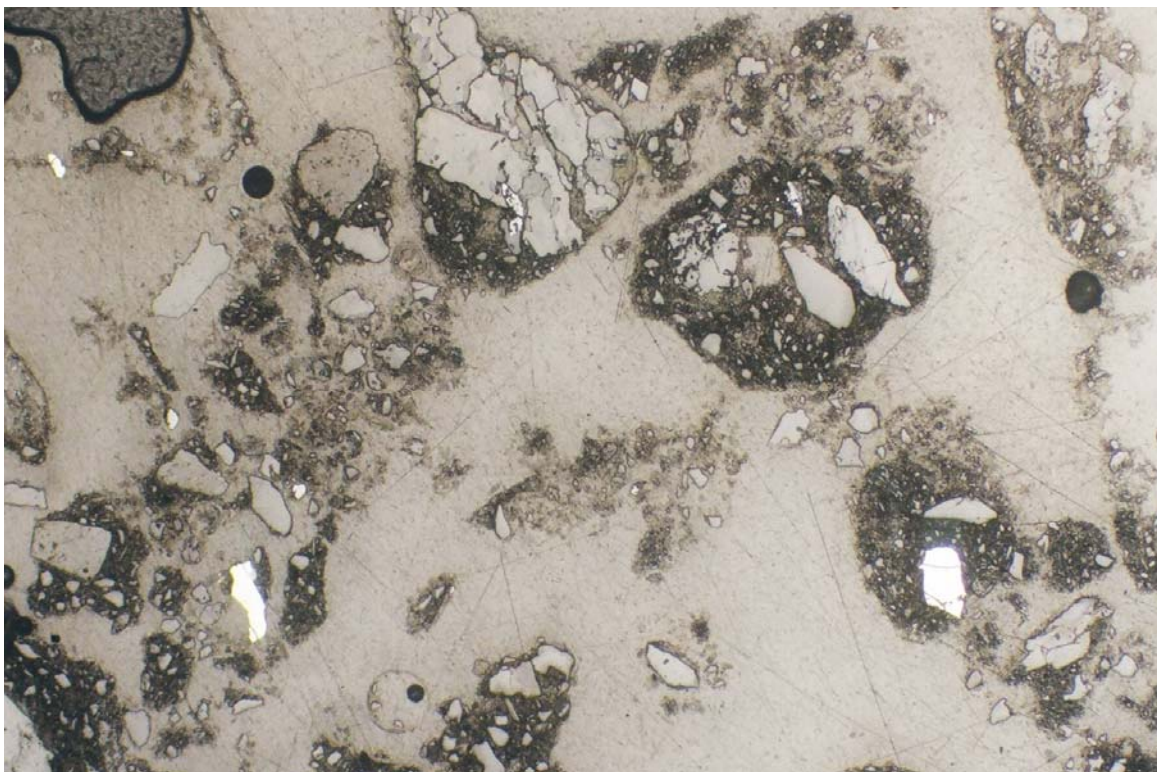
The as-received material was darker than NA-05-03 and minor, poorly cohesive aggregation was present. The larger clumps were disaggregated simply by applying finger pressure, and the largest rock particles, up to  $\frac{1}{2} \times 1 \times 1$  cm, were removed by hand-picking. No further treatment was done.

The polished thin-section shows that the sample is a coarse grit in which the largest particle is about  $2 \times 4$  mm. Microscopy with transmitted light revealed that the grit consists of diverse rock types that vary from shale and sandstone to granitoid rocks, including large particles of monomineralic quartz. Two of the lithic particles, both of which may be altered mafic extrusions, contain small amounts of sulfides; one of the particles contains a few grains of pyrrhotite and marcasite, the largest about  $45 \times 110$   $\mu\text{m}$ , and the other is host to a few grains of disseminated pyrite whose maximum size is only  $\sim 10$   $\mu\text{m}$ . None of the lithic-hosted sulfide grains is altered. No carbonates were observed in the section.

Within the fines, liberated angular grains of pyrite up to about 150  $\mu\text{m}$  in diameter are commonly observed but are quantitatively sparse. Marcasite, chalcopyrite, and sphalerite are also present, but only in trace amounts relative to pyrite. The marcasite, chalcopyrite, and sphalerite are closely associated with pyrite or attached to it (Fig. 7). The total sulfide-mineral content was estimated to be  $<0.1\%$ .

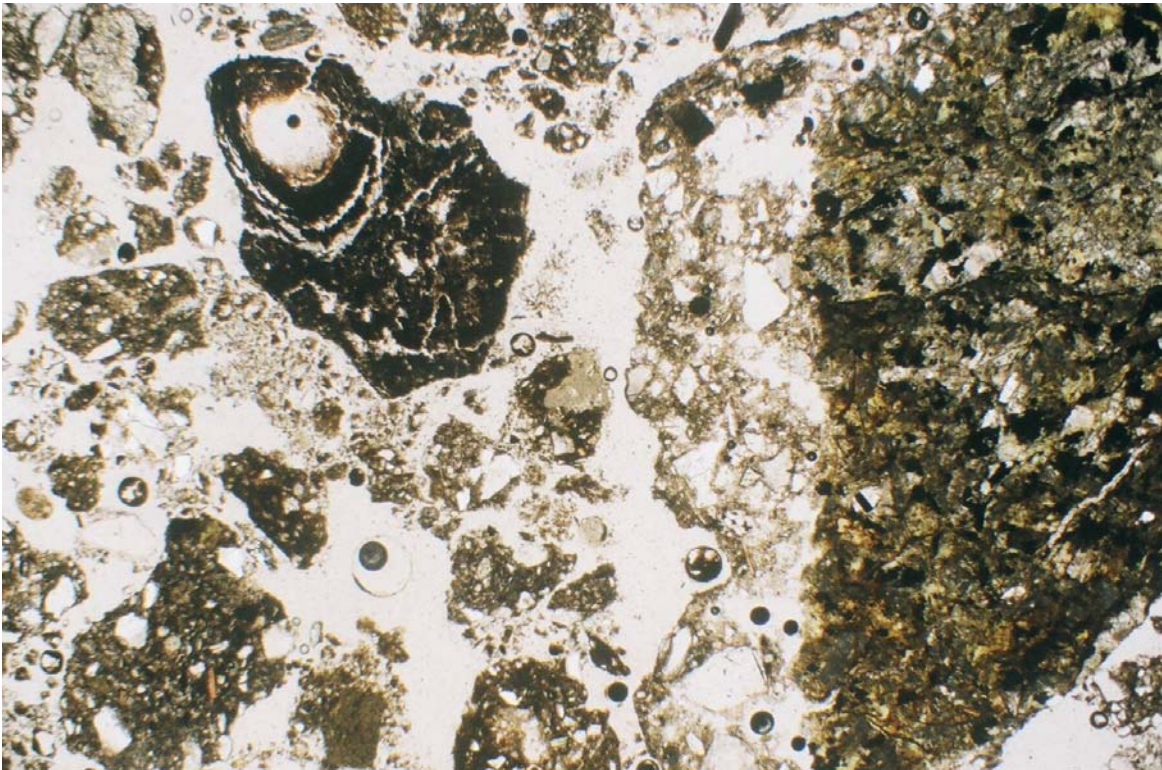
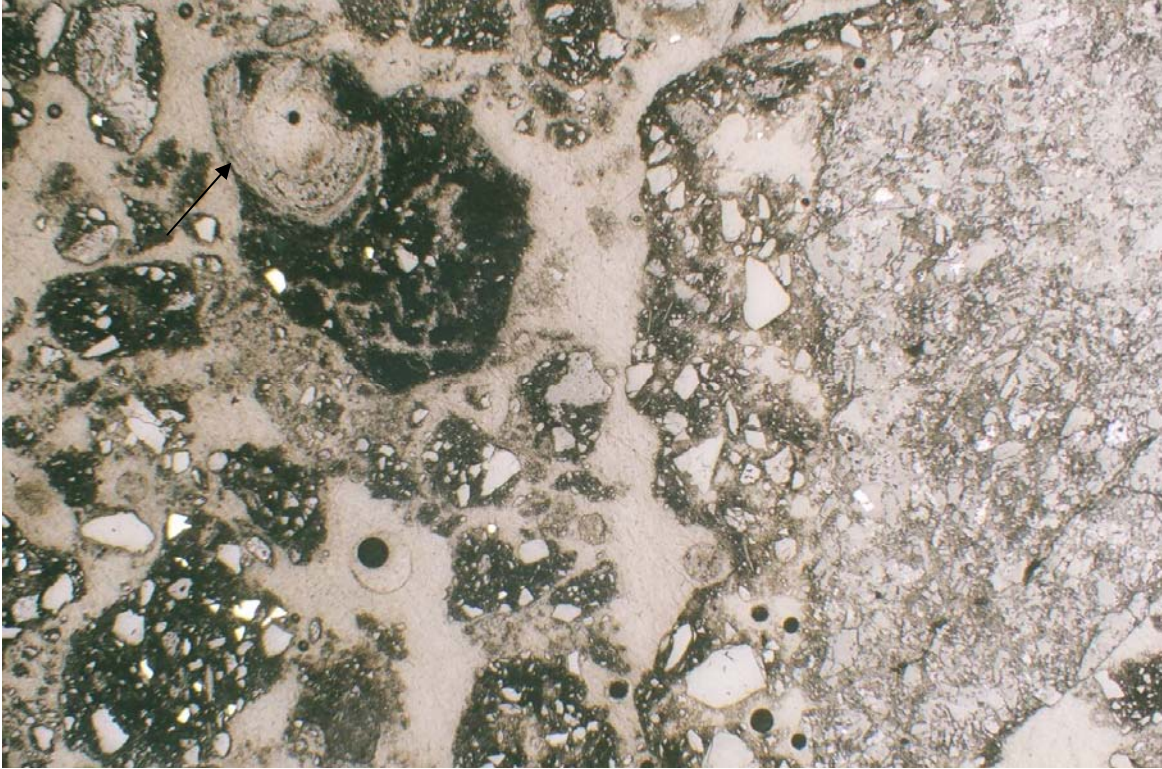
No indication of sulfide-mineral oxidation, deposition of secondary sulfides, or accumulation of Fe oxyhydroxides is evident. However, a few large carbonaceous particles of organic origin were observed. The particle illustrated in Figure 8 has a cellular structure that is annular and appears to be a cross-section of a twig. Another cellular structure is illustrated in Figure 9. EDS spectra of the twig-like body indicate that it is rich in Fe and S and contains detectable Zn that is highest in the outer rings (Fig. 10). The organic body shown in Figure 9 is likewise high in Fe and S, and also contains detectable Zn (Fig. 11). Thus, attenuation of dissolved Zn is occurring at this site, and the amount of attenuation would seem to be roughly proportional to the content of organic carbon.





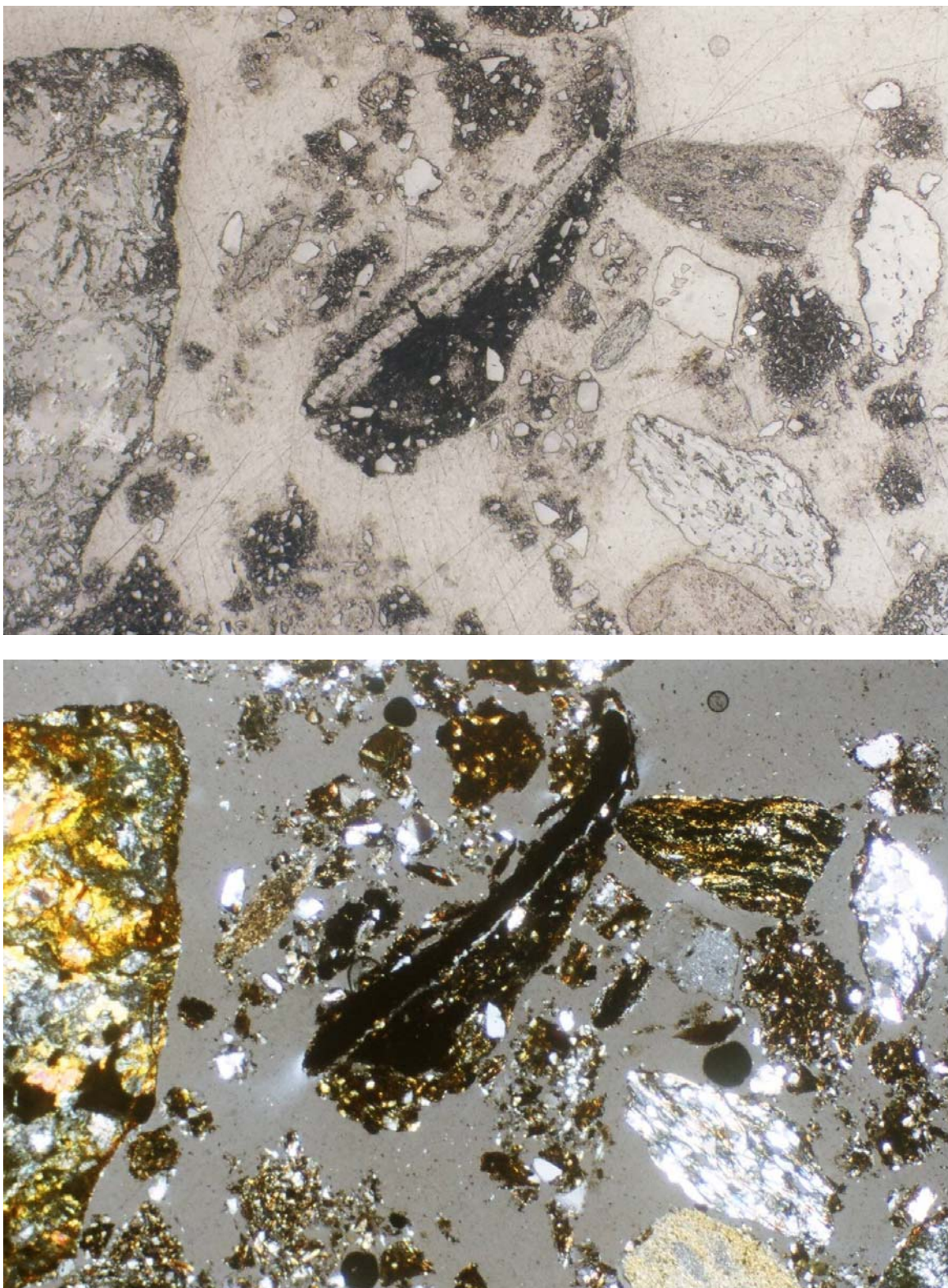
**Figure 7.** NA-05-05 (9-9.1) in plain reflected light. The upper photo (width of field 2.6 mm) shows the general character and two large grains of pyrite (white). A minute area of attached sphalerite is at the upper right of the pyrite grain on the left, and above the pyrite at mid-height are two light-grey, minute grains of ilmenite. The lower photo (width of field 0.625 mm) shows a large brownish grey grain of ilmenite on the left, and opposite on the right is roughly polished pyrite with peripheral, whiter grains of marcasite.





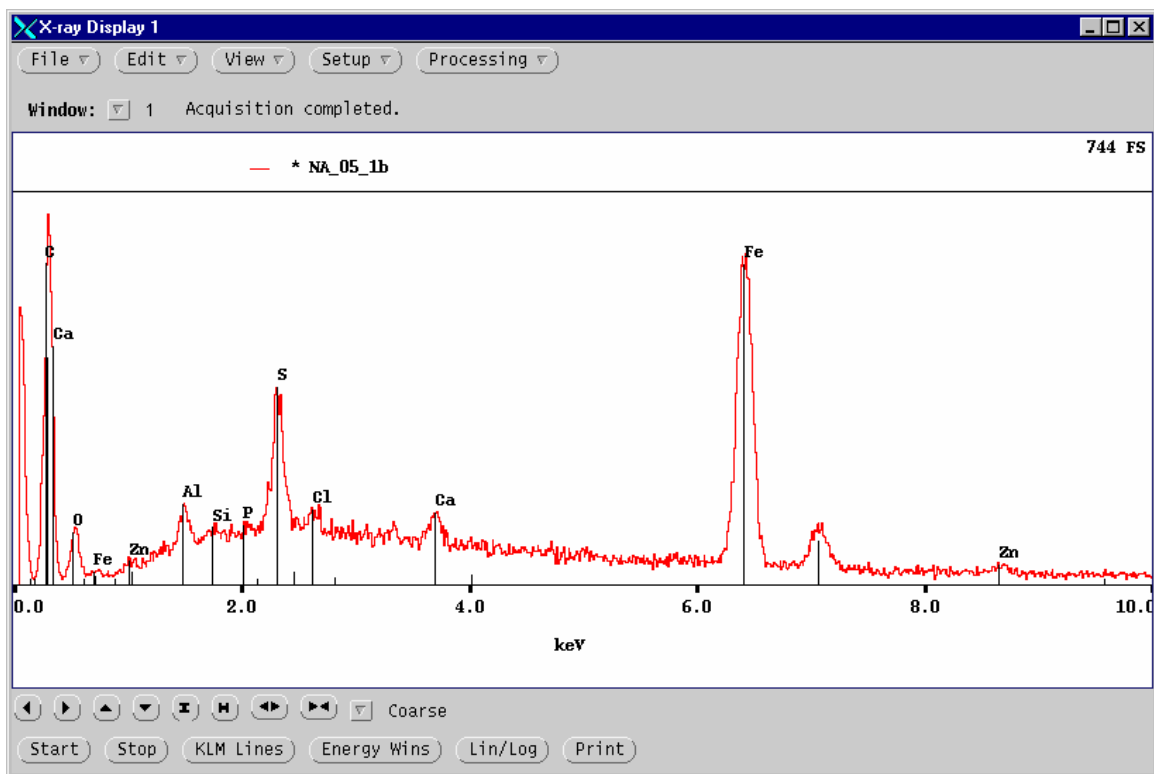
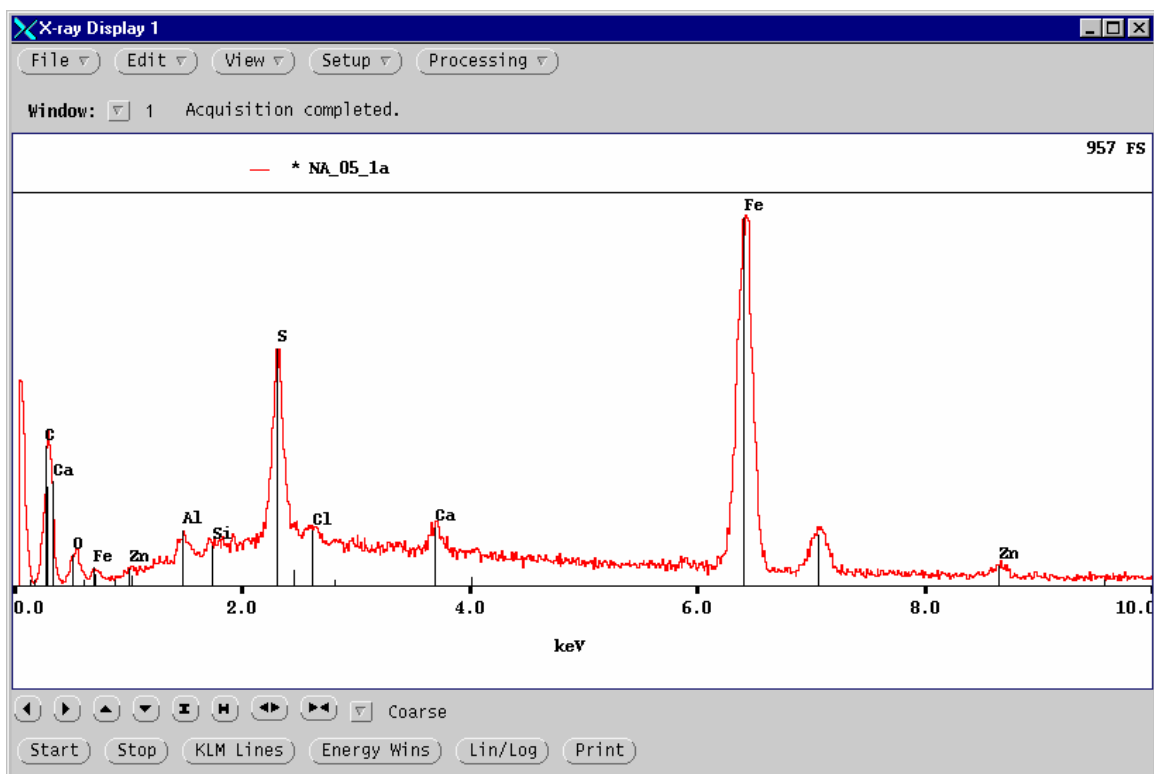
**Figure 8.** NA-05-05 (9–9.1) in plain reflected (top) and plain transmitted light (bottom), width of field 5.2 mm. The white grains are pyrite, and on the right is a large lithic particle. The arrow at the top left points to an annular particle of organic material for which EDS spectra are given in Figure 10.



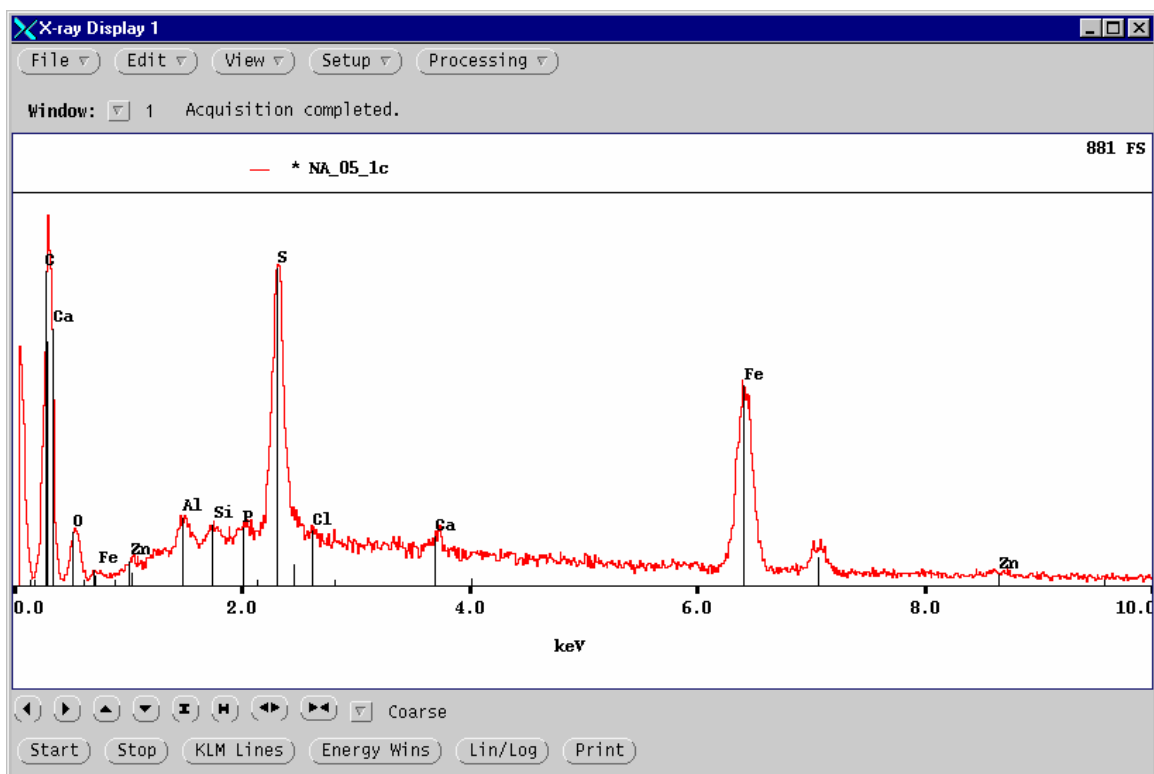


**Figure 9.** NA-05-05 (9-9.1) in plain reflected light (top) and in transmitted light with crossed polarizers (bottom), width of field 2.6 mm. At the centre is a cellular organic structure for which an EDS spectrum is given in Figure 11.

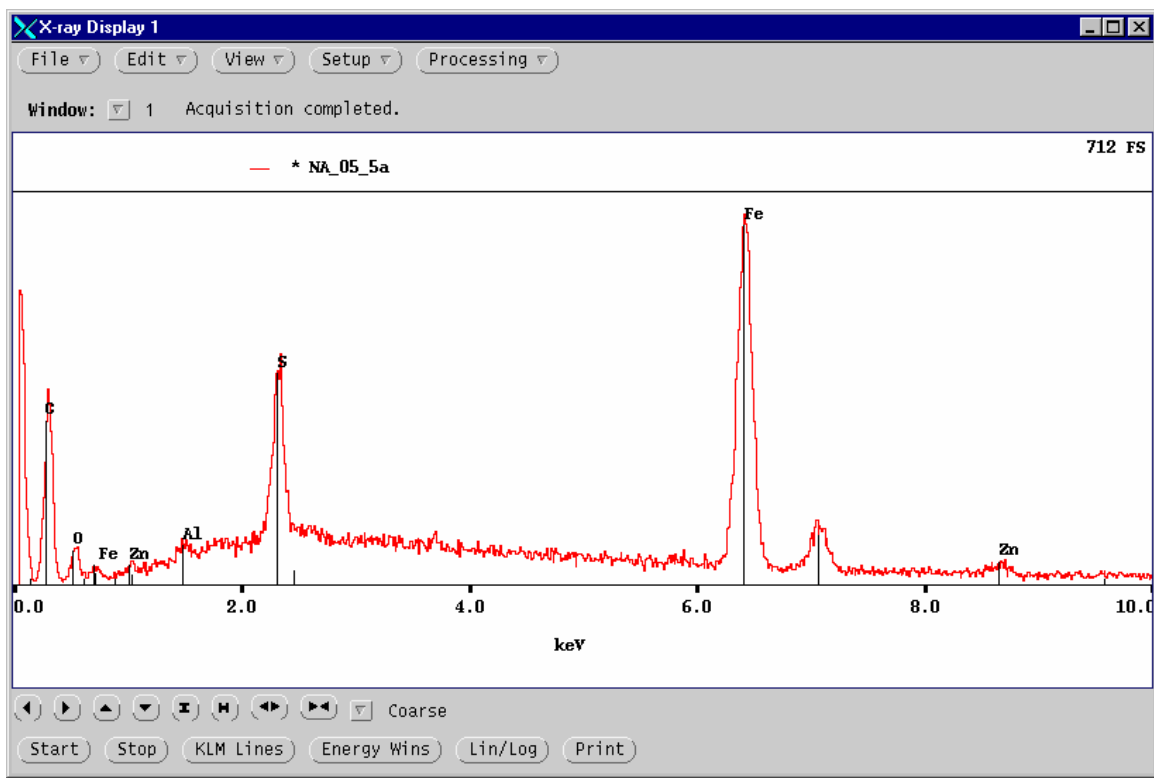




**Figure 10.** EDS spectra for the organic particle of Figure 8. The upper spectrum is for the outermost part of the structure, and the lower spectrum is about 20  $\mu\text{m}$  farther inward, toward the core. See also the next page.



**Figure 10** (cont'd). EDS spectrum for the core area, thus indicating that all of the analyzed points of the organic material are Zn-bearing, but the Zn content is highest in the outermost part of the structure.

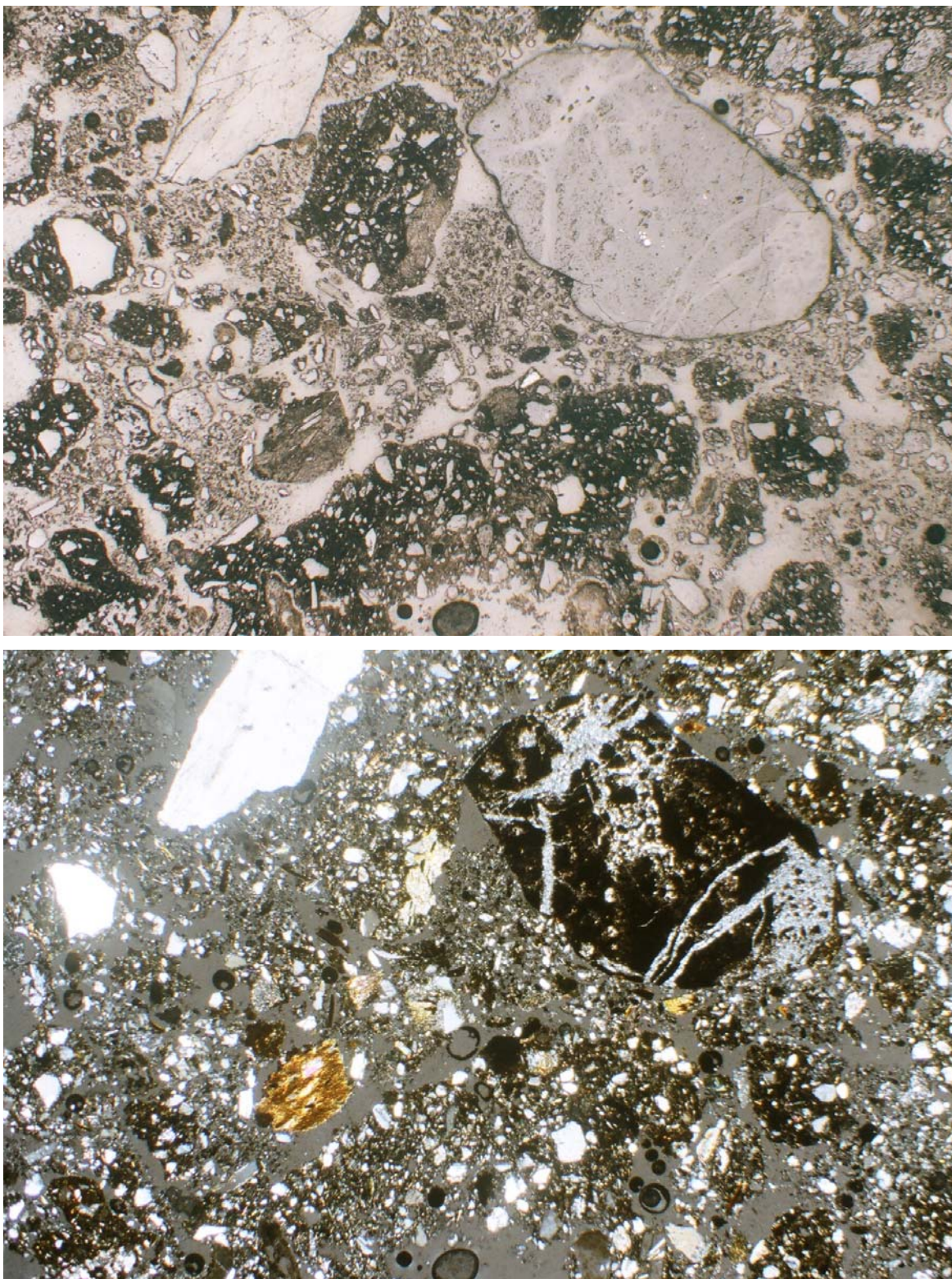


**Figure 11.** EDS spectrum of the organic structure shown in Figure 9.

**NA-05-05 (9.1–10.9)**

The sample, presumably the down-hole continuation of the preceding one, was similarly blackish but slightly browner and had a more cohesive, mud-like consistency. Three small pebbles, up to  $\frac{1}{2} \times \frac{1}{2} \times 1$  cm, and two others only half that size, were removed by hand-picking. The larger clumps of fine particles were crushed by using finger pressure, but no other treatment was done.

The optical section consists of grit and sand, with the largest granule about 3 to 4 mm in diameter. The sample has fewer large particles than does the preceding sample, and most are  $<300 \mu\text{m}$  across. A cherty lithic particle contains a small amount of unaltered pyrite, but the clasts are otherwise sulfide-barren (Fig. 12). Most of the high-reflectance grains amidst the fines are ilmenite and rutile, and no primary or secondary sulfides, no discrete accumulations of Fe oxyhydroxides, and no concentrations of organic material were observed.



**Figure 12.** NA-05-05 (9.1–10.9) in plain reflected light (top) and in transmitted light with crossed polarizers (bottom), width of field 5.2 mm. At the upper right is a large cherty particle containing minute grains of pyrite (white), but the field is otherwise sulfide-barren.

**NA-05-06 (7.3–7.8)**

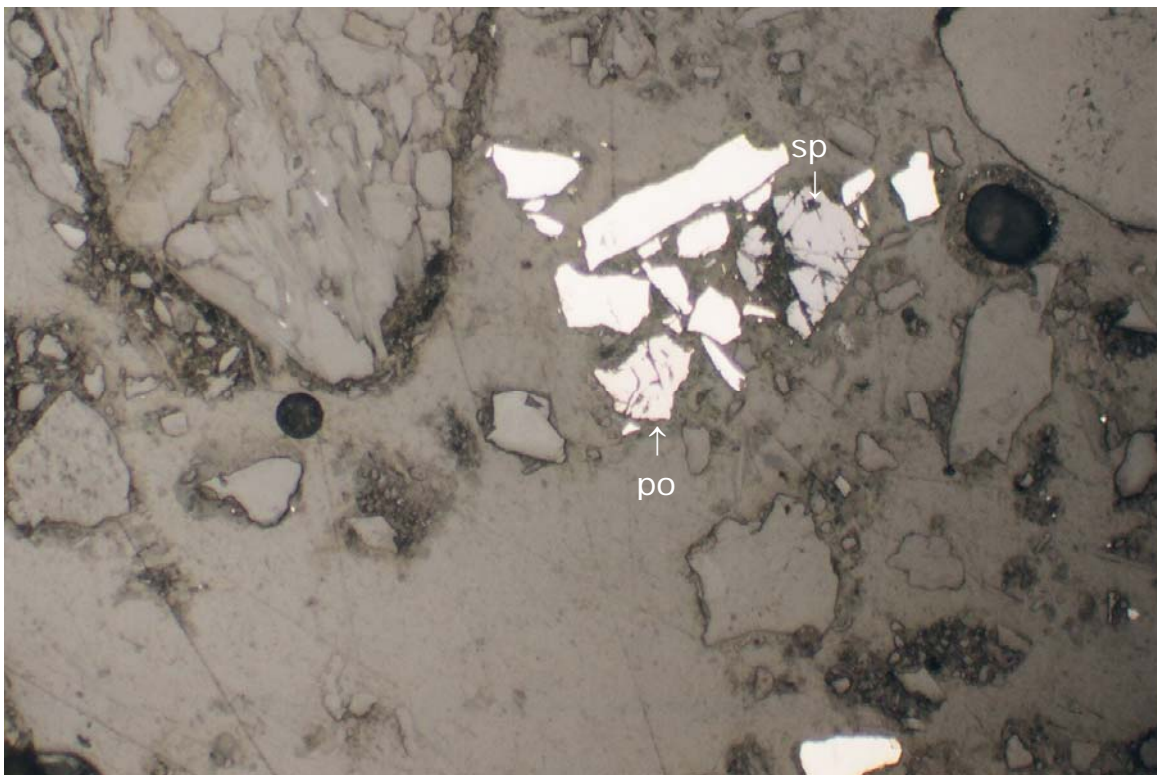
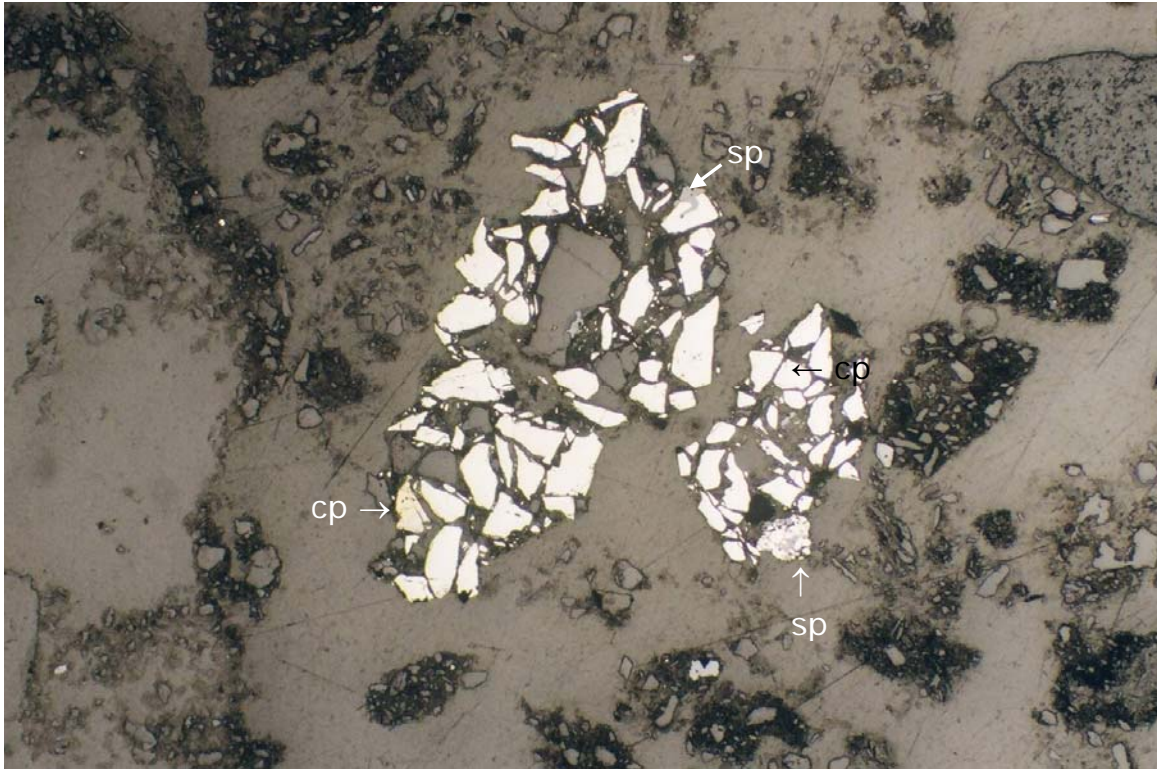
The as-received material was blackish and almost identical to the colour of the upper of the two NA-05-05 samples. Six small pebbles, up to  $\frac{1}{2} \times 1 \times 1$  cm across, were removed by hand-picking, but otherwise the bulk sample was used for the preparation of a polished thin-section.

The optical section megascopically shows the sample to be grit-like, with apparent granules up to 3 mm across. The section is sulfide-rich, and the content is of a percentage rather than sub-percentage magnitude.

Transmitted-light microscopy revealed that the apparently large granules are mainly aggregates of fines rather than lithic particles. Numerous clusters of angular, liberated tailings-type pyrite grains are present (Fig. 13), and the total sulfide content is in the range of 2 to 3%, of which >95% is pyrite. Sphalerite was commonly observed both as liberated grains and as middlings; the relative proportions among the subordinate minerals are sphalerite > chalcopyrite > marcasite, pyrrhotite, and galena, with all but sphalerite occurring in only trace amounts. Galena was noted to be present only as minute occluded grains within sphalerite, but some of the grains of the other sulfides, including pyrrhotite, are liberated.

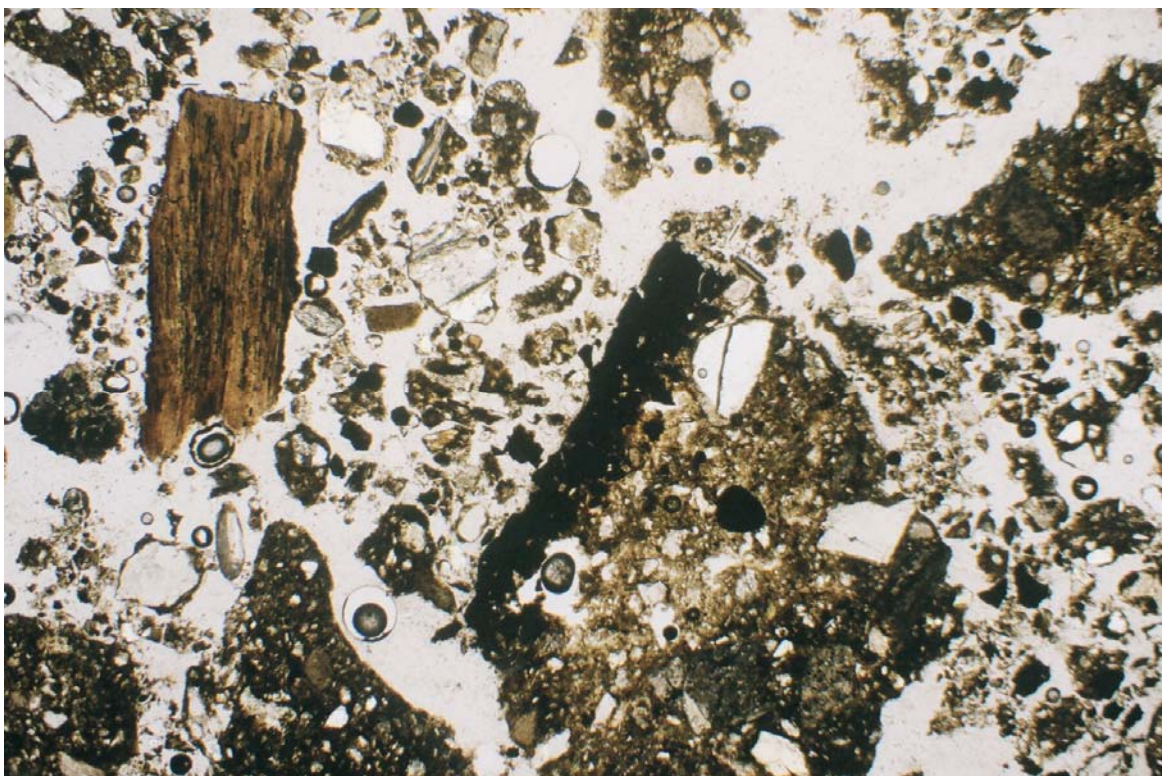
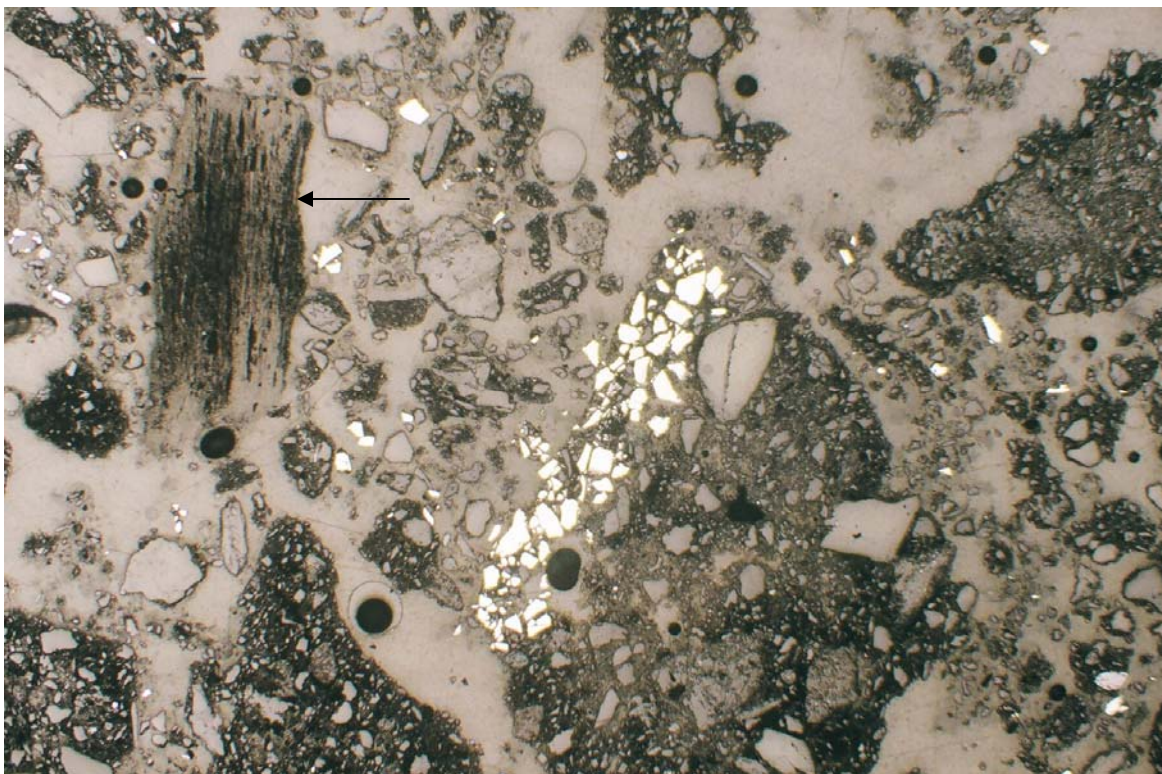
No alteration of pyrrhotite or the other sulfides, no precipitates of secondary sulfides, and no accumulations of Fe oxyhydroxides were observed. The section does contain a few particles of organic matter, but most of the organic bodies are of the siliceous, Zn-free type that is illustrated in the discussion of samples NA-05-07 and NA-05-08. EDS analysis of the carbonaceous particle shown in Figure 14 did not yield detectable Zn; the analyses indicated that the opaque parts of the particle contain more Fe than do the translucent parts, but neither is Zn-bearing.





**Figure 13.** NA-05-06 in plain reflected light, width of field 2.6 mm (top) and 1.3 mm (bottom), showing clustered tailings sulfides, mainly pyrite. In the upper photo the arrows at 1 and 6 o'clock point to sphalerite (grey) intergrown with pyrite, and arrows at 3 and 8 o'clock point to chalcopyrite. The lower photo shows pyrite, pyrrhotite (at arrow), and grey sphalerite.





**Figure 14.** NA-05-06 in plain reflected light (top) and the same field in plain transmitted light (bottom), width of field 5.2 mm. The upper photo shows clustered and disseminated pyrite; the arrow at the left points to a large particle of organic material.

#### **NA-05-07 (2.4–2.6)**

The colour of the sample is dark brown and similar to that of NA-05-03. A whitish precipitate, so sparse that its presence was uncertain, appeared to have formed locally on the dried sample; subsequent examination with a binocular microscope confirmed the presence of a precipitate, which was concluded to be gypsum. A few pebbles, the largest  $\frac{1}{2} \times 1 \times 1$  cm, were removed from the bulk sample that was submitted for a polished thin-section.

The optical section is similar to that of NA-05-06 insofar as it is sulfide-rich and the sulfides are concentrated in clumped aggregates (Fig. 15). A few lithic granules up to  $2\frac{1}{2} \times 3\frac{1}{2}$  mm are present, but most of the section consists of sandy fines and clumps of fines. The lithic material includes shale and granitoid fragments; other than a trace of pyrite, in grains to a maximum of 50  $\mu$ m across, that occurs in shale, the lithic material is sulfide-barren.

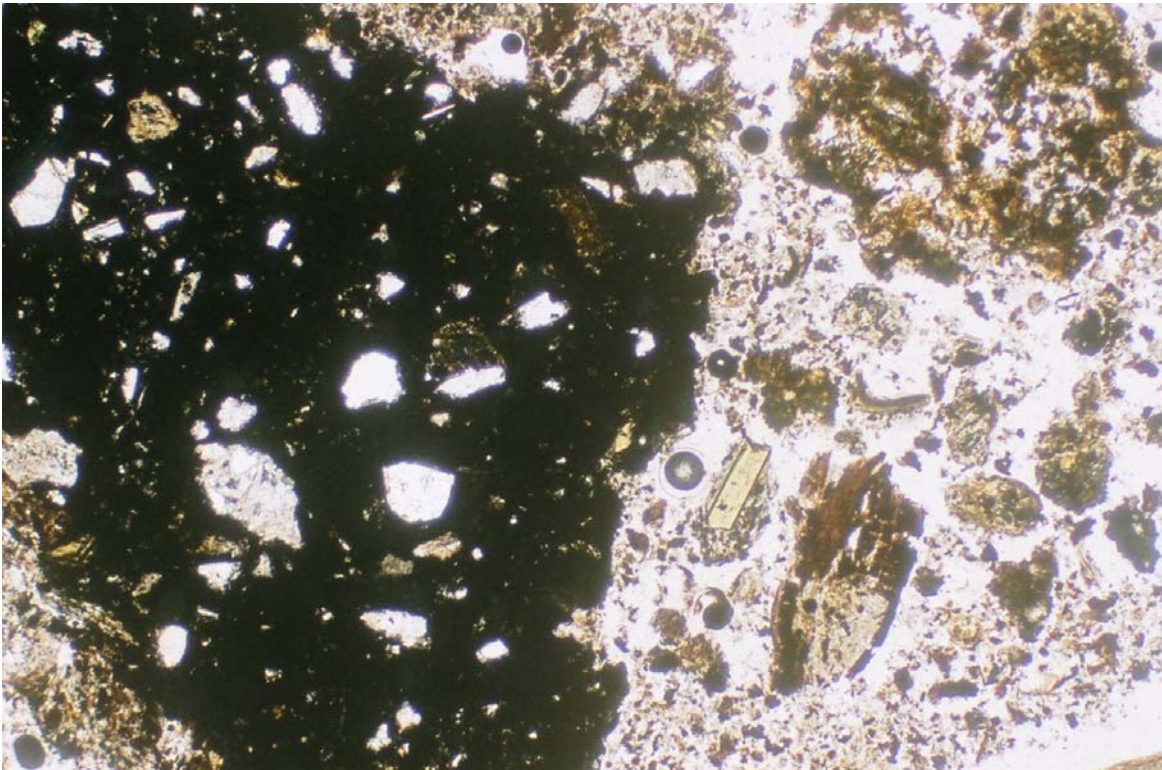
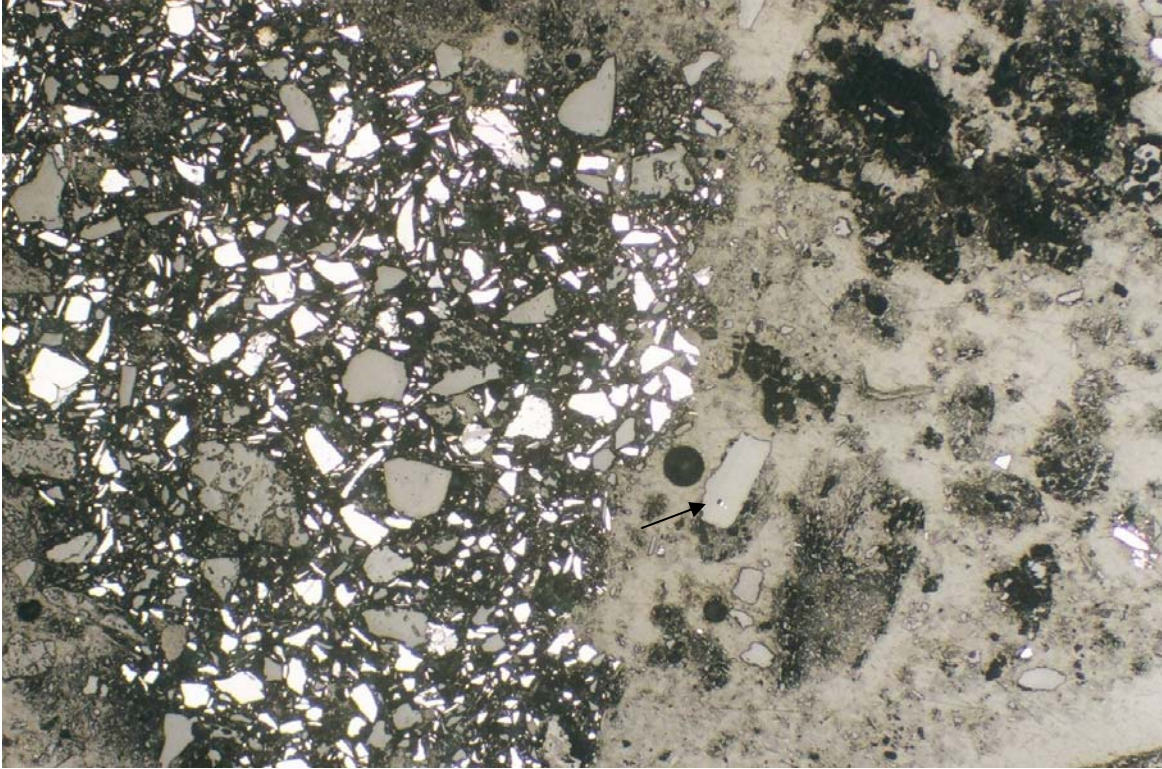
The sulfides that are concentrated in clumps are of a tailings type; the grains are typically sharply angular, with a limited upper size range. The sulfides are predominantly pyrite, which is accompanied by a few grains of other sulfides in each of the clumps. Sphalerite is consistently present, and the relative abundance is sphalerite > marcasite > chalcopyrite > galena.

The section contains a large amount of organic matter of two distinct types, one of which is siliceous and the other is carbonaceous (Fig. 16). The siliceous material is spore-like, consists largely of Si, and is devoid of Zn (Fig. 17, upper spectrum); in contrast, the carbonaceous material has high contents of S and Fe, and most particles contain detectable Zn (Fig. 17, lower spectra).

The Zn content of the carbonaceous material is variable (Figs. 18, 20). In general, an inverse relationship with Fe seems to be present, i.e., the Zn content is lowest where Fe is highest. Although no discrete particles of secondary Fe oxyhydroxides were observed, very rare local areas of optically slightly high reflectance suggest that a foetal development of Fe oxyhydroxide might be present, as shown in Figure 21.

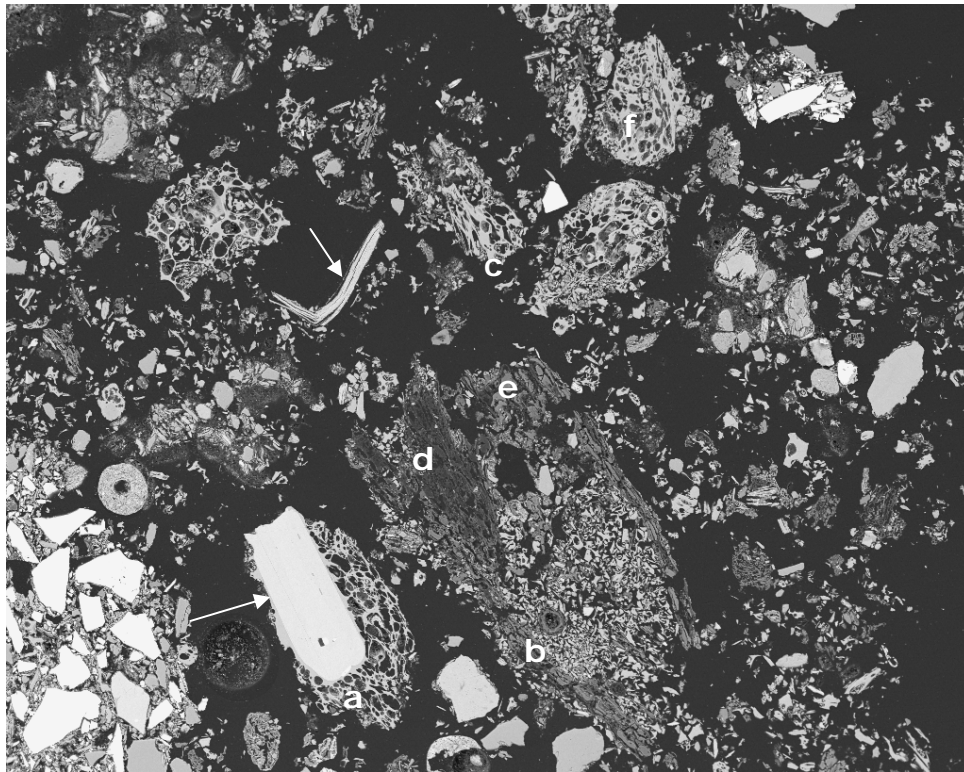
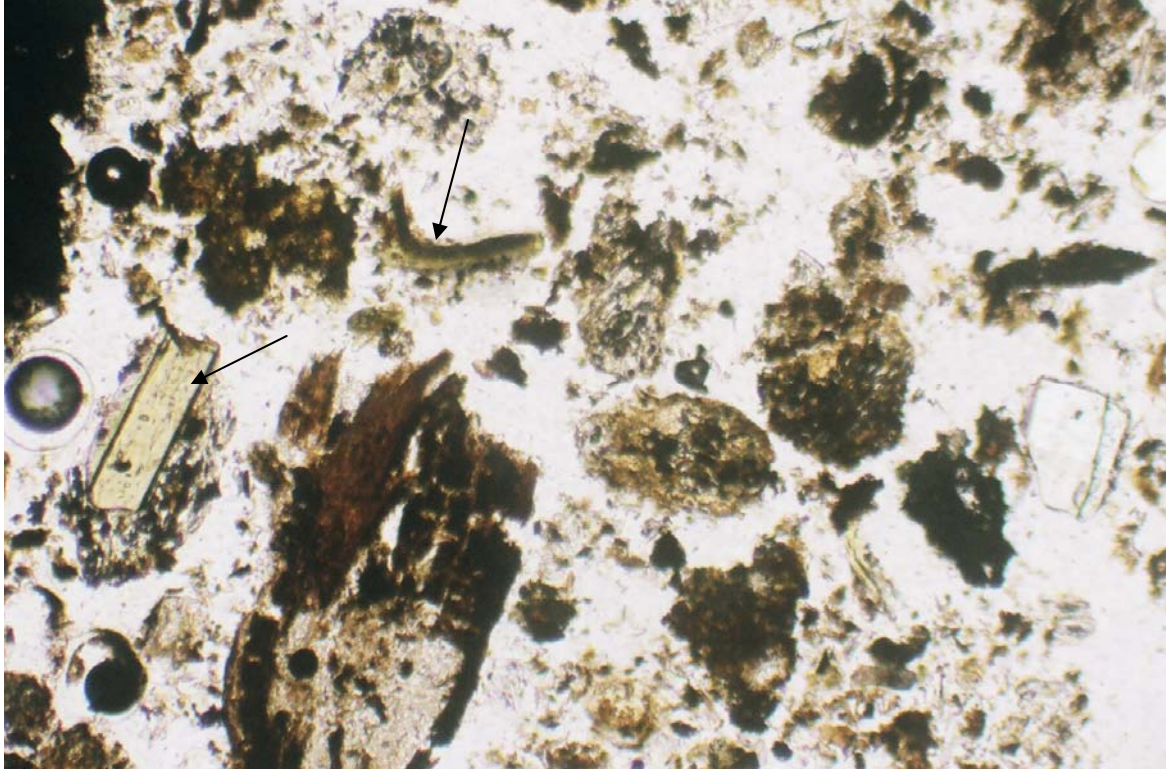
In summary, the results of the mineralogical examination indicate that NA-05-07 is high in organic material and presumably is representative of the peat layer referred to in the Introduction. The carbonaceous organic material has sorbed Zn; enough analyses have been done to indicate that such sorption has occurred widely rather than in isolated spot or two in the sample. Thus, the organic carbon in NA-05-07 is concluded to be a major attenuator of dissolved Zn.



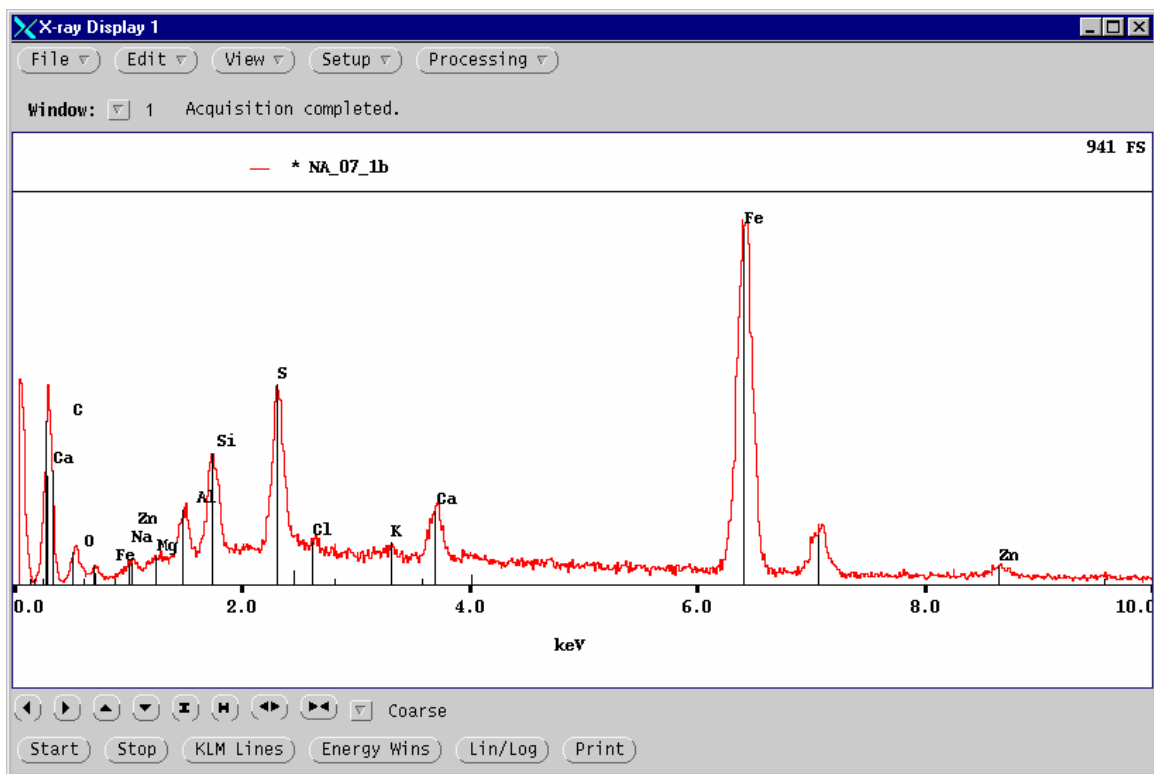
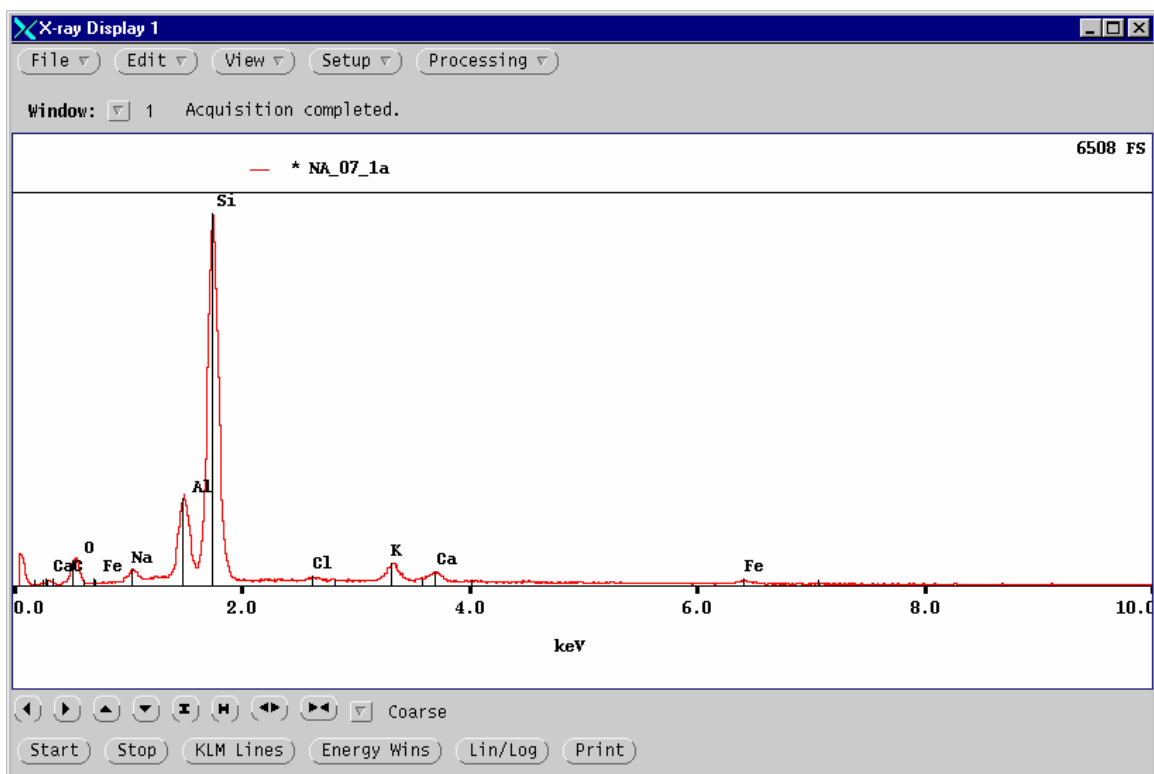


**Figure 15.** NA-05-07 in plain reflected light (top) and in plain transmitted light (bottom), width of field 2.6 mm. The clustered sulfide grains on the left are mainly pyrite, and the sulfide-poor area on the right is organic-rich. The arrow points to the reference prismatic grain shown in Figure 16.

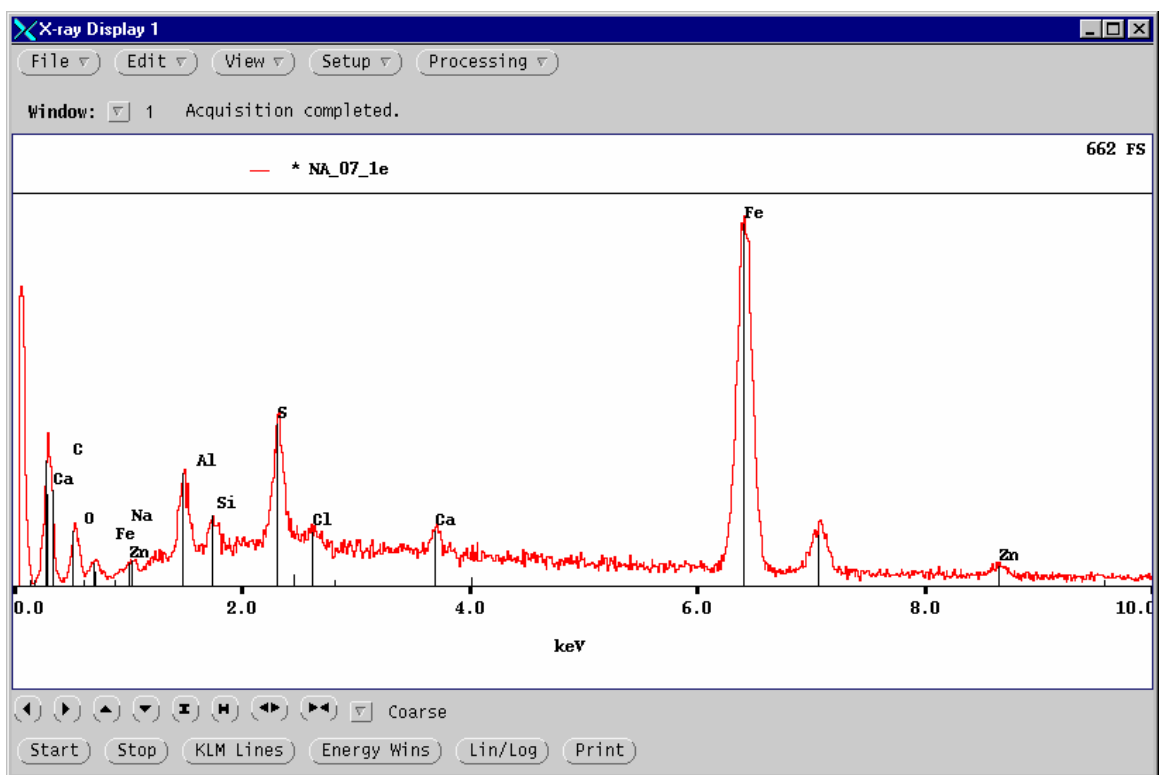




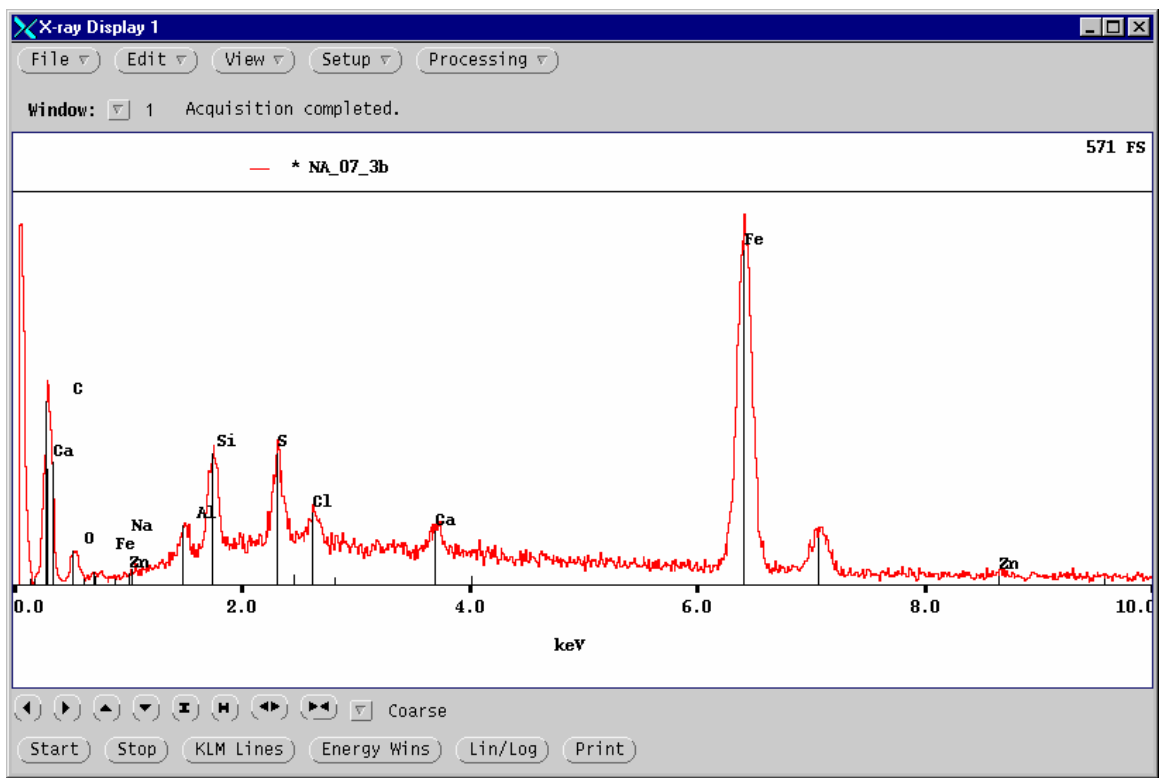
**Figure 16.** Enlargement of the right side of Figure 15, in plain transmitted light, width of field 1.3 mm. The arrows point to the reference prismatic grain (left) and to a mica grain, with both also indicated in the backscattered-electron (BSE) image. EDS spectra for **a** (at bottom), **b**, and **e** are shown in Figure 17.



**Figure 17.** EDS spectra of areas **a**, **b**, and **e** shown in Figure 16.

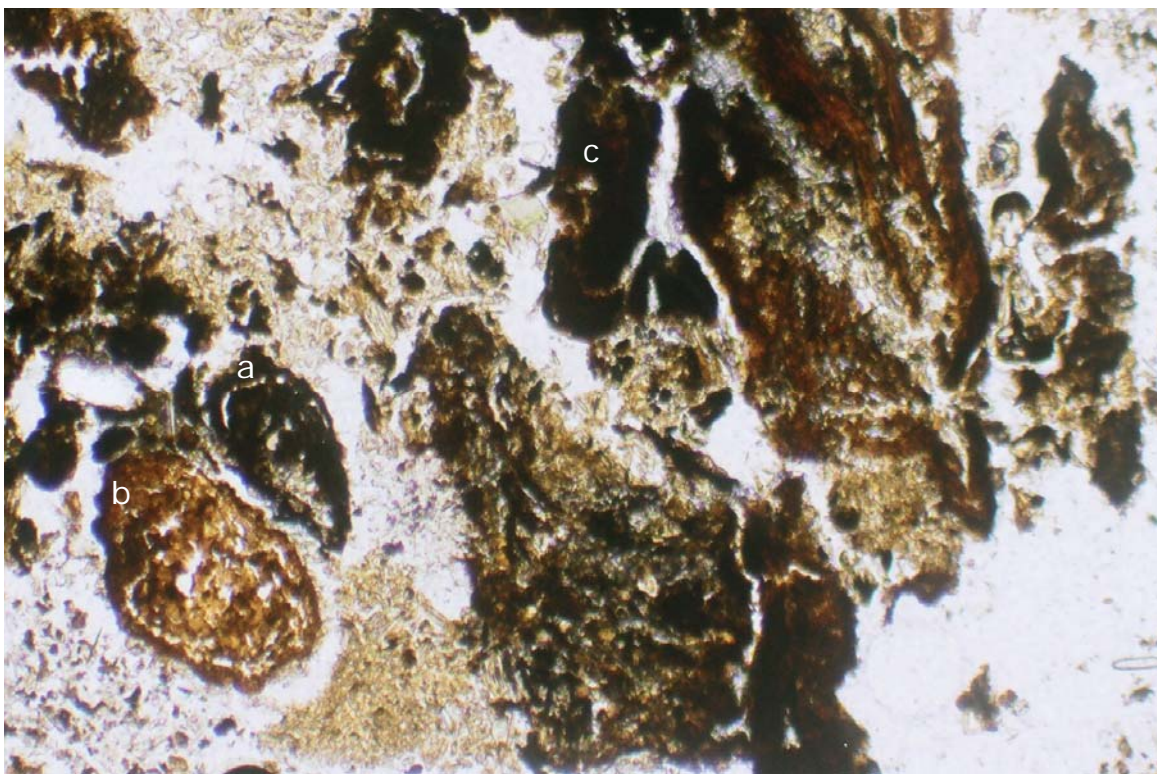
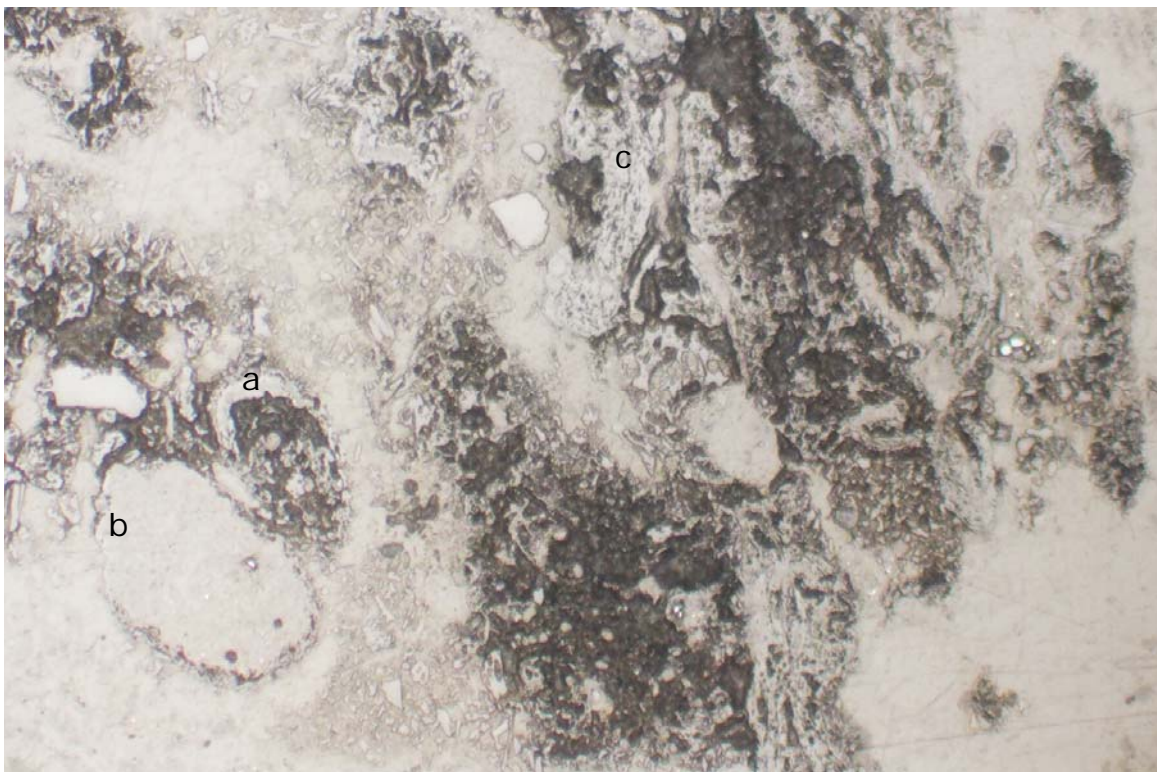


**Figure 17** (cont'd). EDS spectrum of carbonaceous material at **e** in the BSE image of Figure 16.

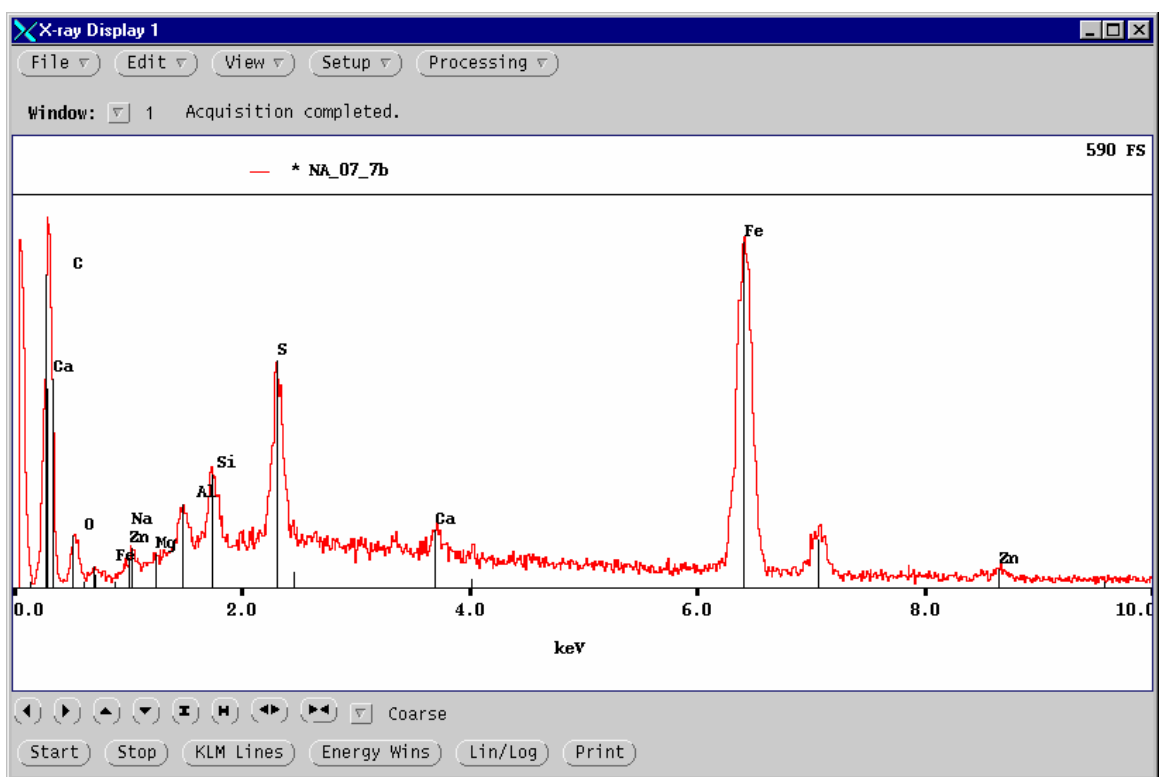
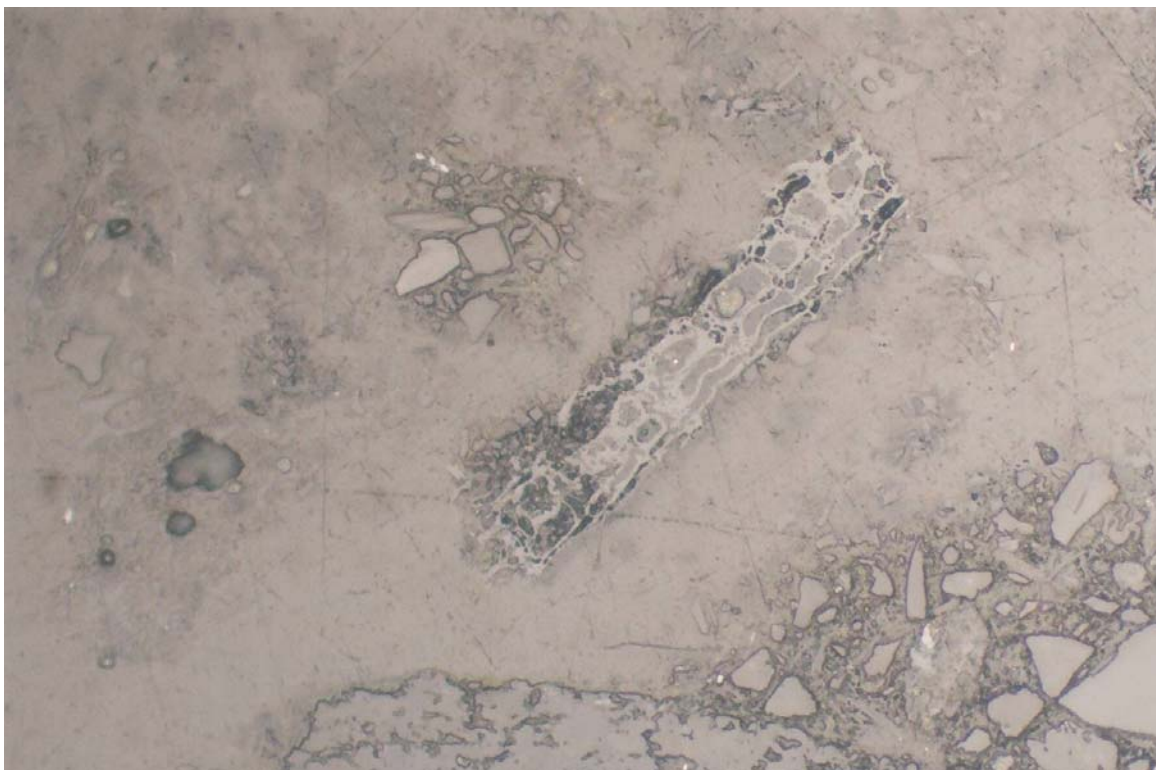


**Figure 18.** EDS spectrum of **b** shown in Figure 19.



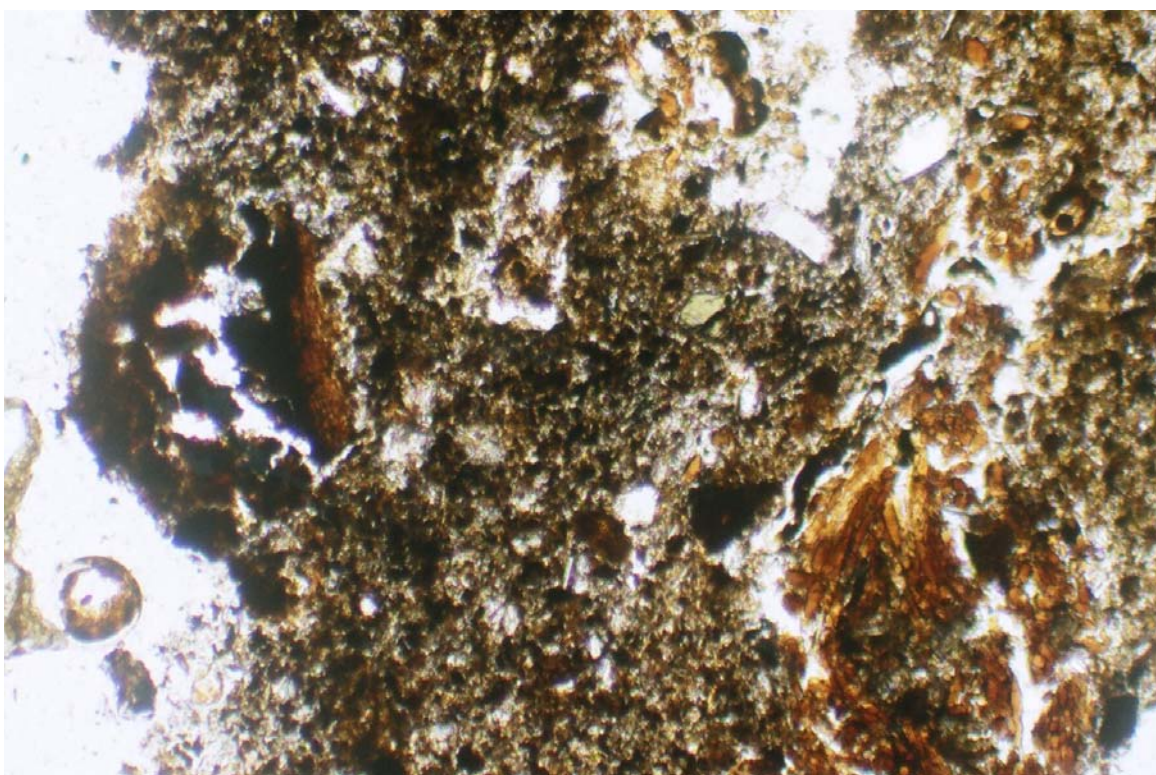
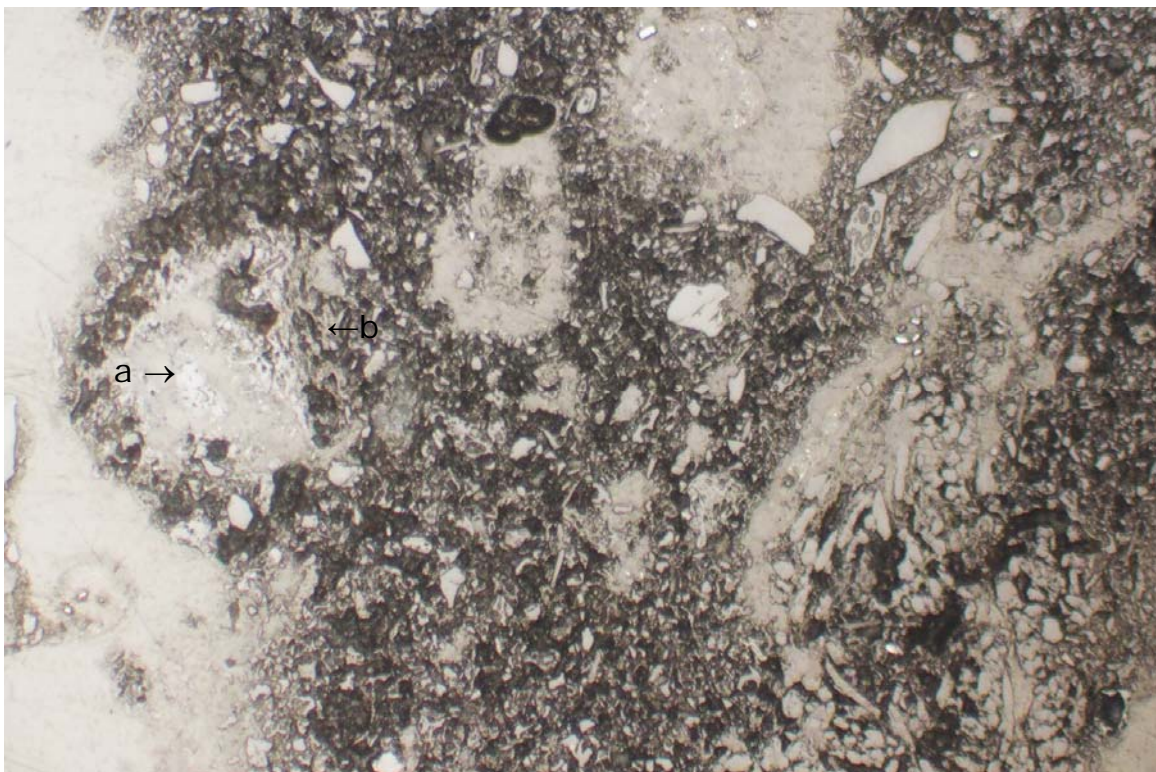


**Figure 19.** Carbonaceous area in NA-05-07 in plain reflected (top) and plain transmitted light (bottom), width of field 1.3 mm. The EDS spectrum of **a** showed the presence of low amounts of Zn, but **b** and **c** have higher Fe and barely detectable Zn whose presence was confirmed in an expanded-scale spectrum.

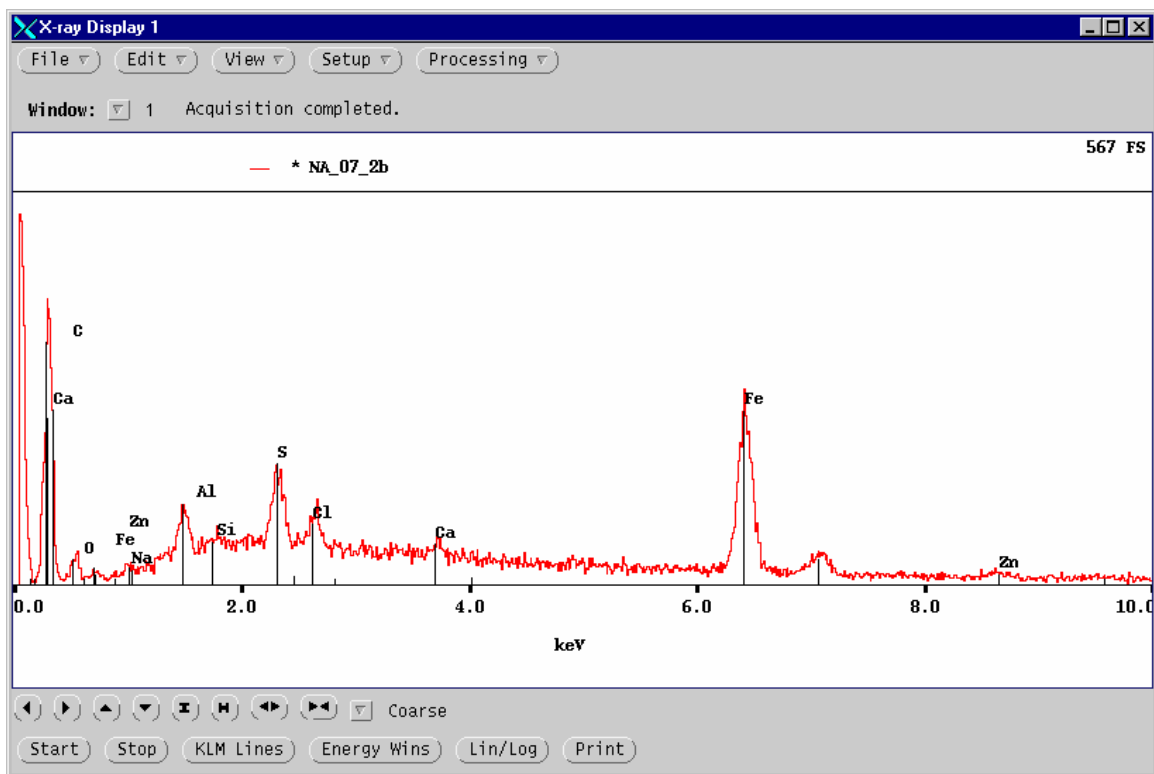
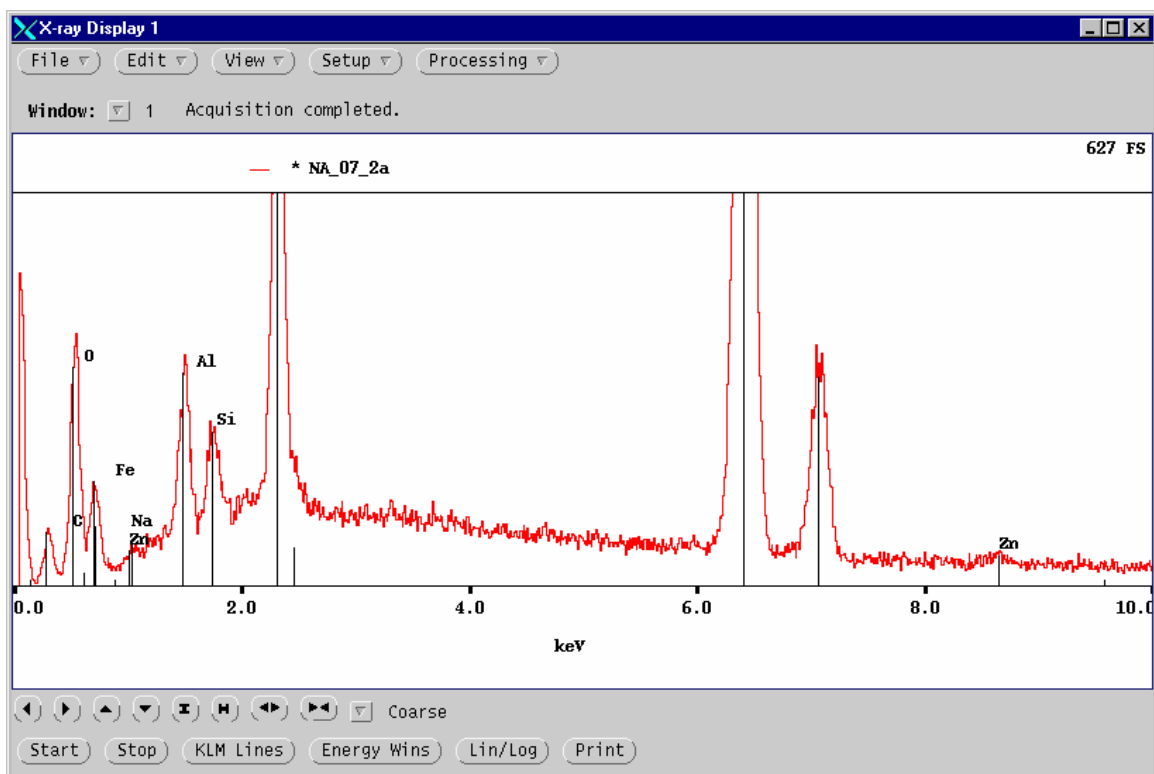


**Figure 20.** Cellular carbonaceous material in NA-05-07; plain reflected light, width of field 0.625 mm, and the corresponding EDS spectrum.





**Figure 21.** A-05-07 in plain reflected light (top) and in plain transmitted light (bottom), width of field 1.3 mm. Arrow **a** points to higher reflectance material that may represent the initial stage of development of secondary Fe oxyhydroxide; arrow **b** points to less extensively replaced carbonaceous material.



**Figure 22.** EDS spectra of **a** (upper spectrum) and **b** (lower spectrum) of Figure 21. The upper spectrum is at an expanded scale to show that Zn is present; the two off-scale highest peaks are for S (on the left) and Fe (on the right). The lower spectrum at standard scale is for **b**, which contains less S and Fe, but more Zn, than does **a**.



**NA-05-08 (7.4–8.8)**

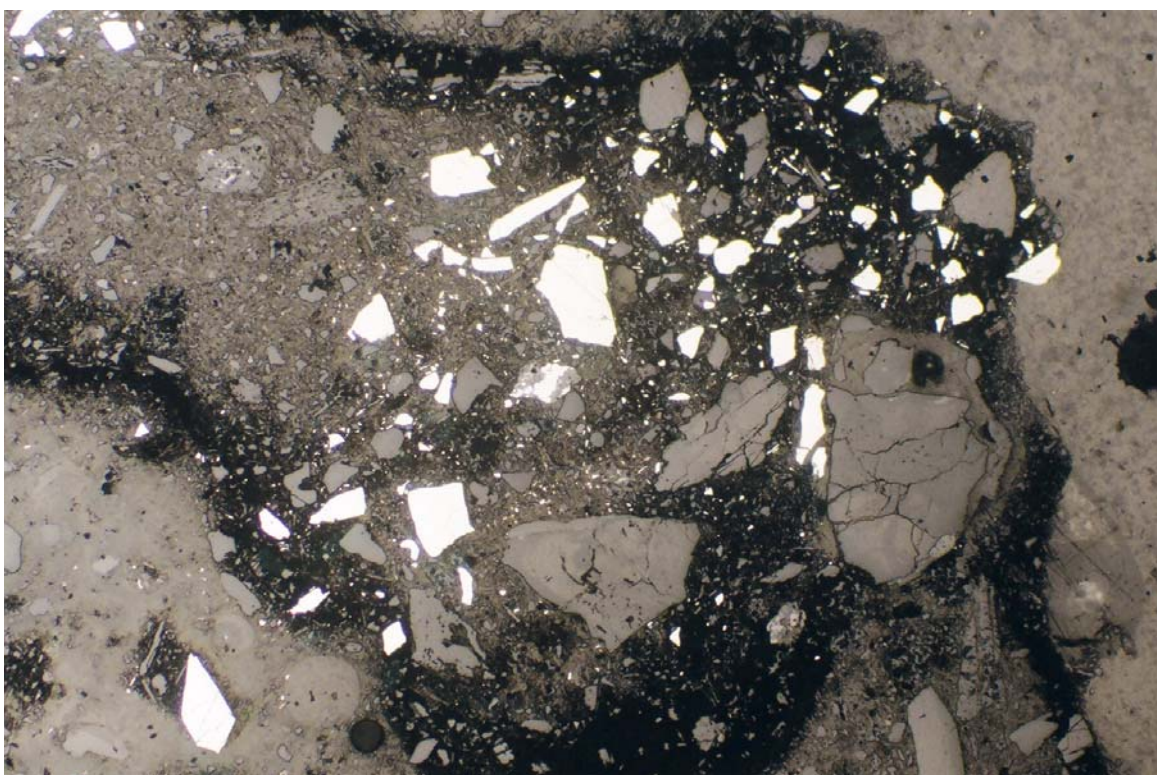
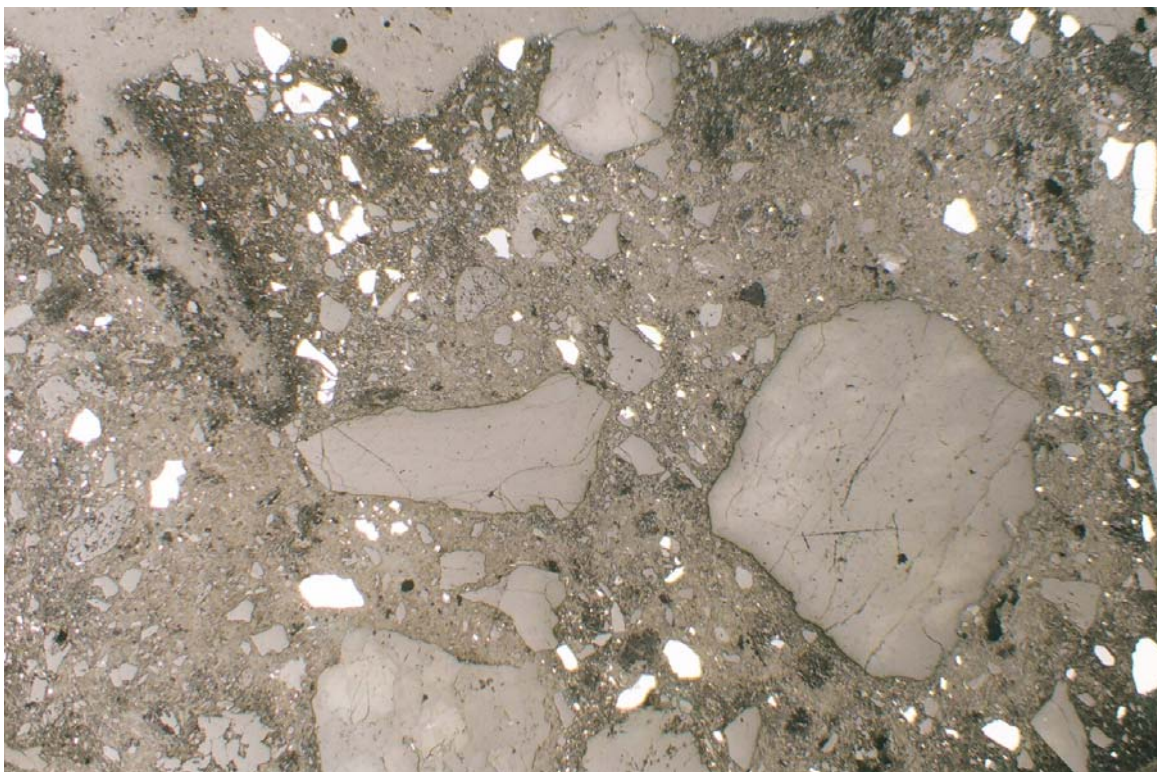
The sample had a mud-like consistency and was extruded from its container as a paste. The material was chiefly dark brown, but had a minor admixed fraction consisting of similarly pasty material that was cream-coloured. A few pebbles, up to  $1 \times 1 \times 1$  cm, were removed, but the sample was not treated further.

The optical section is generally similar to that of NA-05-07 except that the coarsest sulfide grains are not as densely packed, and sulfide fines are abundant within the sulfide-rich clusters (Fig. 23). The typical assemblage dominated by pyrite and accompanied by small amounts of sphalerite is present. Traces of galena, marcasite, and pyrrhotite, none of which is altered, were also observed. A minute amount of gypsum occurs in irregular aggregates in which crystal forms are not resolved; the fine-grained habit is suggestive of rapid precipitation during the drying process.

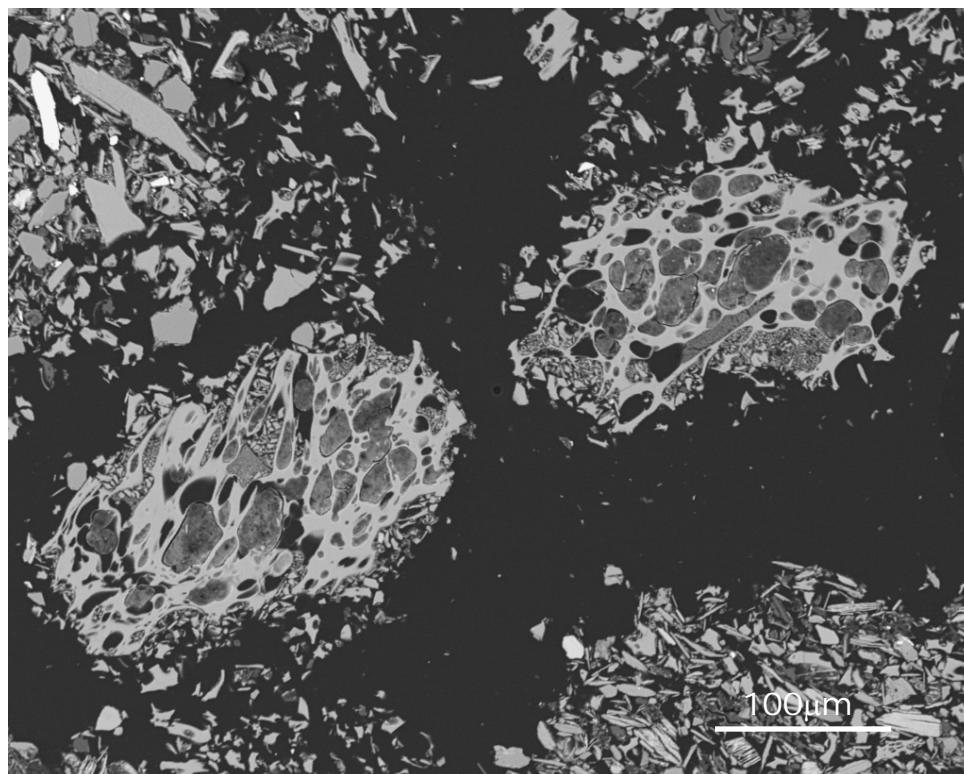
The section has a high proportion of opaque area, but this effect seems to be mainly a polishing artifact rather than related to organic material. Nevertheless, discrete organic particles are common. The organic content does not seem to be as high as that of NA-05-07, and most of the organic particles are of the siliceous, spore-like type. Secondary sulfides and accumulations of Fe oxyhydroxides are not present.

Only a few areas were checked by EDS analysis because, despite their optically almost opaque appearance, all of the examined organic particles were found to be of the siliceous type (Fig. 24). Both the siliceous framework, which is white in the BSE image of Figure 24, and the darker cellular material within the framework are low in Fe and do not contain detectable Zn.

Although attenuation of Zn may be occurring at this sample site, the effect could not be demonstrated mineralogically, unlike in NA-05-07. Possibly some winnowing of the larger carbonaceous particles has occurred, as is suggested by the high content of sulfide fines.



**Figure 23.** NA-05-08 in plain reflected light, width of field 5.2 mm (top) and 2.6 mm (bottom), showing the distribution of pyrite (white) and non-sulfide particles in the sample.



**Figure 24.** BSE image of spore-like siliceous particles in NA-05-08.

**NA-05-10** (12.9-13.5)

The as-received material was gritty, akin to NA-05-02 but with a higher proportion of fine-grained, mud-like material. Pebbles up to  $1 \times 1\frac{1}{2} \times 1\frac{1}{2}$  cm were present. The finer grained dried material was friable and disintegrated easily under finger pressure. The sample was gently screened to pass 60 mesh, and the fine fraction was used for the polished thin-section.

The optical section consists largely of quartz, feldspar, biotite, and lithic fragments. Nearly all of the sulfide grains are  $<30$   $\mu\text{m}$ , and the largest is  $50 \times 100$   $\mu\text{m}$ . One grain of pyrite has occluded galena and an attachment of sphalerite. One grain is marcasite and another is pyrrhotite about 50  $\mu\text{m}$  across; both grains are liberated and neither is oxidized. No secondary sulfides were observed, and the total sulfide content was estimated to be  $\leq 0.1\%$ .

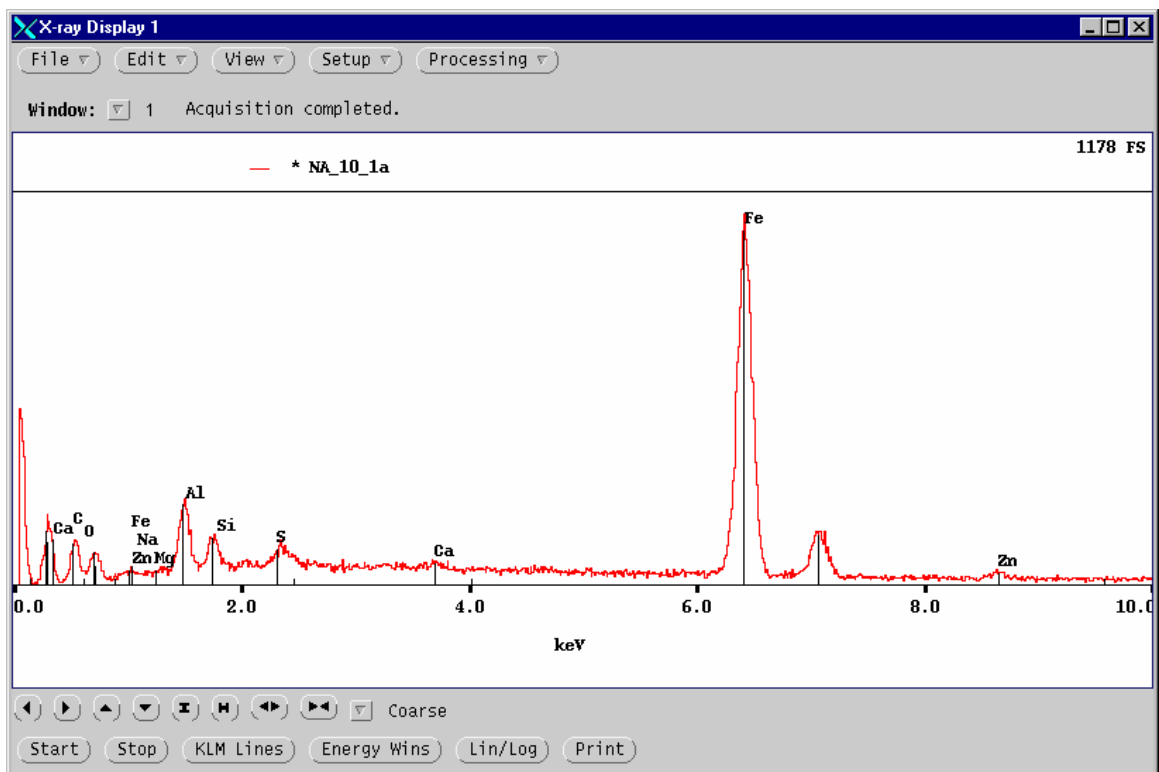
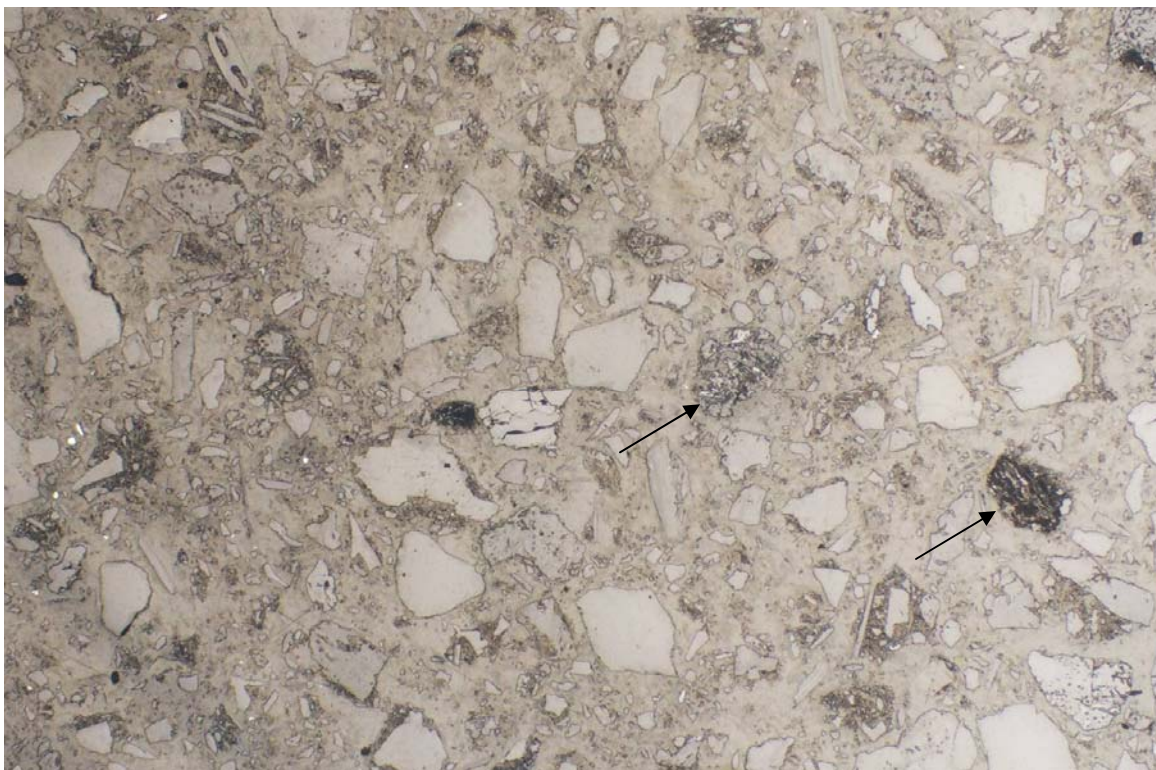
Organic matter and Fe oxyhydroxides are sparse, but some of the oxyhydroxide particles have unusual textures suggestive of possible secondary formation. The locations of several of these particles were marked for SEM examination.

Figure 25 shows the general character of the sample and two particles within it that were deemed to merit EDS analysis. The more central particle (Fig. 25) proved to be highly heterogeneous and predominantly chloritic, but the other particle contains Fe oxyhydroxide that is Zn-bearing (Fig. 25).

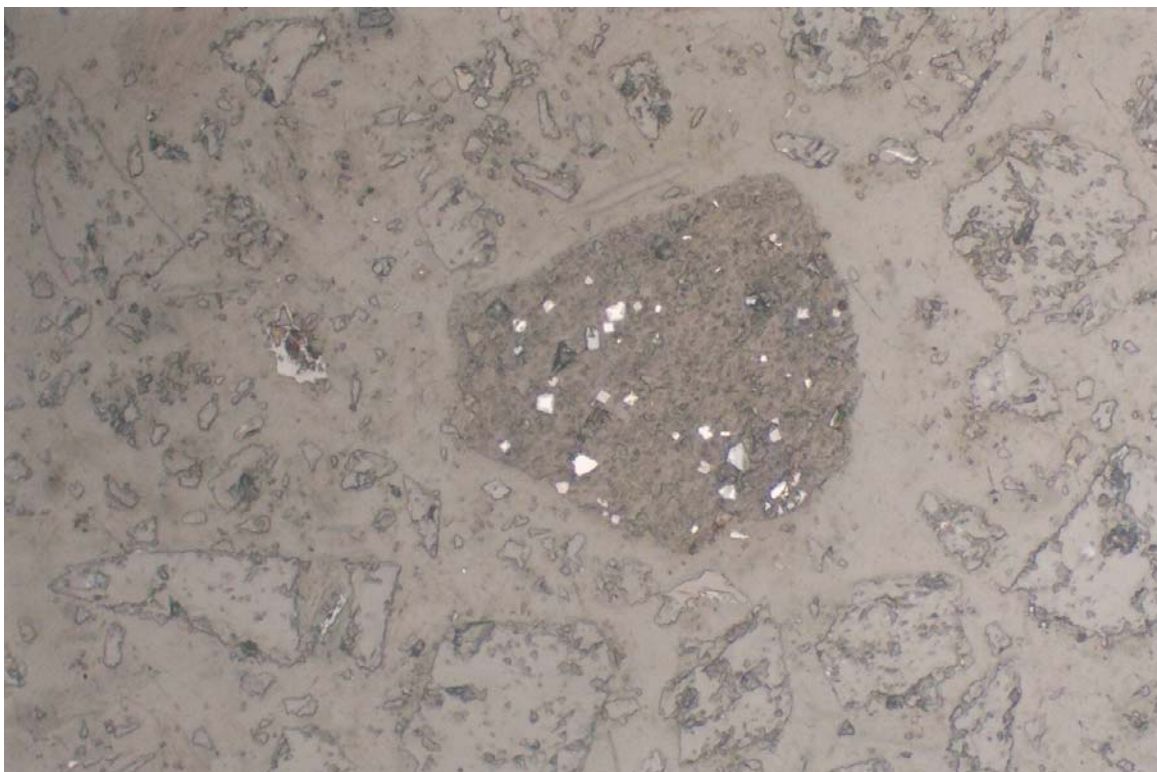
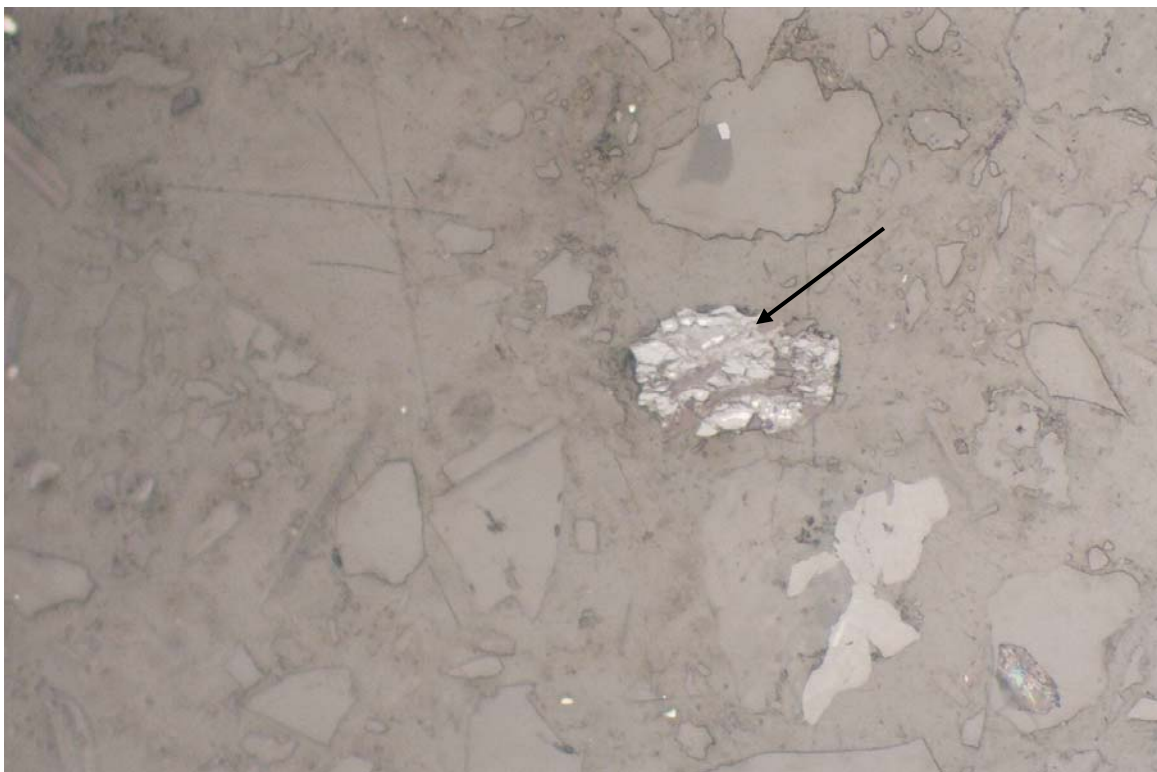
The upper photo of Figure 26 shows a particle of Fe oxyhydroxide containing remnants of pyrite. The oxyhydroxide is not Zn-bearing. In the lower photo (Fig. 26), the white grains are pyrite, some of which have Fe oxyhydroxide rims, but the rims are Zn-barren. The particle also contains disseminated grains of barite. The two particles illustrated in Figure 27 are goethite-type Fe oxyhydroxides, but neither was found to be Zn-bearing. It is likely that the particles illustrated in Figures 26 and 27 are previously oxidized clasts that do not represent *in-situ* conditions.

The possibility that local cementation or sorption by oxyhydroxides is occurring is thought to be better represented by the particles in Figures 28 and 29. Both particles are highly heterogeneous and one is Cr-bearing (Fig. 30); however, both also contain detectable Zn, thus suggesting that, regardless of the genesis of the particles, their associated oxyhydroxides are attenuating dissolved Zn. The volume of this type of material is small; nonetheless, the occurrences are significant in pointing out that sorption of Zn does not fall totally within the domain of carbonaceous material to the exclusion of all other hosts.



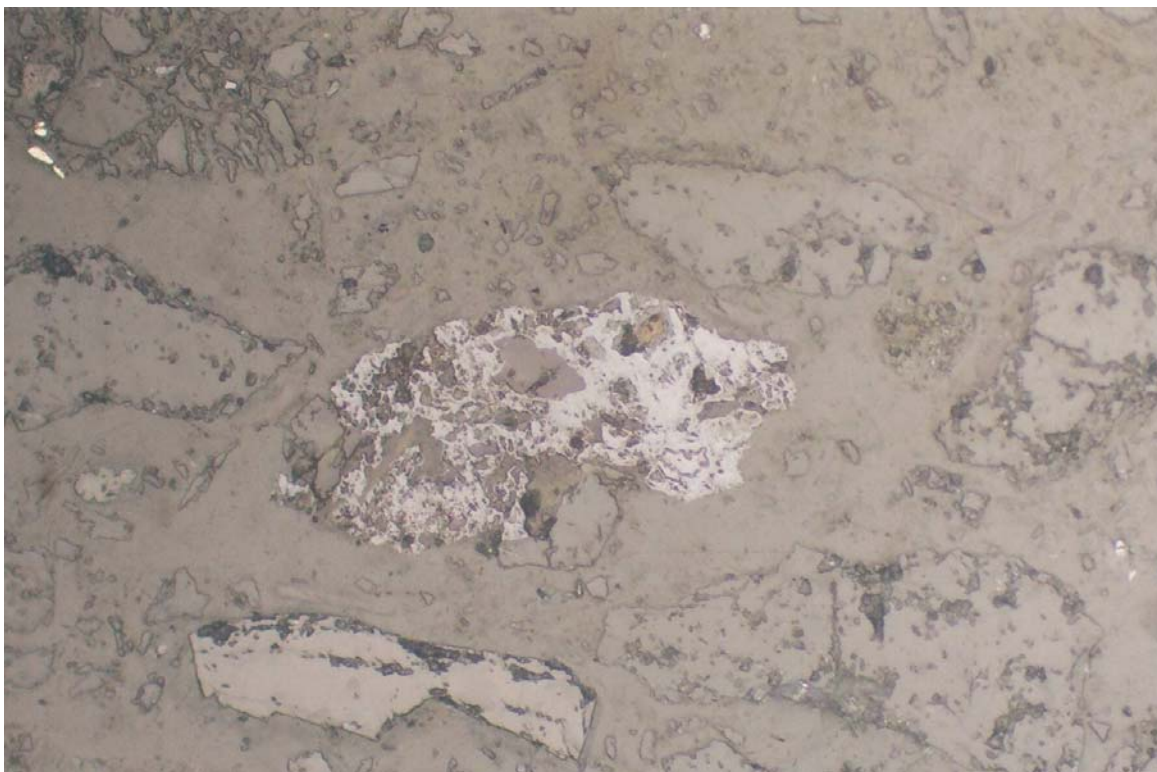
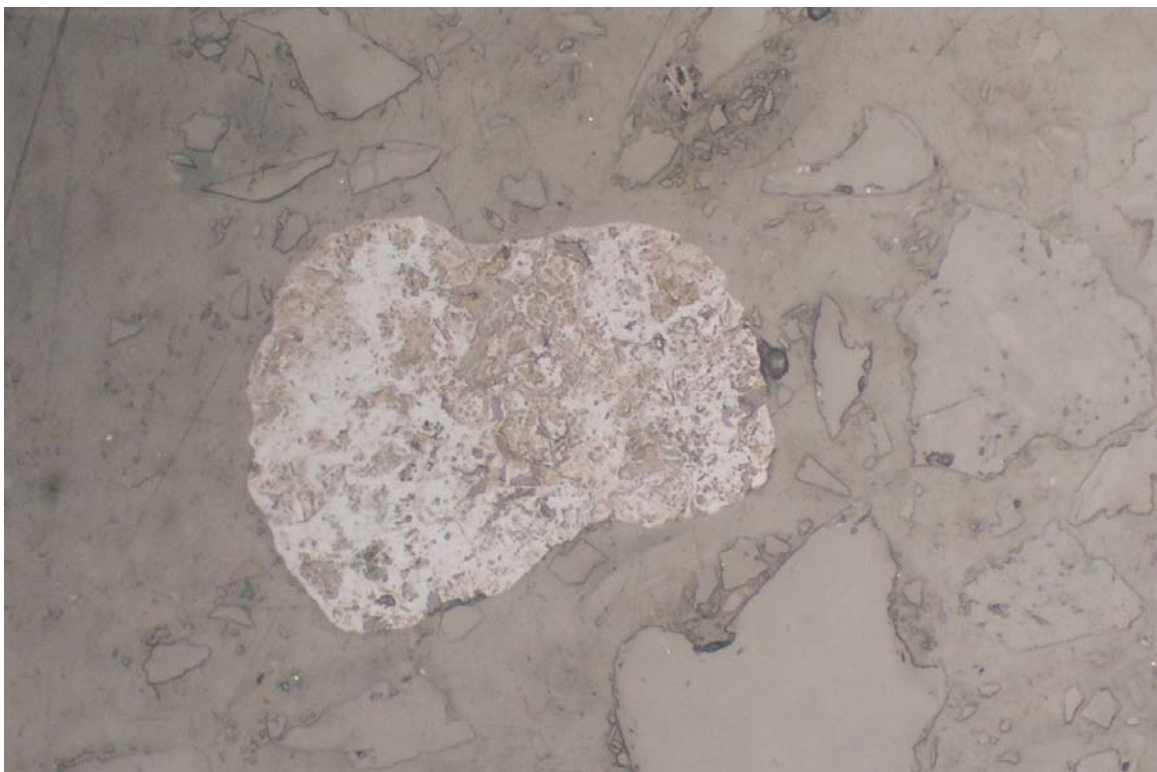


**Figure 25.** NA-05-10 in plain reflected light, width of field 2.6 mm. The EDS spectrum is for the particle on the right, which is Zn-bearing.

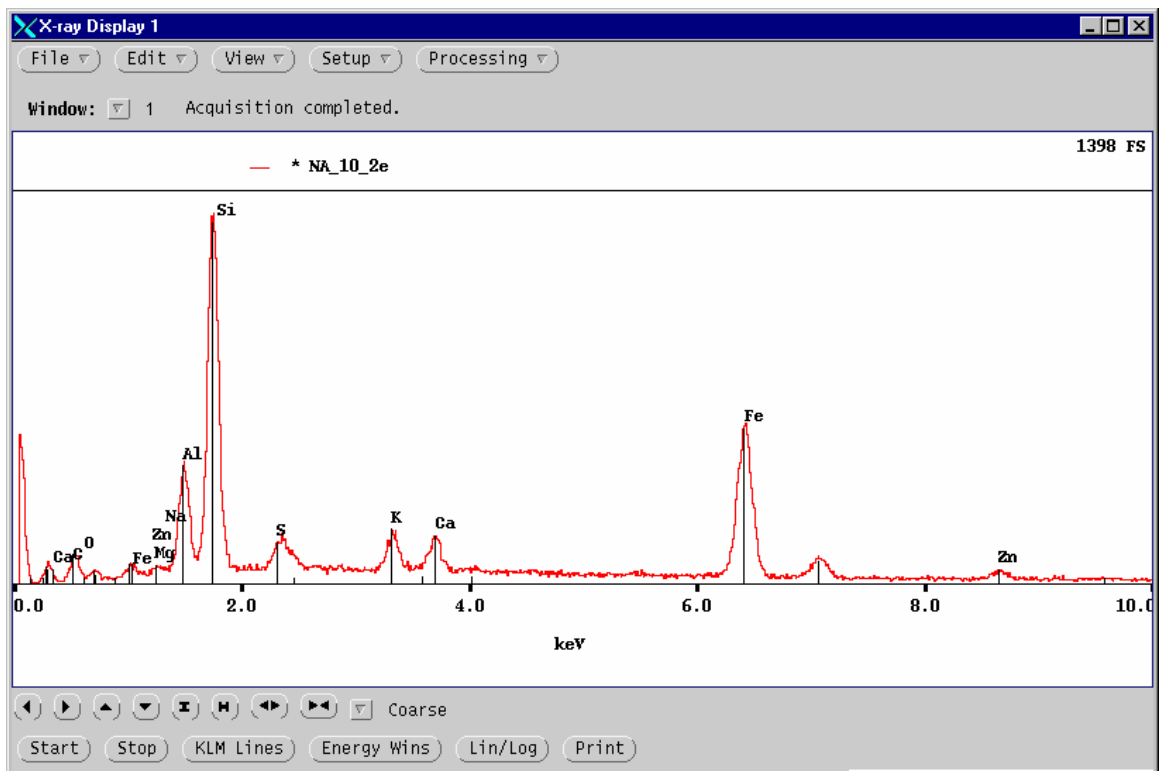
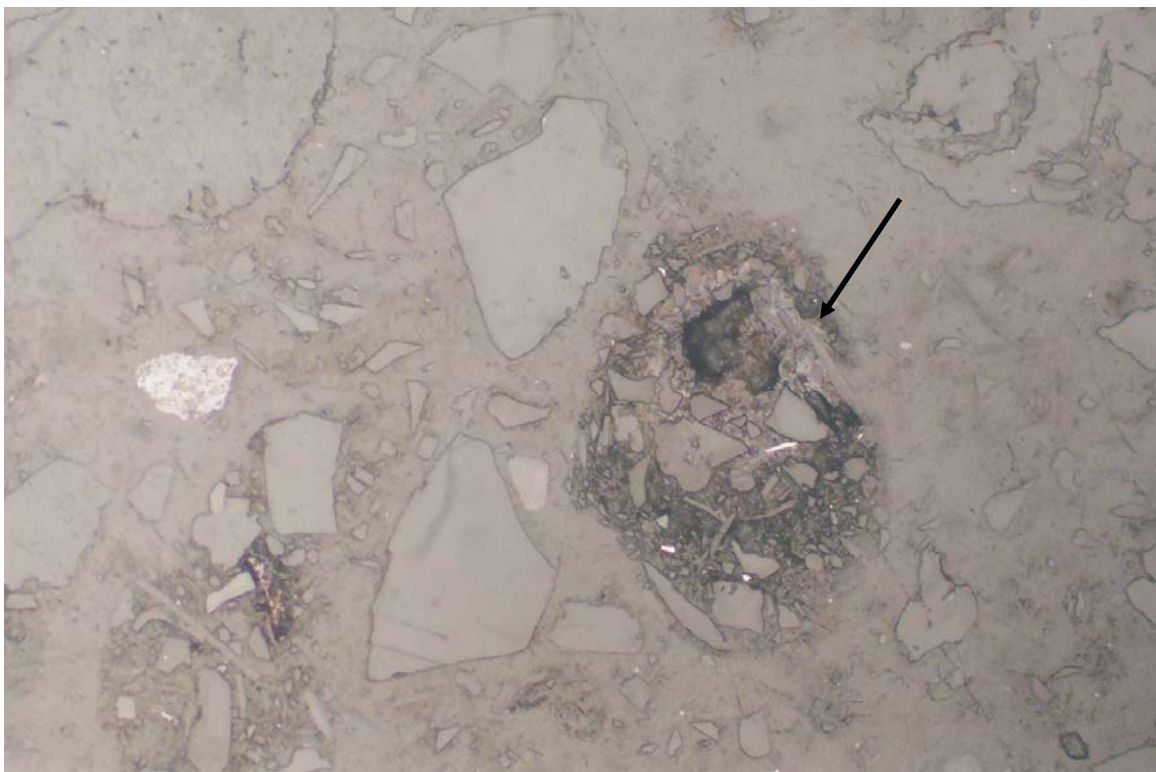


**Figure 26.** NA-05-10 in plain reflected light, width of field 0.625 mm. The upper photo shows a goethite-type particle containing whitish residual pyrite. The central clast in the lower photo contains white grains of pyrite, some of which have rims of Fe oxyhydroxide. The oxyhydroxides in both photos do not contain detectable Zn.



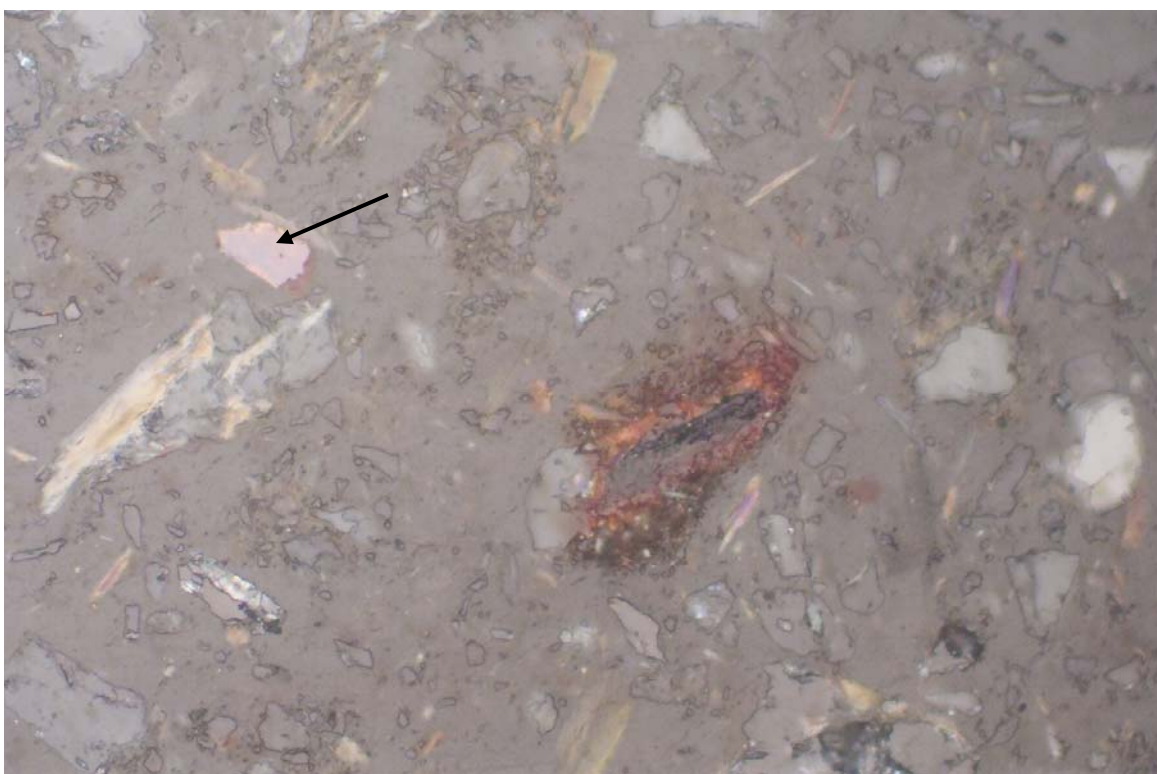
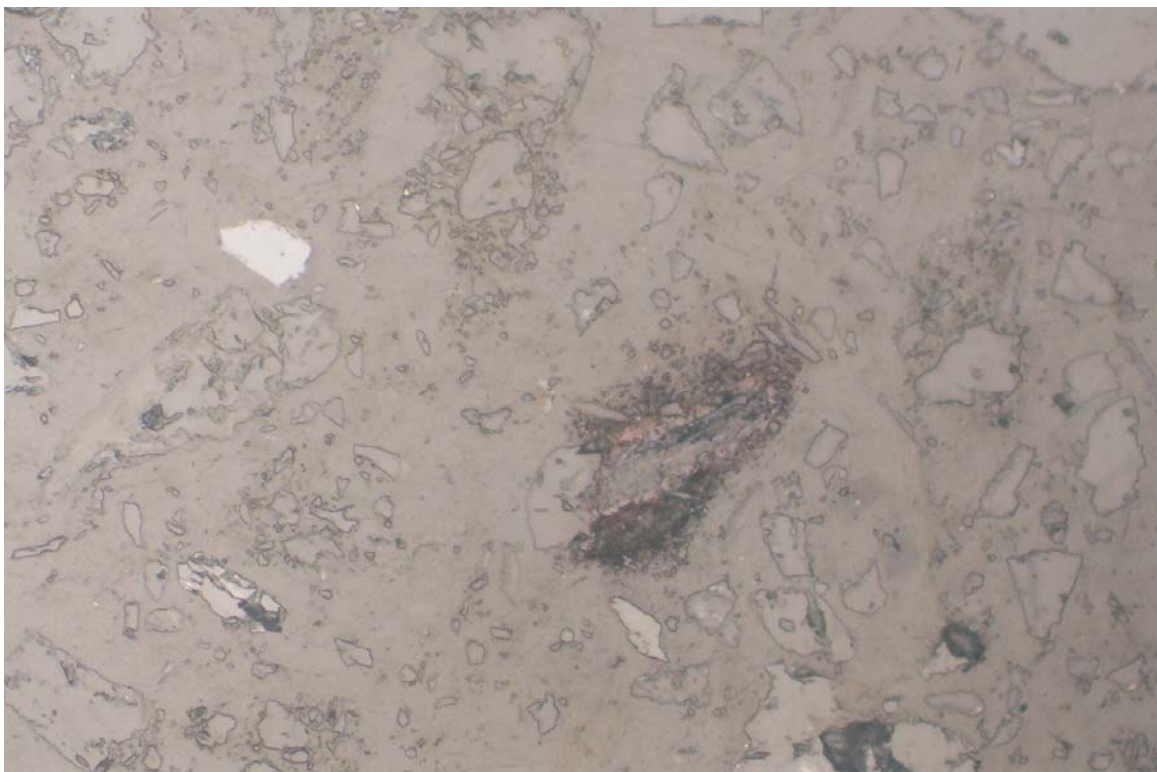


**Figure 27.** NA-05-10 in plain reflected light, width of field 0.625 mm, showing goethite-type particles that were probably deposited as oxyhydroxide clasts. Neither of the particles contains detectable Zn.

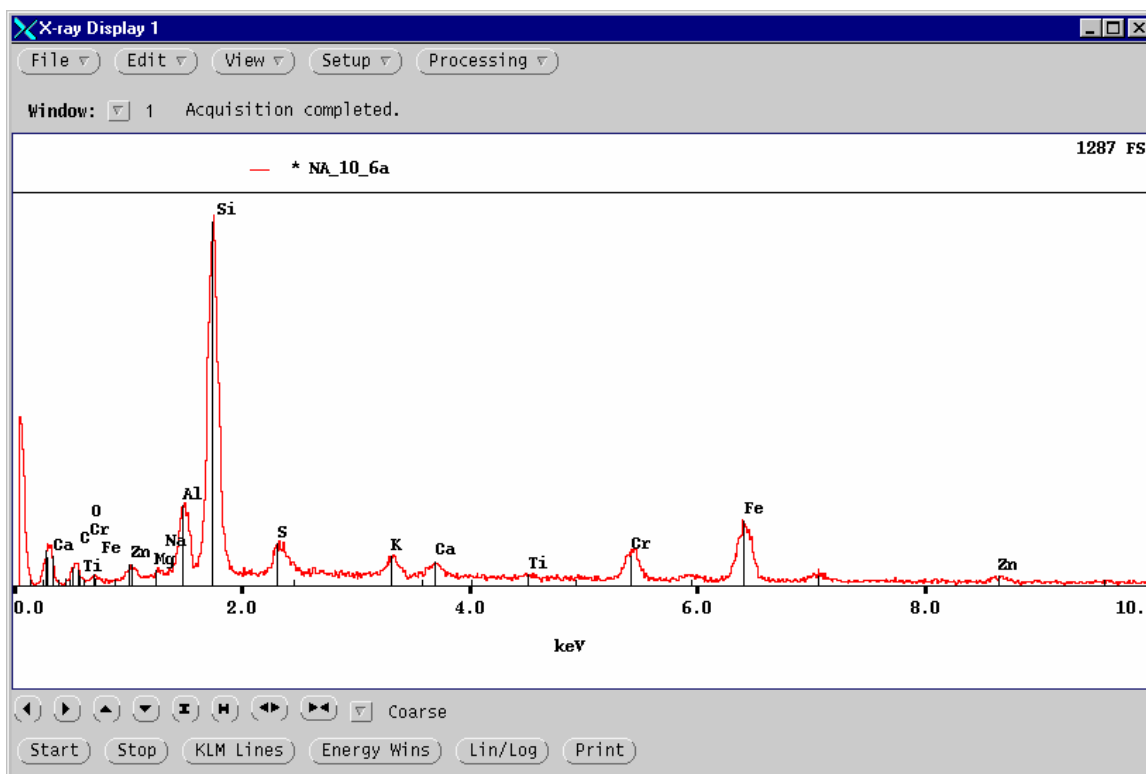


**Figure 28.** NA-05-10 in plain reflected light, width of field 0.625 mm. The arrow points to a ring-like zone of Fe-oxyhydroxide cementation within a particle that contains minute grains of unaltered pyrite (white). The EDS spectrum of the heterogeneous oxyhydroxide indicates that it is Zn-bearing.





**Figure 29.** NA-05-10 in plain reflected light (top) and with almost crossed polarizers and internal reflection (bottom), width of field 0.625 mm, showing a heterogeneous oxyhydroxide particle (reddish internal reflection) for which the spectrum is in Figure 30. The smaller, homogeneous particle (arrow) is Zn-free.



**Figure 30.** EDS spectrum of the heterogeneous main oxyhydroxide particle shown in Figure 29.

## ELECTRON-MICROPROBE ANALYSIS

Although many of the EDS spectra revealed the presence of Zn, the peak height in a spectrum provides only a general indication of the abundance of the element. To obtain a correlation with the EDS spectra, electron-microprobe analyses were obtained for the carbonaceous material illustrated in Figures 8 and 9, and for which EDS spectra are given in Figures 10 and 11, respectively. The carbonaceous material is unstable under the beam of the electron microprobe, but the results nonetheless provide an indication of the magnitude of Zn incorporation. The results are applicable not only to NA-05-05 (9–9.1), but also to the EDS spectra for other samples in the Faro suite because all of the spectra were obtained with identical instrumental operating conditions and at approximately the same time.

The microprobe results (Table 1) show that up to 0.6 wt% Zn is present in the carbonaceous material. The silica content was also determined to ensure that the results were not

influenced by unobserved inclusions of quartz. The Zn contents vary from spot to spot, as was observed in the EDS analyses.

Table 1. Results of electron microprobe analysis of carbonaceous material

wt%	Si	Fe	S	Zn
F8 -1	0.06	7.26	0.97	0.61
-2	0.31	8.77	0.75	0.37
-3	2.28	5.50	0.42	0.24
-4	0.40	6.86	0.67	0.36
-5	0.32	9.27	2.11	0.62
-6	0.05	9.88	1.22	0.38
-7	0.14	5.79	1.63	0.46
F9 -1	0.01	11.70	1.30	0.41
-2	0.02	8.23	1.22	0.52
-3	0.02	10.42	0.96	0.32
-4	0.02	7.52	1.24	0.51

Results are for 8 points in Figure 8, and 4 points in Figure 9