Evaluation of the Mineralogy of A Sample of Carmacks Acid Leach Residue

Report Prepared for:

Kilborn Engineering Pacific Ltd.

400 - 1380 Burrard Street

Vancouver, BC

V6Z 2B7

May 31, 1996

MINING AND MINERAL PROCESS ENGINEERING

UNIVERSITY OF BRITISH COLUMBIA

THE UNIVERSITY OF BRITISH COLUMBIA

Department of Mining and
Mineral Process Engineering
517 - 6350 Stores Road
Vancouver, B.C. Canada V6T 1Z4
Tel: (604) 822-2540 Direct Line: (604) 822-6781
Fax: (604) 822-5599

May 31, 1996

Tony Wachmann
Manager, Civil Engineering
Kilborn Engineering Pacific Ltd
400 - 1380 Burrard Street
Vancouver
BC V6Z 2B7

Re: Western Copper Holdings Ltd - Carmacks Project (Kilborn Project 8555-16)

Dear Tony:

Following discussions with Val Ness of your company and with reference to your letter of February 27, 1996, we have carried out preliminary testwork to investigate the nature of the neutralizing potential of the sample of Carmacks ore provided by Dr. Morris Beattie of Beattie Consulting Ltd. A copy of the correspondence from Dr. Beattie, which includes information on the preparation of the sample composite, is provided in Appendix I. It is understood that after acid leaching, difficulties have been encountered with raising the pH of the leach residues to allow satisfactory abandonment. Base consumptions to achieve neutral pH have been very high. This letter provides a summary report of our testwork.

During acid base accounting (ABA) testing of samples over the past few years, I have developed a qualitative tool to assist in assessing the interpretation of values obtained for NP (neutralizing potential). This technique involves the plotting of the titration curve during the back titration carried out following sample digestion either in the Sobek method or modified ABA methods. The shape of the curve can often provide useful indicators of the mineralogy of a sample. For example, the dissolution of aluminum silicates during acid digestion can be inferred if a significant inflection is observed in the curve between pH 4 and 5 due to the precipitation of aluminum in this pH range. Although the use of this technique to provide a qualitative assessment of the mineralogy of a leach residue might be limited, I have proceeded, at your request, to carry out three back titrations following digestions according to the following methods:

(i) ABA of Sobek (1978), using an acid addition corresponding to a fizz rating of "slight"
(ii) ABA of Sobek, using an acid addition corresponding to a fizz rating of "Strong"
(iii) Modified ABA, based on the method of Lawrence (1990)

Results of the ABA tests, including the back titration curves, are provided in Appendix II. Using the Sobek method, a NP value of 54 kg $CaCO_3$/t was obtained for the two tests with acid additions corresponding to slight and strong fizz ratings.

An acid leach residue would be expected to have little or no NP remaining after leaching. Testing using the Sobek method provided moderate NP values. Testing under the more moderate conditions of a Modified ABA procedure, provided a lower, but still detectable, NP value. The results, therefore, indicate the presence of some material which can consume significant amounts of acid. It is likely that this material is a reaction product which formed either under leach conditions or during attempts to neutralize the residue.

The back titration curves do not provide any clear information as to the nature of this material. The presence of a precipitated material such as aluminum sulfate in the residue which would be dissolved under the Sobek test conditions, would be evident if buffering from aluminum precipitation during the titration was shown . This is not the case.

A sample of the leach residue was screened at 100 mesh and the whole sample and the minus 100 mesh fraction were analyzed by x-ray diffraction (XRD). The fine fraction was analyzed because it was postulated that if a very fine-grained component of the leached sample is responsible for the buffering of the pH during neutralization, then it might be more apparent by analyzing this fraction. It is realized that such a material would more likely be amorphous in nature and would not, therefore be detectable by XRD.

The XRD data are provided in Appendix III. For the whole sample, a listing of the 48 most likely components of the sample are listed in order of abundance. The data indicate the presence of feldspars, predominantly albite. Many other mineral species are likely present but their abundance is too low to provide a definitive identification. Likely minor minerals include biotite, chlorite and amphibole (actinolite).

Four scanning electron micrographs were obtained, with corresponding energy dispersive x-ray analyses (EDS) of selected particles/particle groups. Both crystalline and non-crystalline species can be analyzed using this technique. Micrographs and corresponding EDS spectra are provided in Appendix IV.

As with the XRD data, the EDS spectra of apparently primary grains indicate a predominance of feldspars, both Na and Ca rich (albite and anorthite respectively). Analysis of very fine-grained and amorphous-looking material, which might be secondary species formed during the leaching process, did not reveal the presence of any species which could be obviously responsible for the pH buffering effect. Some mica was evident both from the spectra and morphological observations. There is some indication of Fe-O coatings. The absence of any significant sulfur peaks rules out an abundance of secondary

sulfate compounds formed during the leach. Chemical analyses of the material for total and sulfate sulfur confirm this observation.

A final test was set up with the objective to neutralize a slurry of the residue with slaked lime to observe the relationship between the change in pH and base addition. It was immediately observed that the slurry pH before base addition was approximately pH 5. This would indicate that neutralization of the residue had already been attempted. Since it was my understanding from Kilborn and Dr. Beattie that this was not the case, further discussions concerning the history of the residue were held with Dr. Beattie who indicated that the current sample had been produced in a bottle roll test because no column leach residues were available. It is now my understanding that the neutralization problems were only observed with the column tests.

Please call me if you have any questions or comments on this work. I appreciate the opportunity to work with you on this project.

Yours very truly,

Richard W. Lawrence, Ph.D.
Acting Head and Chair in Mining Environment

Appendix II

Acid Base Accounting Data and Back Titrations

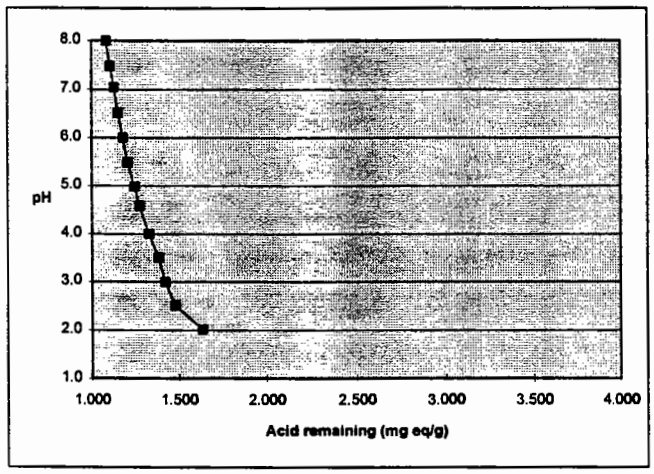
Sample: **Carmacks Leach Residue**

Method: Sobek (alternate fizz rating)
Fizz Rating: none

Measured NP: **54.1** kg CaCO3/t

Fizz category used in test	slight
Mass (g)	2.00
HCl (vol)	40.0
HCl (N)	0.10
NaOH (N)	0.10

pH	NaOH (ml)	Acid Remaining (mg eq/g)
1.7	0.00	2.000
2.0	7.30	1.635
2.5	10.35	1.483
3.0	11.50	1.425
3.5	12.25	1.388
4.0	13.35	1.333
4.6	14.35	1.283
5.0	14.95	1.253
5.5	15.70	1.215
6.0	16.25	1.188
6.5	16.80	1.160
7.0	17.30	1.135
7.5	17.75	1.113
8.0	18.20	1.090
8.3	18.35	1.083



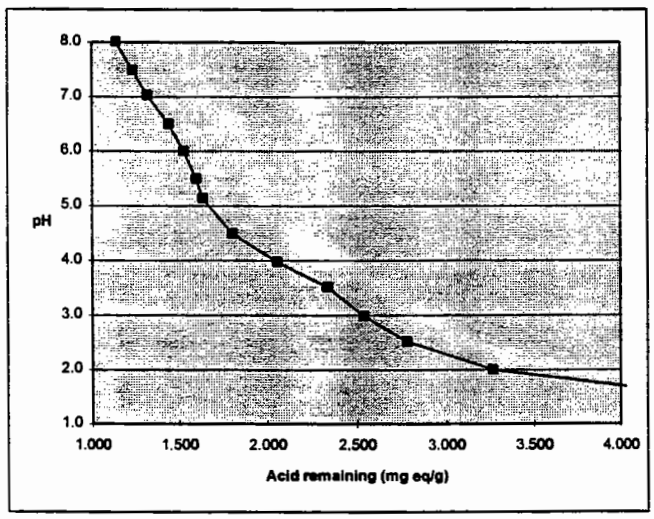
Sample: **Carmacks Leach Residue**

Method: Sobek (alternate fizz rating)
Fizz Rating: none

Measured NP: **54.8** kg CaCO3/t

Fizz category used in test	strong
Mass (g)	2.00
HCl (vol)	80.0
HCl (N)	0.50
NaOH (N)	0.48

pH	NaOH (ml)	Acid Remaining (mg eq/g)
0.7	0.00	20.000
1.0	43.70	9.490
1.5	64.50	4.488
2.0	69.60	3.261
2.5	71.60	2.780
3.0	72.60	2.540
3.5	73.45	2.335
4.0	74.60	2.059
4.5	75.65	1.806
5.1	76.35	1.638
5.5	76.50	1.602
6.0	76.80	1.530
6.5	77.15	1.445
7.0	77.65	1.325
7.5	78.00	1.241
8.0	78.40	1.145
8.3	78.60	1.097



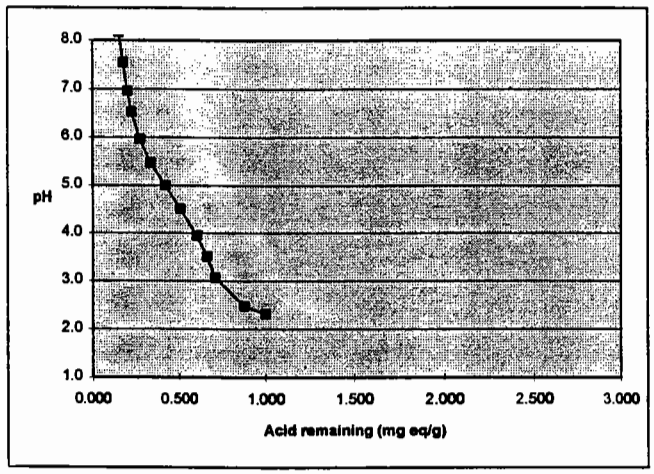
Sample: **Carmacks Leach Residue**

Method: Modified (based on Lawrence, 1990)
Fizz Rating: none

Measured NP: **7.3** kg CaCO3/t

Fizz category used in test	none
Mass (g)	2.00
HCl (vol)	4.0
HCl (N)	0.50
NaOH (N)	0.48

pH	NaOH (ml)	Acid Remaining (mg eq/g)
		1.000
2.3	0.00	1.000
2.5	0.50	0.880
3.1	1.20	0.711
3.5	1.40	0.663
4.0	1.65	0.603
4.5	2.05	0.507
5.0	2.40	0.423
5.5	2.75	0.339
6.0	3.00	0.279
6.5	3.20	0.230
7.0	3.30	0.206
7.5	3.40	0.182
8.2	3.50	0.158
8.4	3.55	0.146



Appendix I

Correspondence and Sample Information from Beattie Consulting Ltd

BEATTIE CONSULTING LTD.
2955 WEST 38th AVENUE
VANCOUVER, B.C.
V6N 2X2

TEL.(604) 263 0695
FAX.(604) 263 0695

February 29, 1996

Dr. Rick Lawrence
Department of Mining and Mineral Processing
University of British Columbia
6350 Stores Road
Vancouver, B.C. V6T 1Z4

Dear Rick,

RE: Back Titration Test for Carmacks Project

Enclosed please find a sample of leach tailings from the Carmacks Project. This sample is being provided to you for the purpose of a Back-Titration test as discussed with Val Ness of Kilborn. The origin and background to this sample are as follows:

The feed for this test was an overall composite sample (Comp. H) of diamond drill core samples which had been pepared from individual composites described as +2700H, 2500-2700H and 2300-2500H. The specific drill hole origin of these composites is summarized on the attached "Metallurgical Drill Core Composites". The samples had all been crushed prior to compositing and contained a greater proportion of fines than would be expected from a commercial crushing circuit.

Leaching of the copper was achieved in a 96 hour bottle roll test. An initial addition of 20 kg/tonne acid was added to this test and the solution was treated periodically by means of solvent extraction to remove the dissolved copper and restore a reasonable free acid concentration. The test details are attached. A copper extraction of 77.7% was achieved with an acid consumption of 19.3 kg/tonne. Both these results are slightly lower than expected for the commercial operation. However, the residue from this test is believed to be the most representative material which is available for the leach tailings. Following the leaching, the sample was filtered, washed

and dried before analysis.

Please let me know whether there are any problems with this sample.

Best regards,

BEATTIE CONSULTING LTD

MBeattie

Dr. M.J.V. Beattie, P.Eng.

cc V.H. Ness, Kilborn

WILLIAMS CREEK PROJECT
METALLURGICAL DRILL CORE COMPOSITES

Sample #	DDH #	From	To	Length (feet)	Weight (lbs)
+27L	25	18	101	83	235
	26	10	86	76	215
	31	102	167	65	185
				224	**635**
+27H	25	101	176	75	213
	26	86	146	60	170
	31	32	102	70	199
				205	**582**
25-27L	23	122	241	119	338
	29	252	291	39	110
	33	323.5	334	10.5	30
	51	88.3	174.9	86.6	246
				255.1	**724**
25-27H	23	241	336	95	270
	29	164	252	88	250
	33	275	323.5	48.5	138
				231.5	**658**
23-25L	24	384.5	428	43.5	1.24
	45	436.2	480	43.8	124
	52	406	440	34	97
	52	555	580	25	71
	53	470.8	539.1	68.3	194
				214.6	**610**
23-25H	24	428	553	125	355
	45	480	524.3	44.3	126
	52	440	555	115	326
				284.3	**807**
SE	34	73.5	153.5	80	227
	37	181	245.5	64.5	183
	48	10	68	58	165
	54	160	197.2	37.2	106
				239.7	**681**
		GRAND TOTAL			**4697 LBS**

BOTTLE ROLL ACID LEACHING WITH SX

Test No: 92-007 L6 Date: 5/22/92

Sample Description: Comp. H

TEST CONDITIONS:

Solids: 2000 g H2O: 2000 g

% Solids: 50.0

Solution strength: 20 g/L H2SO4 (initial)

TEST RESULTS:

Solution Analyses:

TIME	PREGNANT SOLN.				RAFFINATE			H2SO4
hrs	ml	Cu g/L	ORP	pH	ml	Cu g/L	pH	g added
0								40
0								0
2	1714	7	326	2.92	1629	2.49	1.14	0
6	1627	4.44	333	2.64	1545	0.85	1.26	0
24	1577	2.5	307	3.01	1494	0.16	1.35	0
48	1274	1.37	315	2.89	1031	0.016	1.67	0
72	1230	0.72	312	2.92	1145	0.003	1.72	0
96	1214	0.43	310	2.97				-1.48
								0
wash	3221	0.05						

Residue Analysis:

TIME	WEIGHT	Cu
hrs	g	%
	1917	0.33

SUMMARY:

TIME	COPPER EXTRACTION		ACID CONSUMPTION	
hrs	INDV. %	CUM. %	INDV. kg/t	CUM. kg/t
0			20.0	20.0
0			0.0	20.0
2	50.4	50.4	0.0	20.0
6	11.5	61.9	0.0	20.0
24	7.4	69.3	0.0	20.0
48	4.5	73.8	0.0	20.0
72	1.9	75.7	0.0	20.0
96	1.3	77.1	-0.7	19.3
	0.0	77.1	0.0	19.3
wash	0.6	77.7		

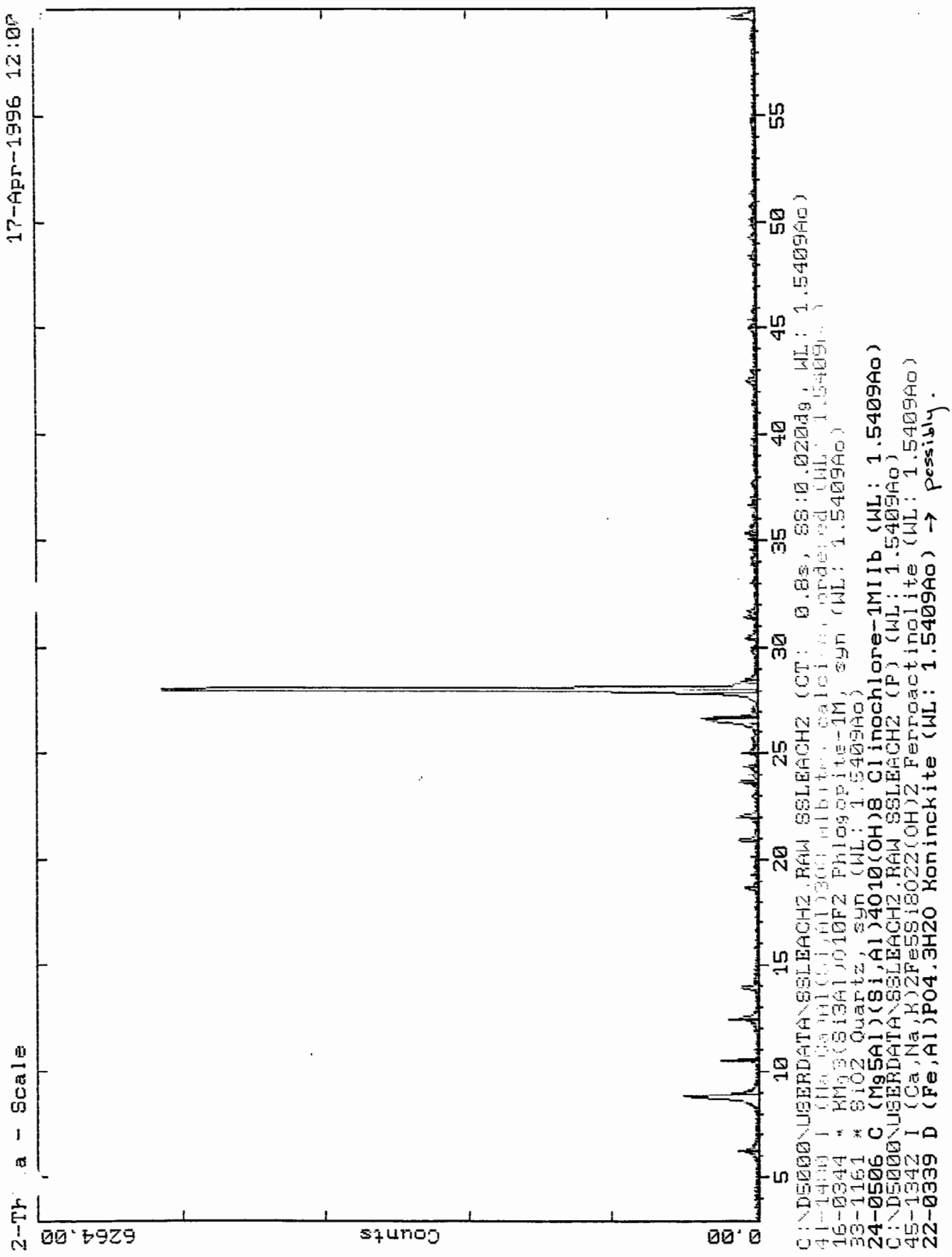
HEAD GRADE
calc. % Cu
1.36

Appendix III

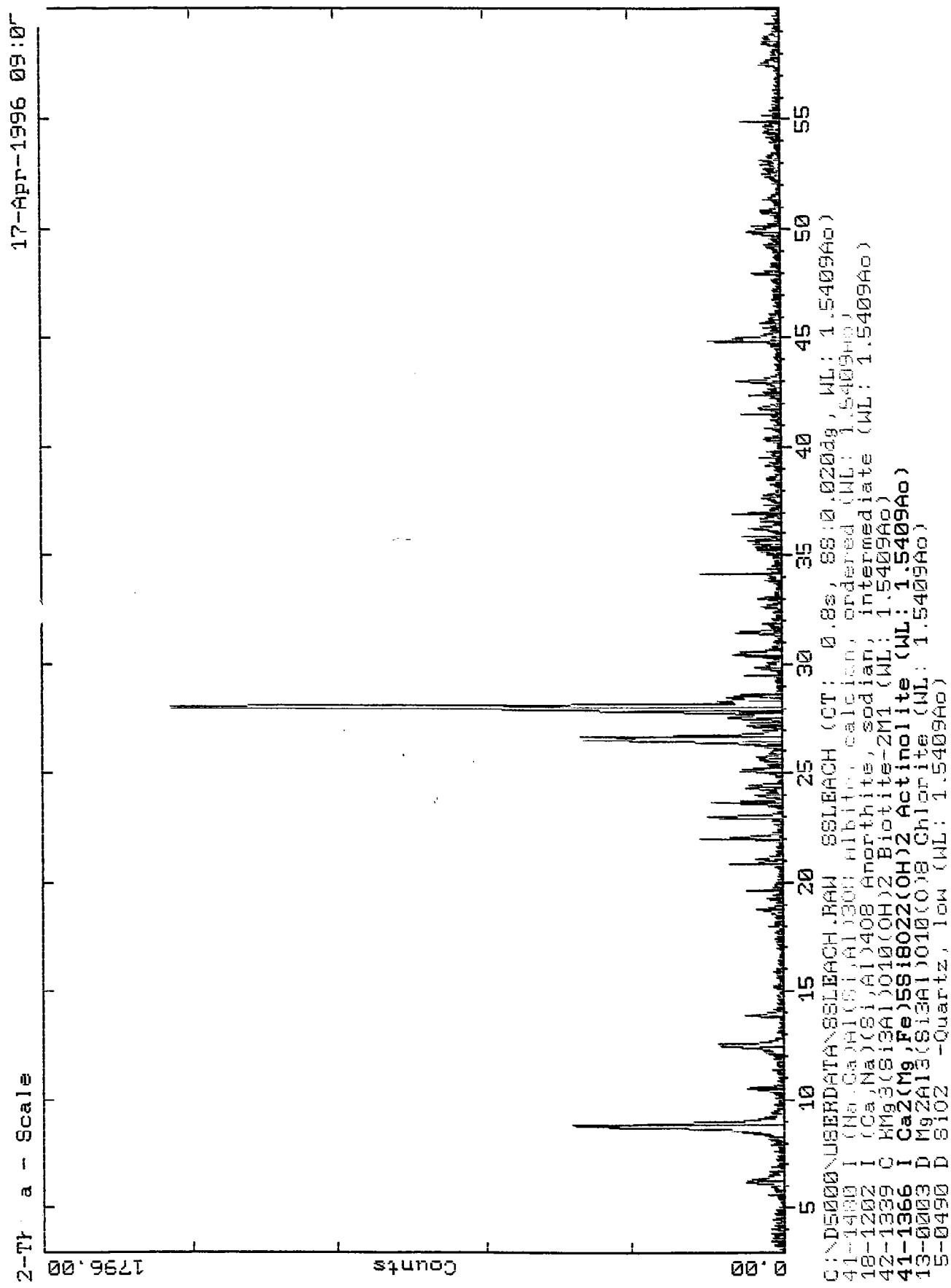
X-ray Diffraction Data

XRD ANALYSIS

Minus 100 mesh Leach Residue



XRD ANALYSIS
Leach Residue - whole sample



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Data base: C:\PDF\JCP.CAT
Criterion: 3, Penalty: 8, 2 theta offset: 0.000, d - offset: 0.00

51532 standards, 51532 match chemistry/subfile, 51453 match intensity, 11.48s

	(Mtc: Matched lines, nM: non Matched lines, FOM: Figure of Merit)			Mtc	nM	FOM
1	41-1480	I	(Na,Ca)Al(Si,Al)3O8 Albite, calcian, ordered	47	5	0.68
2	20-0548	D	(Na,Ca)(Si,Al)4O8 Albite, calcian, ordered	50	7	1.14
3	31-1001	*	KCuPO4.H2O Potassium Copper Phosphate Hydrate	39	9	1.44
4	19-1184	I	NaAlSi3O8 Albite, ordered	70	24	1.45
5	20-0554	D	NaAlSi3O8 Albite, ordered	46	10	1.50
6	29-0440	I	Cs2U4O12 β-Cesium Uranium Oxide	63	9	1.73
7	44-0607	C	Mg15V6Mo6O48 Magnesium Vanadium Molybdenum Oxide	84	14	1.73
8	45-0768	C	C10H23N2O10Pr.H2O Ammonium Praseodymium Acetate Hydra	94	21	1.82
9	18-1202	I	(Ca,Na)(Si,Al)4O8 Anorthite, sodian, intermediate	44	8	1.83
10	43-0495	*	Hg2PCl2 Mercury Chloride Phosphide	48	7	1.84
11	10-0393	*	Na(Si3Al)O8 Albite, disordered	36	6	1.88
12	9-0466	*	NaAlSi3O8 Albite, ordered	37	8	1.88
13	20-0528	C	(Ca,Na)(Al,Si)2Si2O8 Anorthite, sodian, ordered	64	17	1.91
14	43-0149	C	Na7Gd27(Al88.11Si103.90384).19H2O Sodium Aluminum Gad	50	23	1.93
15	45-0128	C	Na48(ZnPO4)96.126H2O Sodium Zinc Phosphate Hydrate Ze	64	9	1.96
16	44-0048	C	Ca0.32Ba3.32(Al8.6Si39.9)O96 Barium Calcium Aluminum	93	27	1.96
17	29-0432	*	Cs2U4O12 α-Cesium Uranium Oxide	38	7	2.00
18	45-0194	*	CaCuV2O7 Calcium Copper Vanadium Oxide	58	12	2.09
19	44-0717	*	C2H8N4O2.Cd(ReO4)2 Cadmium Rhenium Oxide Urea	78	19	2.13
20	27-0047	*	Bi3FeMo2O12 Bismuth Iron Molybdenum Oxide	30	6	2.17
21	37-1468	*	Nb2O5 Niobium Oxide niobium pentoxide	84	23	2.17
22	34-0844	Q	Co3(PO4)2.4H2O Cobalt Phosphate Hydrate	34	10	2.26
23	41-1481	I	(Ca,Na)(Si,Al)4O8 Anorthite, sodian, disordered	35	8	2.26
24	37-0801	*	RbHSO4 Rubidium Hydrogen Sulfate	65	19	2.27
25	43-0784	Q	SiO2 Silicon Oxide	63	13	2.31
26	43-0213	*	CaBi2O4 Calcium Bismuth Oxide	68	15	2.35
27	40-0707	C	Ba3Nd2B4O12 Barium Neodymium Borate	77	22	2.37
28	41-1486	*	CaAl2Si2O8 Anorthite, ordered	46	13	2.37
29	42-0021	C	AlNaSiO4.1.03H2O Sodium Aluminum Silicate Hydrate Zeo	90	21	2.40
30	32-0537	*	Pb3SiO5 Lead Silicate	42	9	2.40
31	39-0480	C	CsSb2Se4 Cesium Antimony Selenide	71	21	2.40
32	43-0364	*	UO3.2H2O Metaschoepite, syn	59	18	2.40
33	42-0365	*	Er3(SiO4)2Cl Erbium Chloride Silicate	47	10	2.41
34	25-0408	C	H3PO4.0.5H2O Hydrogen Phosphate Hydrate	44	14	2.41
35	42-1339	C	KMg3(Si3Al)O10(OH)2 Biotite-2M1	63	15	2.41
36	19-0931	D	KAlSi3O8 Orthoclase	57	15	2.41
37	31-0966	*	KAlSi3O8 Orthoclase	57	15	2.41
38	41-1366	I	Ca2(Mg,Fe)5Si8O22(OH)2 Actinolite	62	18	2.41
39	44-0437	*	Gd6(NO3)8O(OH)8.17H2O Gadolinium Nitrate Hydroxide Hy	60	24	2.43
40	22-0712	I	(Ni,Mg,Al)6(Si,Al)4O10(OH)8 Nimite-1MIIb	16	3	2.44
41	35-0416	I	Dy(MoO4)(ReO4) Dysprosium Molybdenum Rhenium Oxide	40	11	2.44
42	41-0789	C	AsHf3 Arsenic Hafnium	90	19	2.45
43	37-1477	*	Ba3Ti5Nb6O28 Barium Titanium Niobium Oxide barium tit	53	11	2.45
44	22-1397	C	Na2Si2O5 α-Sodium Silicate	36	7	2.46
45	34-0204	*	K7PW11O39(H2O)15.6 Potassium Phosphorus Tungsten Oxid	60	13	2.48
46	45-1371	I	Ca2(Mg,Fe+2)4Al(Si7Al)O22(OH,F)2 Magnesiohornblende,	43	14	2.49
47	39-0461	C	Ca3Si2As4 Calcium Arsenic Silicide	42	8	2.49
48	44-1387	C	Rb7.48Al8Si40O96 Rubidium Aluminum Silicate Mordenite	74	35	2.53

Appendix IV

Scanning Electron Micrographs and Energy Dispersive X-ray Analysis

Electron Micrographs for Carmacks Leach Residue

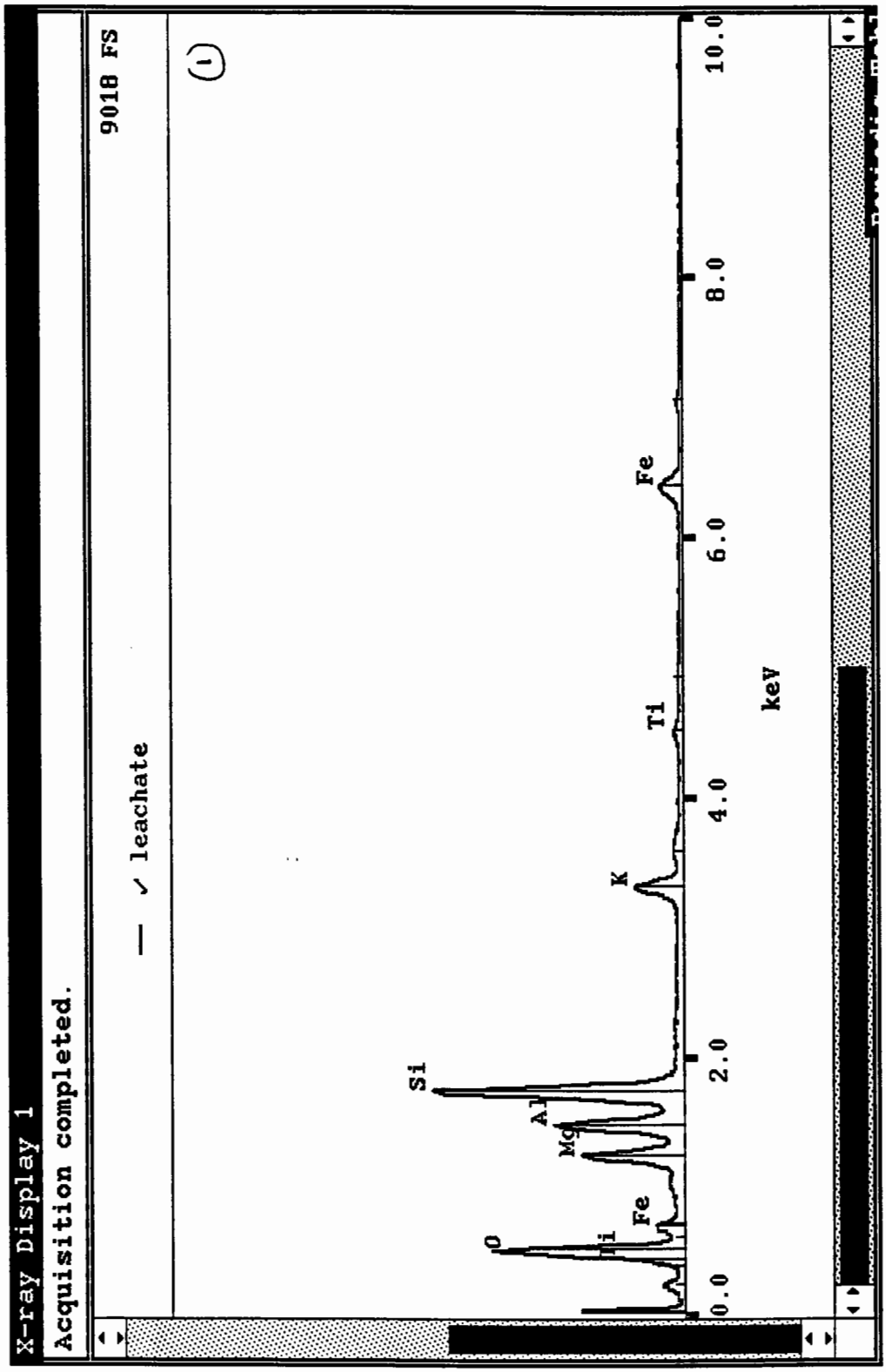
Micrograph 2

Micrograph 4

Micrograph 1

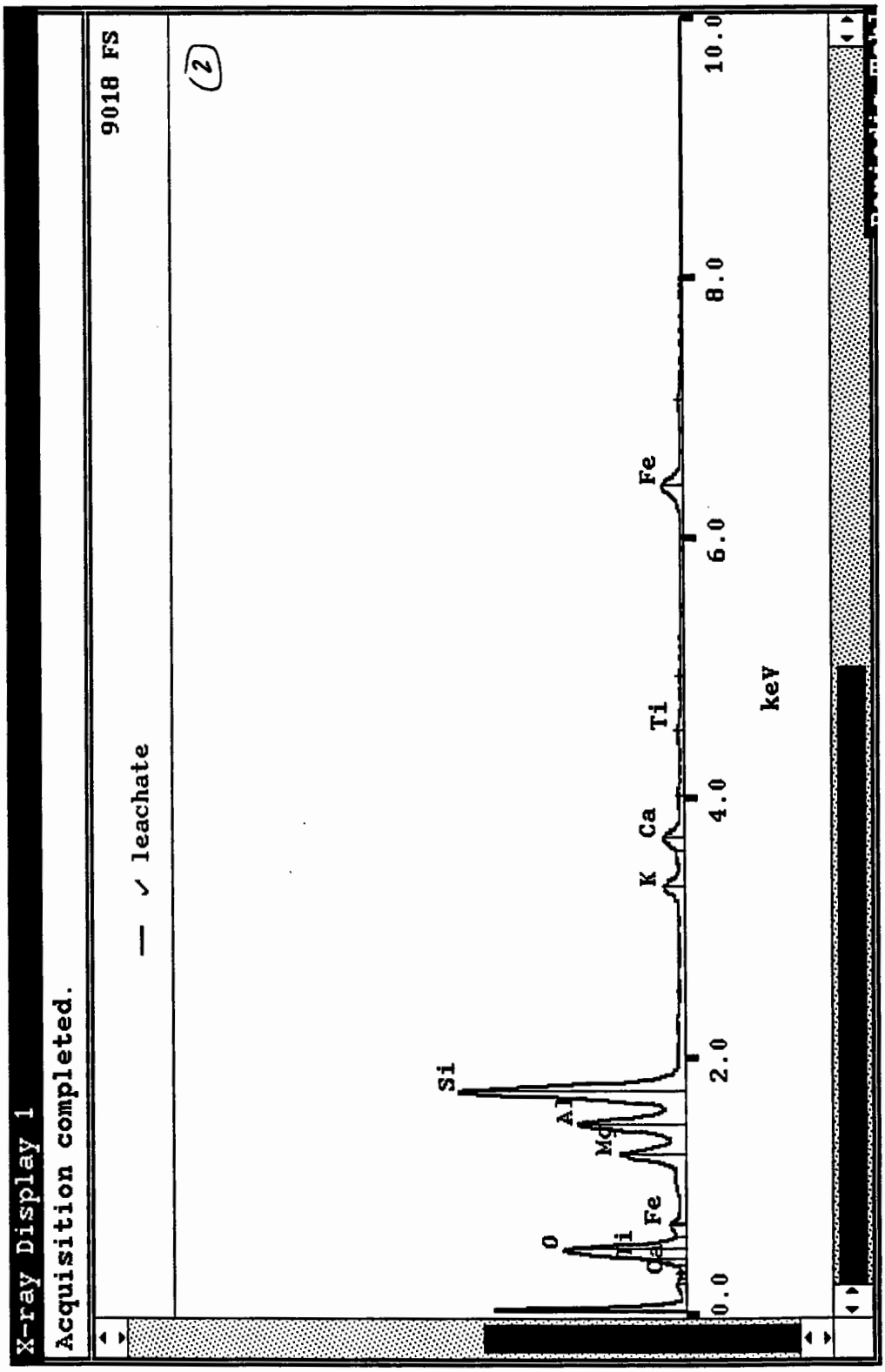
Micrograph 3

EDS Analysis of Carmacks Leach Residue
Micrograph 1 - Point 1



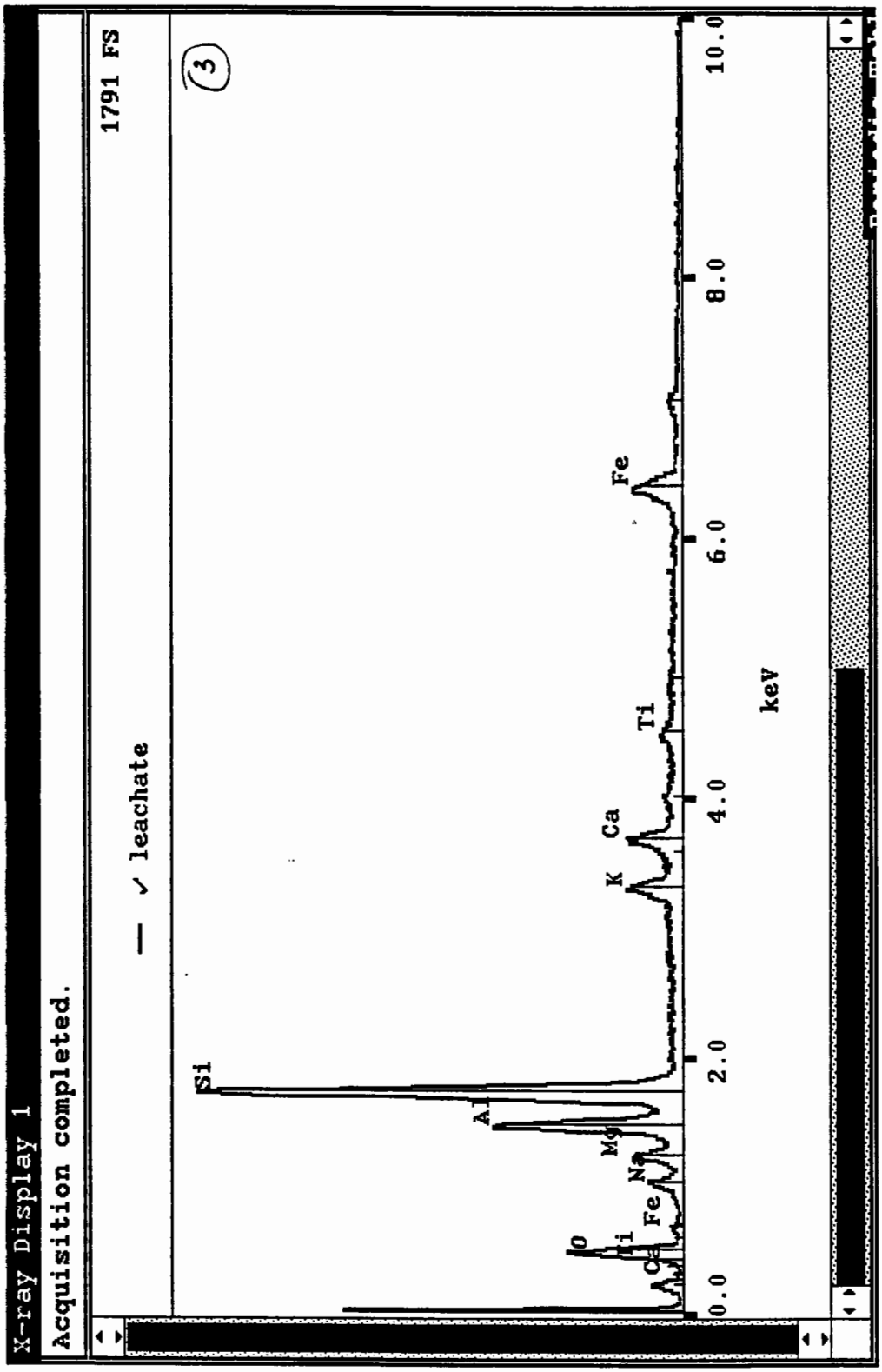
Rick Lawrence: random EDS analysis of leachate

EDS Analysis of Carmacks Leach Residue
Micrograph 1 - Point 2



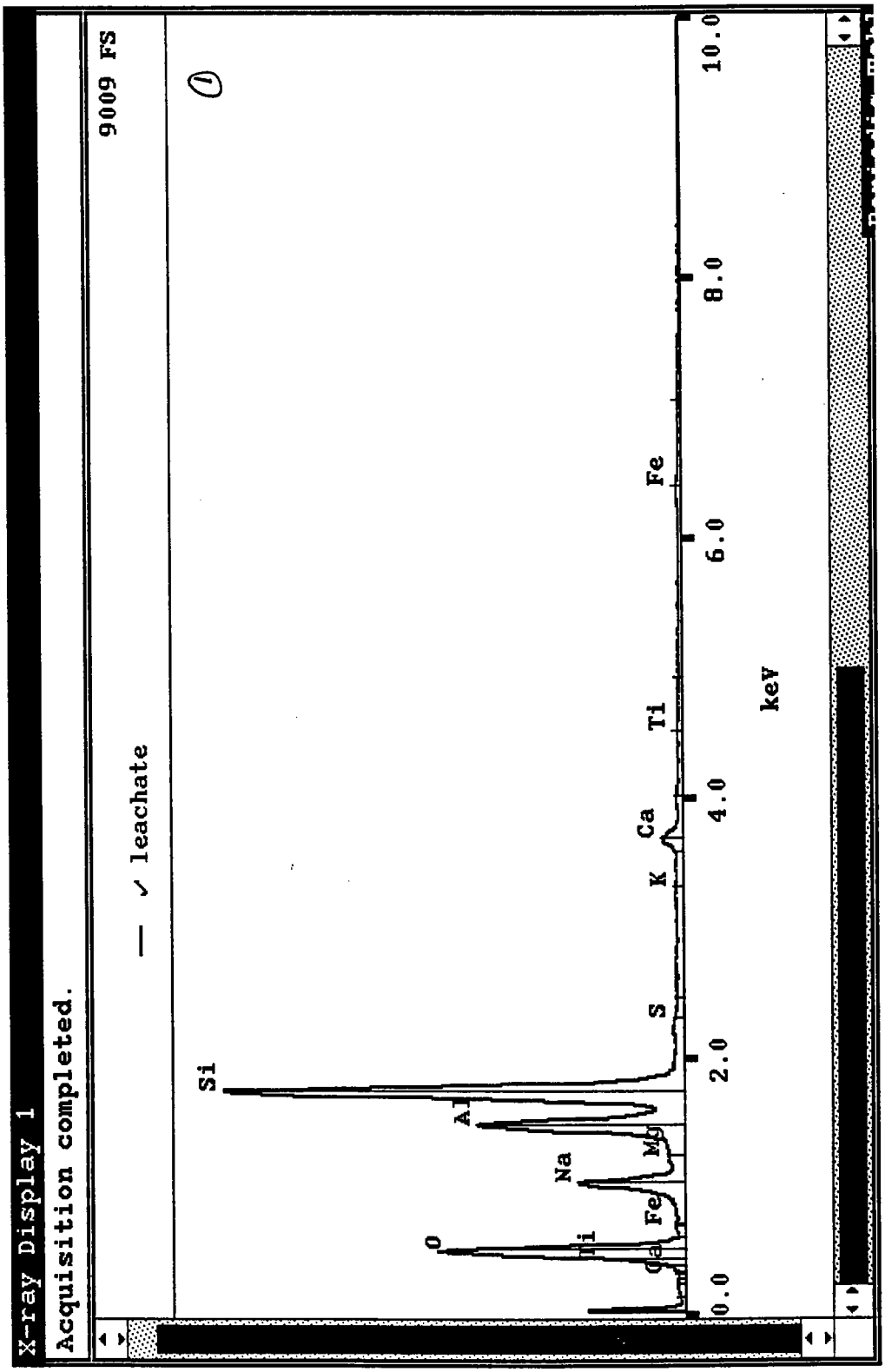
Rick Lawrence: random EDS analysis of leachate

EDS Analysis of Carmacks Leach Residue
Micrograph 1 - Point 3



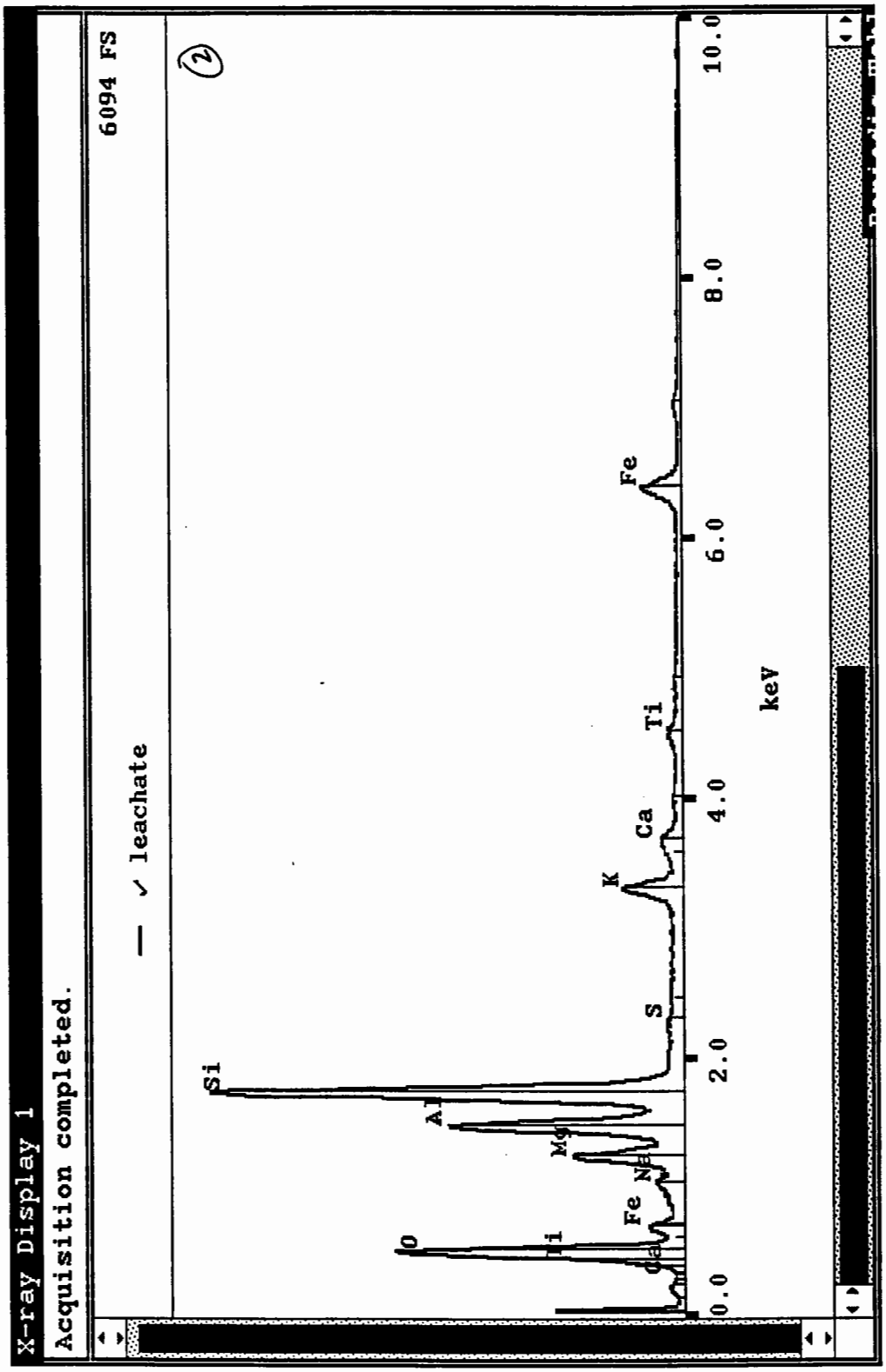
Rick Lawrence: random EDS analysis of leachate

EDS Analysis of Carmacks Leach Residue
Micrograph 2 - Point 1



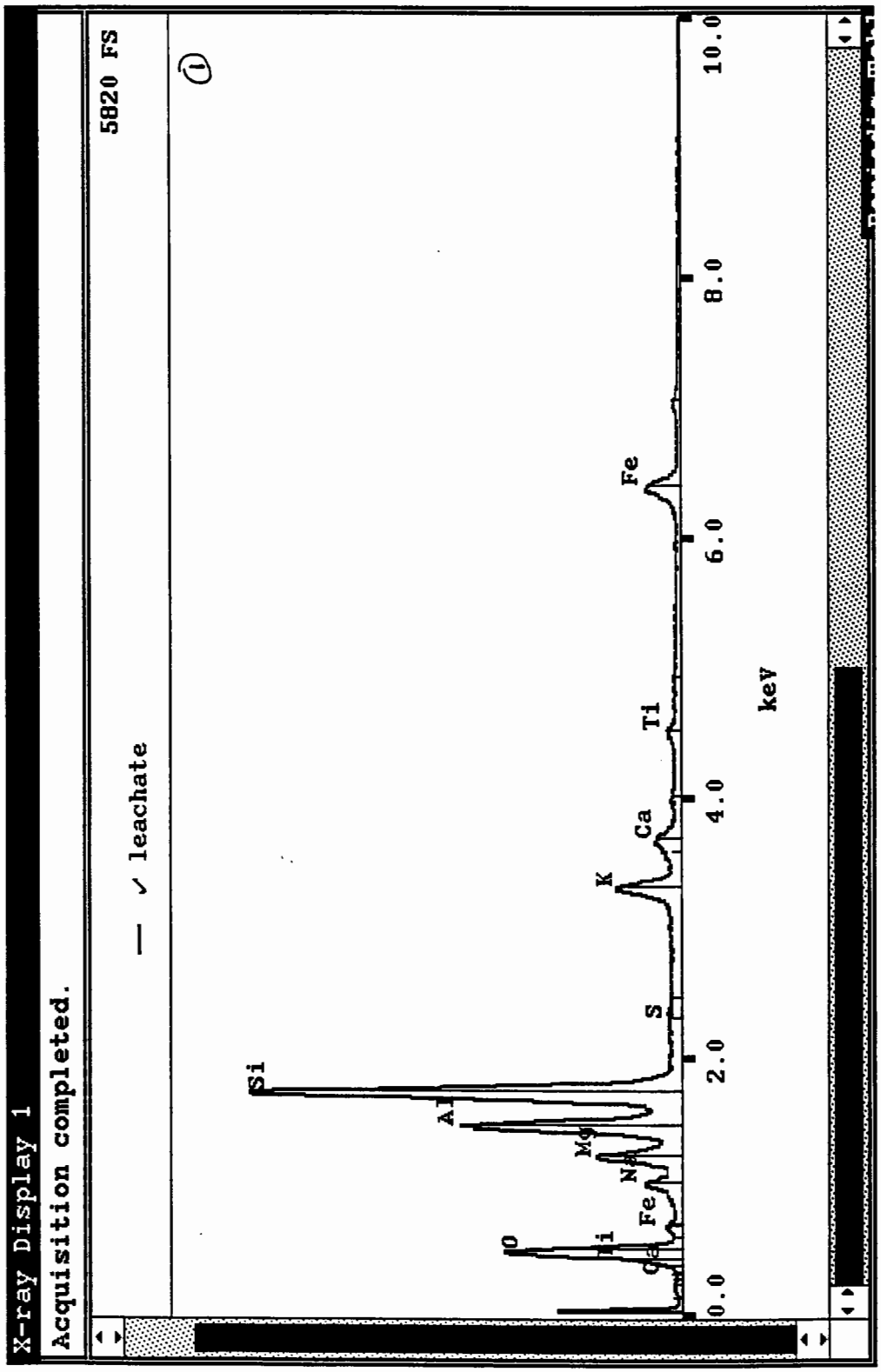
Rick Lawrence: random EDS analysis of leachate

EDS Analysis of Carmacks Leach Residue
Micrograph 2 - Point 2



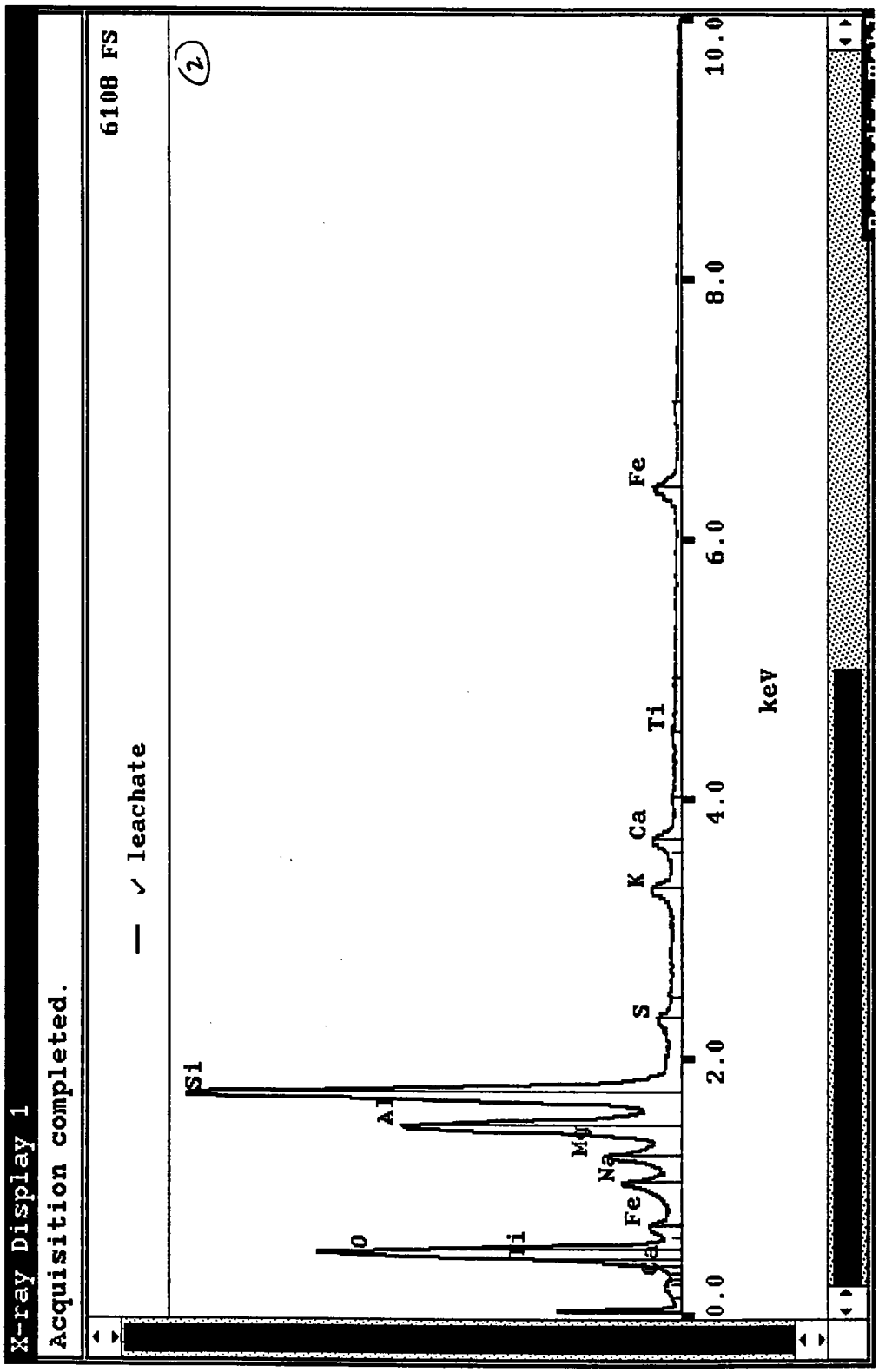
Rick Lawrence: random EDS analysis of leachate

EDS Analysis of Carmacks Leach Residue
Micrograph 3 - Point 1



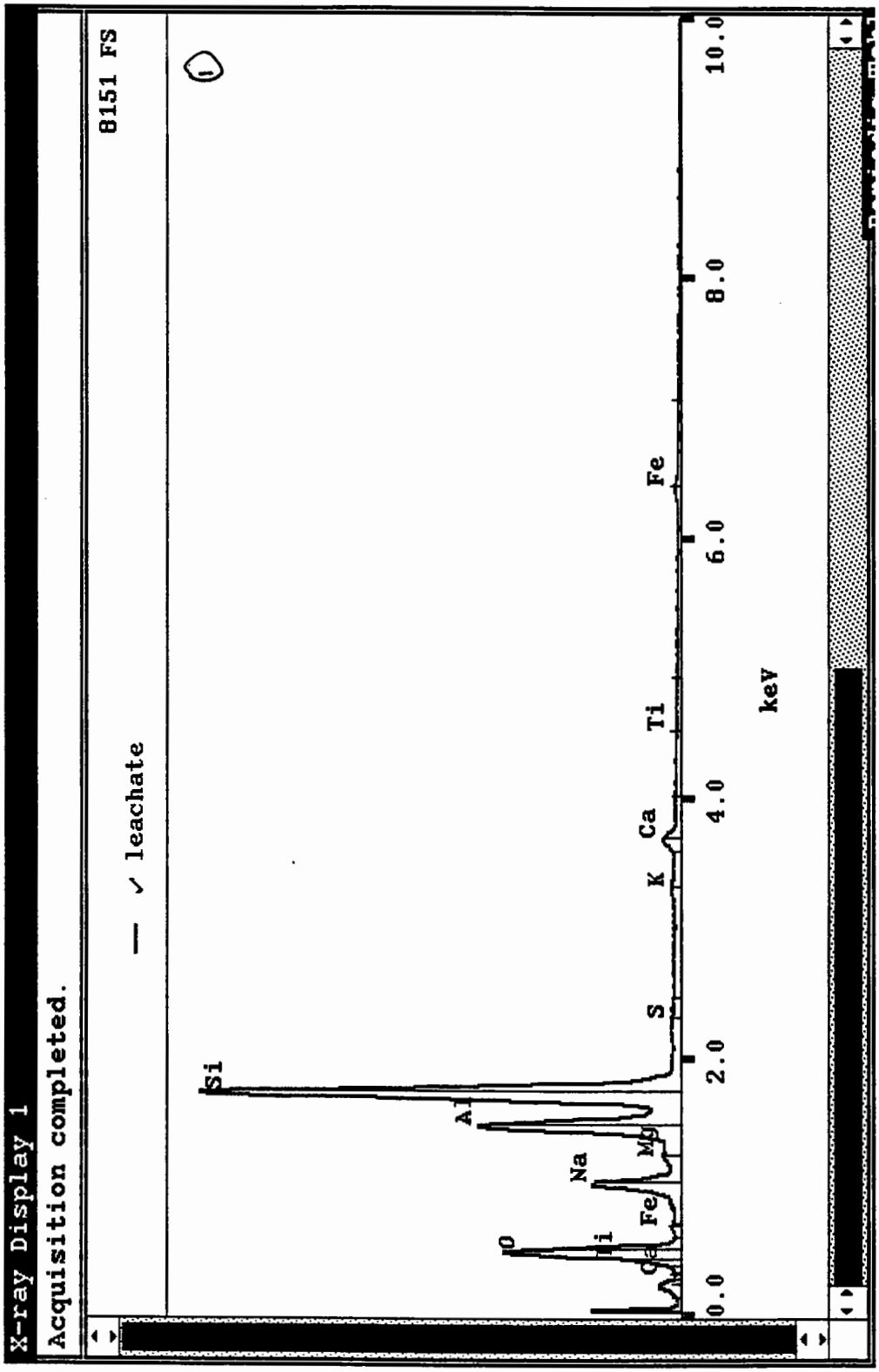
Rick Lawrence: random EDS analysis of leachate

EDS Analysis of Carmacks Leach Residue
Micrograph 3 - Point 2



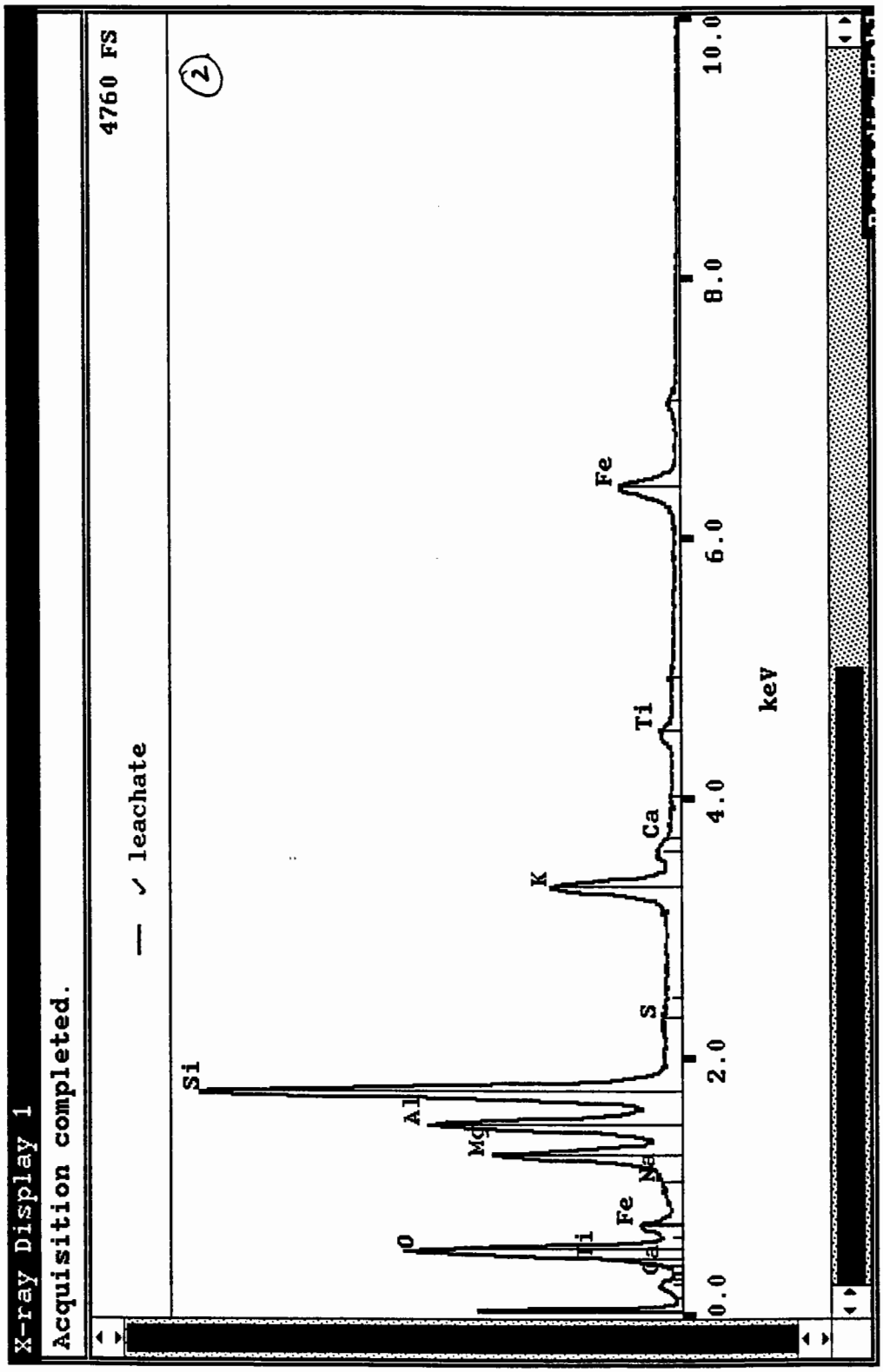
Rick Lawrence: random EDS analysis of leachate

EDS Analysis of Carmacks Leach Residue
Micrograph 4 - Point 1



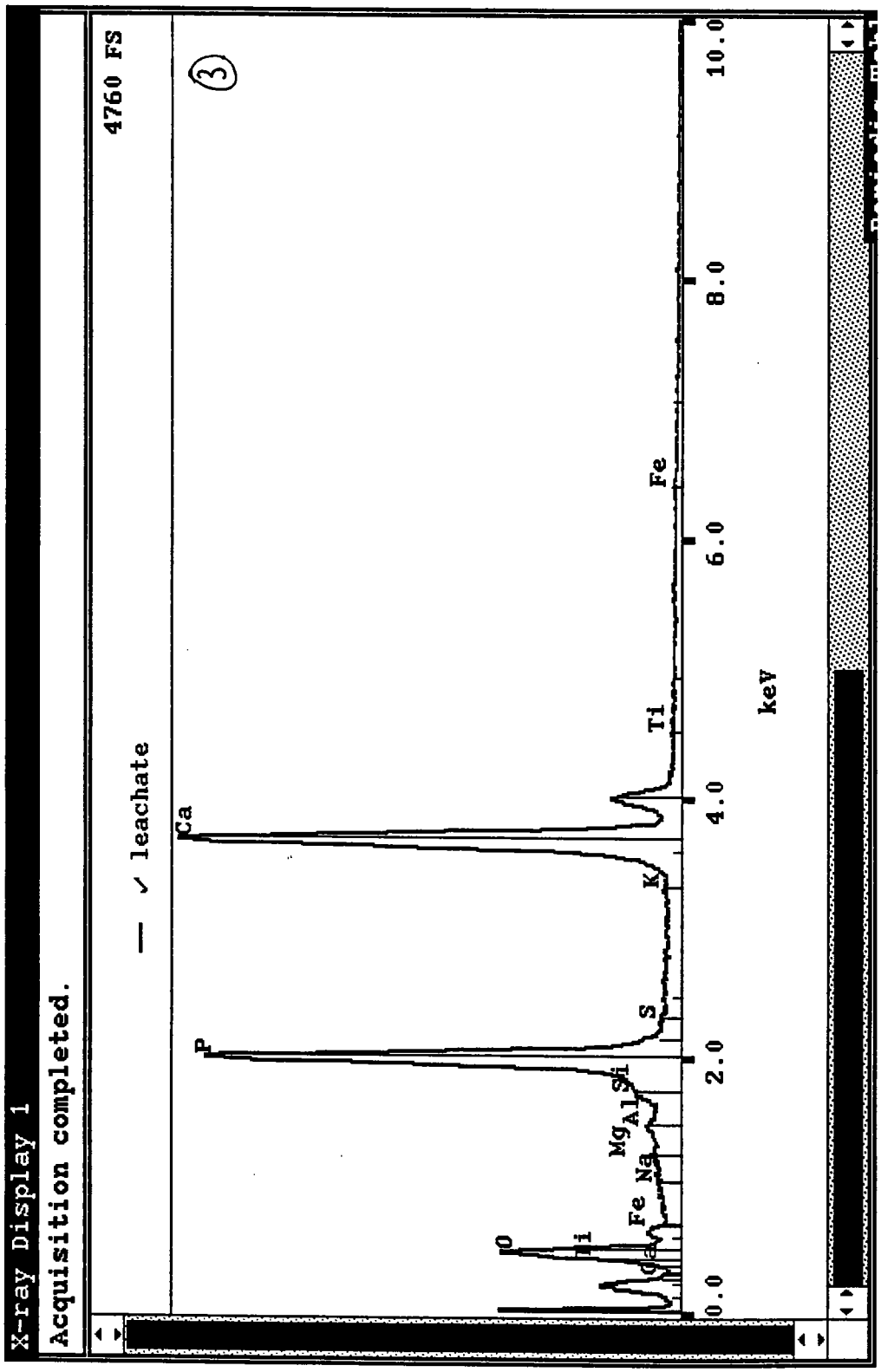
Rick Lawrence: random EDS analysis of leachate

EDS Analysis of Carmacks Leach Residue
Micrograph 4 - Point 2



Rick Lawrence: random EDS analysis of leachate

EDS Analysis of Carmacks Leach Residue
Micrograph 4 - Point 3



Rick Lawrence: random EDS analysis of leachate