SUMMARY OF RESULTS

INVESTIGATIONS IN ALICE ARM

MAY-JUNE, 1981

by

L. HARDING

Environmental Protection Service

Environment Canada

July, 1981

Government of Canada / Gouvernement du Canada

MEMORANDUM NOTE DE SERVICE

SECURITY - CLASSIFICATION - DE SÉCURITÉ	
OUR FILE — N / RÉFÉRENCE	4780-37/C620
YOUR FILE — V / RÉFÉRENCE	
DATE	July 7, 1981

TO / A: Fred Claggett, Manager
Pollution Control Group

FROM / DE: Lee Harding, Coordinator.
Freshwater & Marine Programs

SUBJECT / OBJET: Alice Arm Tailings Plume

With completion of chemical analyses and electron micrography it seems appropriate now to summarize all available information bearing on the tailing plume. Analysis of available data from our May-June cruise in Alice Arm has yielded the following results:

1. Transmissometry

During May 21-27 a zone of suspended material or plume remained at depths of 60-90 meters in Alice Arm, with clearer water above and below it. It occurred throughout the head of the inlet where total depth was greater than 90 meters and extended seaward well beyond Roundy Creek. It limited light transmission from a normal of about 80% to 60-40%. It was highest and most dense near the Kitsault Mine outfall, and deeper and most diffuse near its seawardlimits. It was observed neither to mix with surface waters, nor to descend with time at any given station. This mid-depth plume was separate from the main mass of tailings, which performed as predicted and was observed near the bottom of Alice Arm.

Following shutdown of the mill on May 27, the plume began to dissipate and shrink in extent, until by June 1, when it was only detectable quite near the outfall. When the mill began discharging on June 1,the plume re-appeared immediately. From then until June 16-the last data -the plume increased in both density and distribution, finally extending some four kilometers seaward. Data on which these observations are based, and a summary of results, are presented in the brief, "Data Record on Transmissometry in Alice and Hastings Arms, B.C. 1977-1981" in three volumes by D. Goyette and R. Hinder of my staff.

2. Chemistry

Pre-operational chemical data were presented previously in the brief "Data Report on Trace Metals in Marine Sediments and Biota From Two Mine Waste Disposal Sites in Alice and Hastings Arms, B.C." by D. Goyette.

Solid particulates from water samples were analysed for heavy metals in three batches: on May 29, four samples from the plume and one from surface waters, all taken the previous day, were analysed. Also on May 29, samples from 0, 25, 60, 65, 70, 75, 80 and 85 meters from a station 200 meters off the outfall were analysed. Unfortunately, some filters burst and the particulate residue for the 0, 25 and 70 & 85 meter samples were lost. On June 26, 38 samples taken during May 23-June 6, from various depths and at various stations in the head of Alice Arm, were analysed. More than twice that number had been submitted but were unfortunately lost due to the same filtering difficulty.

For all the above, samples of approximately one liter were filtered (0.4 microns) ashed, digested (aqua regia to 12%) and analysed by Inductively Coupled Argon Plasma Emission Spectrometer. Results are in Appendix 1, Tables 1, 2 and 3. Not all depths are given in Appendix 1, Table 3, however, the samples were taken of the mid-depth plume as indicated by transmissometer readings.

Results are summarized in the following Table 1. Only samples containing greater than 2.0 mg/l of suspended material were included because

(1) This, combined with transmissometer readings (from Goyette and Hinder, 1981) is sure to represent the plume,

(2) In samples with less total material, background content comprising a greater proportion of the total could have biased results,

(3) Filters contained extremely small amounts of residue (Samples with less than 2 mg/l particulate contained less than 0.002 g), so that measured amounts of heavy metals had to be multiplied by a conversion factor (See Appendix 1, Table 3) to express results as mg/g. Normal analytical variability was of course also multiplied, giving a potential for very large errors in the smaller particulate amounts.

Note in Table 1 that lead, cadmium, molybendum, Arsenic, iron and aluminum in surface waters are outside the range of concentration of those metals abserved in the mid-depth plume. This is consistent with results from a single series collected on May 27-28 and analysed on May 29 (Appendix 1, Table 1), and with the water column profile sampled May 24 and analysed May 29 (Appendix 1, Table 2). Surface water particules are not, however, chemically different from natural sediment in, either Alice Arm or its drainage basin. Note also, in Table 1 that heavy metal levels in the mid-depth plume are generally consistent with those in the deeper plume and with Kitsault Mine tailings.

On several occasions (eg., N-11 on May 23, N-8 on May 23, L-6 on May 29, I-7 June 6, G-5 on June 1, F6 on June 1 and outfall - D May 28) the transmissometry readings indicated a turbid layer about 25 meters deep (Goyette and Hinder, 1981). One of these was sampled (Sample No. 563, Appendix 1 Table 3) at the outfall on May 28 for chemical analysis. It contained 11,900 ug/g of molybdenum, and other metal levels consistent with Kitsault mine tailings.

In order to compare the chemistry of very fine, suspended particulates with bulk tailings slurry, I asked CanTest Ltd. to conduct two analyses using the same analytical techniques as our lab, as follows: (1) a sample of tailings slurry was analysed for total metals, and (2) a subsample of the same slurry was added to distilled water, shaken and allowed to settle for 15 hours. The supernatant was filtered and the residue was analysed for total metals. Their report is Appendix 2.

Table 1 - Comparison of Trace Metals in mid-Depth Plume with Deep Plume. Surface Waters, Kitsault Mine Tailings and Natural Sediments.

Element		Mid-Depth Plume(60-100m)[1]	Deep Plume(155m)[1]	Surface[1]	Mine Tailings[2]	Natural Sediments Alice Arm[3]	Natural Sediments Alice Arm Basin[4]
Cu	$\overline{x}$	102.9	438.0	91.8	43.7	44.4	58
	n	14	1	1	1	38	134
	r	45.0-223.0				29.4-73.2	
Pb	$\overline{x}$	160.5	224.0	*100.1	140.0	66.9	23.5
	n	13	1	1	1	38	134
	r	111.0-370.0				46.5-148.0	
Zn	$\overline{x}$	603	682.0	470.0	280.0	126.1	176
	n	14	1		1	38	134
	r	250-1010				87.2-231.0	
Cd	$\overline{x}$	21.1	*15.4	*10.0	*30.0	0.64	
	n	8	1	1	1	38	
	r	16.7-27.6				0.54-1.09	
Mo	$\overline{x}$	105.9	144.0	*37.5	146.0	*18.0	7.9
	n	14	1	1	1	38	134
	r	52.8-201					
Cr	$\overline{x}$	181.5	382.0	207.0	122.0		
	n	11	1	1	1		
	r	23-440					
As	$\overline{x}$	56.1		301.0			13
	n	3		1			134
	r	43.3-67.4					
Fl	$\overline{x}$	15,307	30,500	39,100	4,320	39,100	38,000
	n	14	1	1	1	38	134
	r	10,200-25,400				29,400-72,900	
Al	$\overline{x}$	3864	12,300	20,000	12,700	21,273	
	n	14	1	1	1	38	
	r	1860-8670				17,000-30,900	

Element		Mid-Depth Plume(60-100)	Deep Plume(155m)	Surface	Mine Tailings	Natural Sediments Alice Arm	Natural Sediments Alice Arm Basin
Mn	$\overline{x}$	914.0	967.0	1070	122.0	985.6	1375
	n	14	1	1	1	38	134
	r	455-1780				533-2310	

* Less than

[1] Analysis of June 26, 1981 of samples taken during May 23 - June 6, 1981

[2] From Appendix 2

[3] From Table 3 in Goyette, 1981

[4] From Table 4 in Goyette, 1981

Based on available data. particles in the mid depth and deeper plumes are chemically different from surface waters and natural sediments. but not chemically different from Kitsault Mine tailings. There is also evidence, both chemical and by transmissometry, that tailings were present at a depth of 26 meters over the outfall.

3. Organic Content

Non-filterable residue (total suspended solids greater than the filter pore diameter of 0.4 um), fixed (mineral) residue and non-filterable volatile (organic) residue of the 38 chemical samples are given in Appendix 1, Table 4. Although organic content of these samples varied from 0 to 1.2 mg/l, most (73%) contained 0.1 to 0.4 mg/l organic material. There was apparent no correlation with depth or location. Organic content was more or less constant, regardless of the amount of total solids present. In the more turbid samples, the bulk (usually greater than 97%) of the material was fixed, or mineral, residue.

For three samples in which the filtrate was filtered again on a 0.1 u filter, the organic contents of the residues were 100%, 100% and 57%, indicating that most of the very fine fraction was organic.

When examined under a 50x microscope at the time of sampling, water samples from the densest part of the plume, from surface waters and from deeper, clear water, all contained traces of plant detritus . Some, including those from the plume, contained live copepods. Surface and plume water samples also contained apparently mineral particles which were more abundant than the plant particles.

4. Particle Size

Particle size analysis was provided previously (Harding-Claggett June 30, 1981, Appendix 3). This sample was the same as that analysed by CanTest, June 9. Forty percent of a tailings sample passed a 44 u sieve, only 0.4% measured 1.38-0.98 u, by sedigraph analysis, and approximately 100% of the sample was above that size.

As noted in Section 3, most (70%, average of 3 samples) particulate material from the plume did not pass a 0.4 u filter, and what did, was mostly organic

5. Electron Micrography

Electron micrographs have been made by Mr. D. DeMill of my staff, of a series of filtered (0.1 u) residues from the mid-depth plume in Alice Arm, and from surface waters (Appendix 4). I have consulted with Dr. McTaggart of U.B.C., a geochemist and electron micrograph expert, who advised that this technique cannot be used to differentiate between tailings and natural sediments because both are essentially ground rock and would be expected to have the same shapes. Differences may be due to minerology of origin but probably not to milling as opposed to natural weathering. The micrographs are of value for particle size measurements, which confirm the size ranges obtained by other means.

6. Relationship to Alice Arm Tailings Deposit Regulations (AATDR)

The AATDR authorize total suspended matter to be deposited in any concentration in Alice Arm, provided that:

1. the solid portion of the tailings do not pass west of a north-south line in the viciity of Hans Point (Sec. 5(a)).

2. the solid portion of the tailings are not deposited on the bed of any part of the estuaries of the Illiance River or the Kitsault River, or the bed of any part of Alice Arm above 100 meters depth (Section 5(b) (i) and (ii),

3. the solid tailings particles do not remain in suspension above a depth of 100 meters (Sec. 6(2), except that (a) solids may be deposited on the bed of Alice Arm in the viciity of the outfall structure where the water is less than 100 m and more than 50 m deep, and (b) solids may be suspended in the vicinity of the outfall structure where the water is less than 100 m and more than 50 m deep (Sec. 7(3)(a) and (b).

For definition of "total suspended matter" the AATDR refer to the Metal Mining Liquid Effluent Regulations (MMLER). The MMLER define "total suspended matter as "the non-filterable residue that results from the operation of a mine, that is contained in liquid effluent from the mine"; and prescribes a test for measuring total suspended matter as a gravimetric method by filtering through "Whatman GF/C or equivalent". The Whatman GF/C retains about 0.5-1 u particles and larger. The gravimetric method used by our lab for these analyses, using a 0.4 micron Nuclepore filter, retains slightly smaller sizes than a Whatman GF/C filter.

The "vicinity of the outfall structure" is not defined in the AATDR. or in the MMLER. An explanatory note covering transmission of the AATDR to AMAX of Canada Ltd. defined the vicinity as being between Lime and Roundy Creeks.

The criteria on which these regulations were based were the environmental concerns that (1) tailings should not contaminate comparatively productive euphotic and littoral zones, which are also the zones used most by salmon, (2) tailings not contaminate comparatively productive estuaries, and (3) tailings not escape beyond Alice Arm. With respect to concerns (1) and (2), the 100 meter depth restriction is clearly an arbitrary depth based on generally accepted productivity estimates for surface waters. With respect to concern (3), however, the 100 meter restriction is less arbitary, being designed to ensure that tailings solids do not escape over the sill near Hans Point, the lowest point of which is about 55 meters deep. The regulations were also based on the company's position, supported by voluminous data, that the tailings would be discharged from the outfall structure as a discrete, descending density flow.

The transmissometry and chemical data here presented and discussed demonstrate that the outfall system of the Kitsault Mine has not functioned in accordance with the design criterion of preventing suspended matter from remaining in suspension above 100 meters depth. Size analysis and electron micrography demonstrate that much of the suspended matter measured in the plume above 100 meters is greater than 0.4 microns, and therefore a proscribed substance. The evidence is clear that the plume has gone well beyond any reasonable interpretation of the vicinity of the outfall. These data demonstrate that the Kitsault Mine tailings discharged through the outfall structure have violated Section 6(2) of the AATDR.

It is clear that operation of the Kitsault Mine as observed during May and June of 1981 is not compatible with the Alice Arm Tailings Deposit Regulations. Bear in mind that these data were generated during a climatically and oceanographically quiescent period. The tailings discharge system will be much more severely tested during the winter, or during years when oceanographic phenomena may be more pronounced. Either the AATDR or the Kitsault Mine tailings system must be changed.

Lee Harding

L. Harding

APPENDIX 1

TABLE 1 Results of Chemical Analysis of Samples Taken From Alice Arm - May 27-28, 1981

Notes:

- Sample volumes approximately 1 litre.
- Samples taken at depths where transmissometer indicated reduced transmissivity, with sample bottle attached to transmissometer probe.
- Sampling period 22.30 hrs. May 27 to 04.00 hrs. May 28.
- Two samples taken at N-8, approx. 300 m northwest of Rocky Point.
- P-13 approx. 0.8 km west of mouth of Roundy Creek.
- N-14 approx 1.1 km northwest of mouth of Roundy Creek.
- Solid portions of samples analyzed by plasma emission spectrometer on May 29. Results in mg./kg.

Depth (m)	0	65.0	65.0	90.0	80.0	
Element	Surface	N-8-1 Near Outfall	N-8-2 Near Outfall	P-13 Centre Channel	N-14 Near North Shore	Average of N-8-1, N-8-2 P-13 & N-14
As	*47.2	*179.0	*136.0	*357.0	*234.0	
Ba	323.0	267.0	273.0	324.0	379.0	
Be	.629	*2.38	*1.82	*4.76	*3.12	
Cd	4.21	10.0	10.9	*19.0	13.4	11.4
Cr	31.7	86.8	54.6	152.0	76.7	92.5
Cu	69.3	41.4	45.6	24.8	40.9	38.2
Mn	1,010.0	491.0	518.0	630.0	590.0	557.3
Mo	*9.43	48.8	36.4	71.9	66.6	55.9
Ni	42.5	*95.2	*72.7	*190.0	*125.0	
P	1,130.0	524.0	533.0	*714.0	632.0	563.0
Pb	*25.2	212.0	102.0	*190.0	*125.0	157.0
Sr	44.0	41.4	54.5	38.6	98.1	
Ti	437.0	68.8	51.6	56.7	62.5	59.9
Va	73.6	*47.6	*36.4	*95.2	*62.5	Not detected
Zn	202.0	447.0	467.0	154.0	467.0	383.8
Al	17,300.0	1,820.0	1,450.0	2,410.0	1,820.0	1,875.0
Fe	38,800.0	9,510.0	9,940.0	7,670.0	12,000.0	10,483.3
Si	815.0	655.0	540.0	825.0	553.0	
Mg	11,400.0	2,250.0	2,200.0	1,930.0	3,090.0	2,367.5
Ca	5,860.0	8,800.0	11,900.0	7,520.0	21,700.0	12,480.0
Non-Filterable Residues						
(g)	0.0159	0.0042	0.0055	0.0021	0.0032	
(mg/l)	15.82	3.96	5.14	2.19	3.09	3.60

*Less than

APPENDIX 1

TABLE 2 RESULTS OF CHEMICAL ANALYSIS OF TAILINGS AND A WATER COLUMN PROFILE AT STATION N-8

TAILINGS[1]		STATION N-8, May 24, 1981 - 1000 HR.							
Depth(m)		0	25	60	65	70	75	80	85
As	< 142.0	Insufficient Filtrate[2]	Insufficient Filtrate[2]	< 203.0	< 625.0	Insufficient Filtrate[2]	< 214.0	< 174.0	Insufficient Filtrate[2]
Ba	212.0			373.0	1880		720.0	738.0	
Bl	< 1.9			< 2.7	< 8.33		< 2.86	< 2.33	
Cd	< 7.6			< 10.8	< 33.3		16.7	17.6	
Cr	< 14.2			229.0	247.0		120.0	126.0	
Cu	9.87			91.9	314.0		69.7	179.0	
Mn	47.4			677.0	2410		911.0	806.0	
Mo	83.7			171.0	537.0		221.0	165.0	
Ni	< 76.0			< 108.0	< 333.0		< 114.0	< 93.0	
P	625.0			694.0	2840		1290	1410	
Pb	< 76.0			133.0	713.0		178.0	185.0	
Sr	11.6			133.0	343.0		161.0	127.0	
Ti	139.0			198.0	1000		371.0	366.0	
Va	< 38.0			< 54.1	< 167.0		< 57.1	< 46.5	
Zn	123.0			289.0	1410		557.0	696.0	
Al	2300			7430	18200		8320	7520	
Fe	9350			12000	54300		20900	21700	
Si	2830			10600	28600		13100	13900	
Mg	1130			12600	14900		8780	5510	
Ca	1310			19600	81600		35600	30600	
Wt(g)		0.0	0.0	003.7	.0012	0.0	.0035	.0043	0.0
mg/l				3.33	1.04		3.20	3.87	

1 Collected April 24 - analysed for total metals in solid portion.

2 Filters for 0, 25, 70 and 85 meters burst during laboratory filtering.

APPENDIX 1

TABLE 3 ALICE ARM WATER SAMPLES, 1981 - TRACE METALS

Sample #	Station	Date	Depth (m)	Conversion Factor	Sample Wt. (mg/l)	Unit	Cu	Pb	Zn	Cd	Mo	Cr	As	Fe	Al	Mn
							Trace Metals									
309	N-11	0523	60	0102		mg/l	.0006	*0.0	.0009	*0.0	*0.0	.0008	*.001	.0165	.006	.0011
309	N-11	0523	60	20000	0.5	ug/g	1210	*800.0	1750	*80.0	*300.0	1610	*1500	33200	12100	2220
310	N-11	0523	65	0097		mg/l	.0005	*0.0	.0015	*0.0	0.0	.0009	*.001	.0264	.008	.003
310	N-11	0523	65	8333	1.2	ug/g	417.0	382.0	1310	*33.3	129.0	737.0	*625.0	23100	6890	2620
311	N-11	0523	70	6667	1.4	ug/g	163.0	*267.0	410.0	*26.7	*100.0	*50.0	*500.0	11700	3350	1190
311	N-11	0523	70	0096		mg/l	.0002	*0.0	.0006	*0.0	*0.0	*.0001	*.001	.017	.005	.0017
312	N-11	0523	72.5	2564	3.7	ug/g	102.0	149.0	446.0	*10.3	93.6	*19.2	*192.0	12500	2930	796.0
312	N-11	0523	72.5	0095		mg/l	.0004	.001	.0017	*0.0	*0.0	*.0001	*.001	.0461	.011	.0029
313	N-11	0523	75	2273	4.4	ug/g	97.7	122.0	404.0	*9.09	136.0	*17.0	*170.0	11400	2580	751.0
313	N-11	0523	75	0099		mg/l	.0004	.001	.0017	*0.0	.001	*.0001	*.001	.0487	.011	.0032
314	N-11	0523	77.5	3333	2.8	ug/g	121.0	*133.0	390.0	*13.0	162.0	*25.0	*250.0	13700	3260	1020
314	N-11	0523	77.5	0093		mg/l	.0003	0.0	.0011	*0.0	0.0	*.0001	*.001	.0382	.009	.0028
315	N-11	0523	80	6250	1.4	ug/g	397.0	346.0	439.0	*25.0	278.0	463.0	*469.0	12000	3220	1020
315	N-11	0523	80	0088		mg/l	.0006	0.0	.0006	*0.0	0.0	.0006	*.001	.0163	.004	.0014
316	N-11	0523	85	10000	1.0	ug/g	156.0	*400.0	493.0	*40.0	*150.0	980.0	*750.0	10800	2970	1300
316	N-11	0523	85	0100		mg/l	.0002	*0.0	.0005	*0.0	*0.0	.001	*.001	.0108	.003	.0013
317	N-11	0523	90	6667	1.5	ug/g	232.0	*267.0	496.0	*26.7	*100.0	706.0	*500.0	13600	3140	1190
317	N-11	0523	90	0100		mg/l	.0004	*0.0	.0007	*0.0	*0.0	.0011	*.001	.0201	.005	.0018
458	Q-20	0525	100	2778	3.0	ug/g	144.0	173.0	250.0	*11.1	82.8	238.0	*208.0	23100	7310	885.0
458	Q-20	0525	100	0084		mg/l	.0004	.001	.0008	*0.0	0.0	.0007	*.001	.07	.022	.0027

* less than

APPENDIX 1

TABLE 3 ALICE ARM WATER SAMPLES, 1981 - TRACE METALS

Sample #	Station	Date	Depth (m)	Conversion Factor	Sample Wt. (mg/l)	Unit	Cu	Pb	Zn	Cd	Mo	Cr	As	Fe	Al	Mn
459	P-16	0526		3704	2.4	ug/g	223.0	370.0	346.0	*14.8	97.8	343.0	*278.0	23000	8670	1040
459	P-16	0526		0088		mg/l	.0005	.001	.0008	*0.0	0.0	.0008	*.001	.0551	.021	.0025
477	1-7	0526		5556	1.8	ug/g	195.0	*222.0	494.0	*22.2	147.0	504.0	*417.0	21000	6500	1380
477	1-7	0526		0103		mg/l	.0004	*0.0	.0009	*0.0	0.0	.0009	*.001	.0385	.012	.0025
324	N-11	0523	100	2857	3.5	ug/g	51.4	132.0	288.0	*11.4	94.3	232.0	*214.0	10200	1860	455.0
324	N-11	0523	100	0100		mg/l	.0002	*0.0	.001	*0.0	0.0	.0008	*.001	.0359	.006	.0016
324 **	N-11	0523	100	12500	0.8	ug/g	123.0	*500.0	408.0	*50.0	*188.0	766.0	*937.0	4000	*625.0	57.5
324 **	N-11	0523	100	0100		mg/l	.0001	*0.0	.0003	*0.0	*0.0	.0006	*.001	.0032	*.001	0.0
565	Outfall	0528		3333	3.0	ug/g	181.0	176.0	770.0	18.3	201.0	246.0	*250.0	14500	2680	751.0
565	Outfall	0528		0100		mg/l	.0005	.001	.0023	.0001	.001	.0007	*.001	.043	.008	.0022
565 **	Outfall	0528		0100		mg/l	.0001	*0.0	.0002	*0.0	*0.0	.0004	*.001	.0038	*.001	0.0
565 **	Outfall	0528		100000	0.1	ug/g	1280	*4000	1650	*400.0	*1500	4200	*7500	37900	*5000	350.0
572	R-14	0529	177	9090	1.1	ug/g	116.0	*364.0	422.0	*36.4	*136.0	793.0	*682.0	22500	7110	1420
572	R-14	0529	177	0102		mg/l	.0001	*0.0	.0005	*0.0	*0.0	.0009	*.001	.0252	.008	.0016
572 **	R-14	0529	177	14286	0.7	ug/g	193.0	*571.0	426.0	*57.1	*214.0	570.0	*1070	1190	*714.0	34.3
572 **	R-14	0529	177	0102		mg/l	.0001	*0.0	.0003	*0.0	*0.0	.0004	*.001	.0008	*.001	0.0
656	J-8	0606	89	1389	3.7	ug/g	46.4	143.0	635.0	16.7	52.8	123.0	*104.0	12700	2820	943.0
656	J-8	0606	89	0052		mg/l	.0002	.001	.0024	.0001	0.0	.0005	*0.0	.0475	.011	.0035
649	L-10	0605	94	143	35.3	ug/g	51.1	133.0	1010	27.6	61.0	23.0	43.3	14000	2400	727.0
649	L-10	0605	94	0051		mg/l	.0018	.005	.0361	.001	.002	.0008	.002	.499	.084	.0258

* less than
** 0.1 um filter

APPENDIX 1

TABLE 3 ALICE ARM WATER SAMPLES, 1981 - TRACE METALS

Sample #	Station	Date	Depth (m)	Conversion Factor	Sample Wt. (mg/l)	Unit	Trace Metals Cu	Pb	Zn	Cd	Mo	Cr	As	Fe	Al	Mn
563	Outfall-A	0528	26	2564	3.9	ug/g	392.0	1410	980.0	26.8	11900	310.0	*192.0	73600	3850	804.0
563	Outfall-A	0528	26	0097		mg/l	.0015	.005	.0037	.0004	.044	.0012	*.001	.276	.014	.003
578	N-8	0530	67	6667	1.5	ug/g	194.0	*267.0	834.0	30.3	307.0	929.0	*500.0	22400	6390	1580
578	N-8	0530	67	0101		mg/l	.0003	*0.0	.0013	*0.0	0.0	.0013	*.001	.0338	.01	.0024
608	1-7	0530	82	9090	0.5	ug/g	395.0	487.0	912.0	*36.4	473.0	1020	*682.0	49800	17000	3430
608	1-7	0530	82	0049		mg/l	.0002	0.0	.0005	*0.0	0.0	.0006	*0.0	.0269	.009	.0018
636	N-8	0531	70	11111	2.8	ug/g	409.0	482.0	592.0	*44.4	200.0	1000	*833.0	16700	4840	1490
636	N-8	0531	70	0089		mg/l	.0003	*0.0	.0005	*0.0	*0.0	.0008	*.001	.0134	.004	.0012
646	Outfall-F	0604	51	0049		mg/l	.0005	0.0	.0004	0.0	0.0	.0005	0.0	.0404	.013	.0038
646	Outfall-F	0604	51	4348	1.1	ug/g	412.0	362.0	401.0	24.8	65.2	437.0	*326.0	35700	11900	3320
647	N-8	0605	87	0062		mg/l	.0011	.002	.0108	.0003	.001	.0008	.001	.17	.037	.0096
647	N-8	0605	87	487	12.8	ug/g	88.6	116.0	841.0	22.5	96.1	62.0	57.6	13200	2760	748.0
648	M-9	0605	81	671	7.3	ug/g	45.0	111.0	814.0	21.1	125.0	61.7	67.4	12900	2990	827.0
648	M-9	0605	81	0049		mg/l	.0003	.001	.0059	.0002	.001	.0004	0.0	.0936	.022	.006
336	N-11	0523		0089		mg/l	.0003	*0.0	.0017	*0.0	*0.0	.0007	.001	.138	.071	.0038
336	N-11	0523		2500	3.6	ug/g	91.8	*100.0	470.0	*10.0	*37.5	207.0	301.0	39100	20000	1070
337	N-11	0523	5	0081		mg/l	.0002	*0.0	.0005	*0.0	*0.0	.0006	*.001	.0239	.01	.0017
337	N-11	0523	5	5556	1.5	ug/g	106.0	*222.0	331.0	*22.2	*83.3	441.0	*417.0	16400	6930	1160
437	P-12	0524	155	3846	2.5	ug/g	438.0	224.0	682.0	*15.4	144.0	382.0	*288.0	30500	12300	967.0

* less than

APPENDIX 1

TABLE 3 ALICE ARM WATER SAMPLES, 1981 - TRACE METALS

							Trace Metals									
Sample #	Station	Date	Depth (m)	Conversion Factor	Sample Wt. (mg/l)	Unit	Cu	Pb	Zn	Cd	Mo	Cr	As	Fe	Al	Mn
437	P-12	0524	155	0097		mg/l	.0011	0.0	.0017	*0.0	0.0	.0009	*.001	.0763	.031	.0024
609	G-5	0530	68	0093		mg/l	.0003	0.0	.0012	*0.0	0.0	.0009	*.001	.0508	.015	.0036
609	G-5	0530	68	4545	2.0	ug/g	170.0	216.0	599.0	18.6	130.0	440.0	*341.0	25400	7510	1780
637	N-7	0601	65	0048		mg/l	.0001	0.0	.0007	*0.0	0.0	.0005	*0.0	.0237	.007	.0023
637	N-7	0601	65	8333	0.6	ug/g	252.0	352.0	1180	*33.3	270.0	857.0	*625.0	41100	12000	3910
638	M-9	0601	66	0052		mg/l	.0001	*0.0	.0008	*0.0	0.0	.0005	*0.0	.0213	.007	.0022
638	M-9	0601	66	16667	0.31	ug/g	427.0	*667.0	2550	*66.7	544.0	1710	*1250	70200	22200	7290
655	K-7	0606	76	0048		mg/l	.0005	.001	.0092	.0003	.001	.0004	0.0	.128	.025	.0076
655	K-7	0606	76	492	9.7	ug/g	45.9	121.0	929.0	25.2	72.3	40.8	*36.9	12300	1990	747.0
339	N-11	0523	20	14286	0.6	ug/1g	314.0	574.0	801.0	*57.1	*214.0	875.0	*1070	33300	13800	4510
339	N-11	0523	20	0084		mg/l	.0002	0.0	.0005	*0.0	*0.0	.0005	*.001	.0196	.008	.0026
342	N-11	0523	100	5556	1.5	ug/g	70.6	*222.0	372.0	*22.2	94.7	374.0	*417.0	11700	3330	818.0
342	N-11	0523	100	0084		mg/l	.0001	*0.0	.0005	*0.0	*0.0	.0005	*.001	.0168	.005	.0012
470	G-5	0526		5882	1.5	ug/g	70.6	*235.0	618.0	*23.5	*88.2	430.0	*441.0	15600	4170	1170
470	G-5	0526		0087		mg/l	.0001	*0.0	.0009	*0.0	*0.0	.0006	*.001	.0228	.006	.0017
541	C-5	0527		16667	0.8	ug/g	228.0	*667.0	1160	*66.7	*250.0	1370	*1250	32000	13100	3610
541	C-5	0527		0103		mg/l	.0001	*0.0	.0007	*0.0	*0.0	.0008	*.001	.0197	.008	.0022
619	E-7	0530	75	11111	0.9	ug/g	279.0	*444.0	873.0	*44.4	252.0	945.0	*833.0	26200	9020	1830

*less than

APPENDIX 1

TABLE 3 ALICE ARM WATER SAMPLES, 1981 - TRACE METALS

Sample #	Station	Date	Depth (m)	Conversion Factor	Sample Wt. (mg/l)	Unit	Trace Metals Cu	Pb	Zn	Cd	Mo	Cr	As	Fe	Al	Mn
619	E-7	0530	75	0094		mg/l	.0002	*0.0	.0007	*0.0	0.0	.0008	*.001	.022	.008	.0015
644	E-7	0601		8333	0.6	ug/g	186.0	*333.0	581.0	*33.3	*125.0	705.0	*625.0	28300	9880	3960
644	E-7	0601		0050		mg/l	.0001	*0.0	.0003	*0.0	*0.0	.0004	*0.0	.0168	.006	.0024
653	P-14	0606	90	2041	2.4	ug/g	73.4	124.0	725.0	18.6	78.4	187.0	*153.0	15400	4340	1330
653	P-14	0606	90	0050		mg/l	.0002	0.0	.0018	0.0	0.0	.0005	*0.0	.0382	.011	.0033

* less than

APPENDIX 1

TABLE 4 ALICE ARM WATER SAMPLES, 1981 - RESIDUE ANALYSIS

SAMPLE #	STATION	DATE	DEPTH (m)	FIXED/NFR (100)	NFR MG/L	FIXED RESIDUE (MG/L)	NFVR MG/L
309	N-11	0523	60	100%	0.5	0.5	0
310	N-11	0523	65	83%	1.2	1.0	0.2
311	N-11	0523	70	86%	1.4	1.2	0.2
312	N-11	0523	72.5	92%	3.7	3.4	0.3
313	N-11	0523	75	93%	4.4	4.1	0.3
314	N-11	0523	77.5	75%	2.8	2.1	0.7
315	N-11	0523	80	79%	1.4	1.1	0.3
316	N-11	0523	85	70%	1.0	0.7	0.3
317	N-11	0523	90	80%	1.5	1.2	0.3
458	Q-20	0525	100	100%	3.0	3.0	0
459	P-16	0526		83%	2.4	2.0	0.4
477	I-7	0526		89%	1.8	1.6	0.2
324	N-11	0523	100	83%	3.5	2.9	0.6
324**	N-11	0523	100		0.8	0	0.8
565	Outfall-C	0528		97%	3.0	2.9	0.1
565**	Outfall-C	0528			0.1	0	0.1
572	R-14	0529		55%	1.1	0.61	0.49
572**	R-14	0529			0.7	0.3	0.4
656	J-8	0606	89	97%	3.7	3.6	0.1
649	L-10	0605	94	97%	35.3	34.1	1.2
563	Outfall-A	0528		77%	3.9	3.0	0.9
578	N-8	0530	67	40%	1.5	0.6	0.9
608	I-7	0530	82	60%	0.5	0.3	0.2
636	N-8	0531	70	88%	0.8	0.7	0.1
646	Outfall-F	0604	51	82%	1.1	0.9	0.2

** 0.1 u filter

APPENDIX 1

TABLE 4, Con't. ALICE ARM WATER SAMPLES, 1981 - RESIDUE ANALYSIS

SAMPLE #	STATION	DATE	DEPTH (m)	FIXED/NFR (100)	NFR MG/L	FIXED RESIDUE (MG/L)	NFVR MG/L
647	N-8	0605	87	98%	12.8	12.6	0.2
648	M-9	0605	81	97%	7.3	7.1	0.2
336	N-11	0523	0	97%	3.6	3.5	0.1
337	N-11	0523	5	73%	1.5	1.1	0.4
437	P-12	0524	155	72%	2.5	1.8	0.7
609	G-5	0530	68	75%	2.0	1.5	0.5
637	N-7	0601	65	67%	0.6	0.4	0.2
638	M-9	0601	66	0%	0.31	0	0.31
655	K-7	0606	76	99%	9.7	9.6	0.1
339	N-11	0523	20	50%	0.6	0.3	0.3
342	N-11	0523	100	73%	1.5	1.1	0.4
470	G-5	0526		30%	1.5	0.5	1.0
541	C-5	0527		75%	0.8	0.6	0.2
619	E-7	0530	75	55%	0.9	0.5	0.4
644	E-7	0601		50%	0.6	0.3	0.3
653	P-14	0606	90	96%	2.4	2.3	0.1

can test ltd.

1650 PANDORA STREET, VANCOUVER, B.C. V5L 1L6 • TELEPHONE 254-7278 • TELEX 04-54210

Report On Analysis of Tailings Sample **File No.** 1791E

Report No.

Reported to Environmental Protection Service **Date** June 17, 1981

3rd Floor, Kapilano 100, Park Royal

West Vancouver, B.C.

Attention: Mr. Fred Claggett

We have tested the sample submitted by you on June 5, 1981 and report as follows:

SAMPLE IDENTIFICATION:

The sample was received in a plastic bottle labelled "Amax Tailings, Janet Pel, 922-4314"

METHOD OF TESTING:

A suitable weight of the slurry was acid digested with aqua regia and analyzed for metals using an Inductively Coupled Argon Plasma (ICAP). These results are labelled "Total" metals.

In order to obtain a subsample of the slurry, which would represent the low density fraction of the tailings the sample was threated as follows:

1. 6.0 g of slurry was added to 500 mls of distilled water, the mixture was shaken for 15 minutes and allowed to settle for 15 hours.

2. An aliquot of the now "turbid" water was carefully drawn off and filtered through a 0.45 micron filter.

3. The residue weight from the above step was determined, and the filter cake was acid digested with aqua regia.

The resulting solutions were analyzed for metals by ICAP and these results are labelled "Turbid" metals.

RESULTS OF TESTING:

(on the following page)

Form No. 7 L

CAN TEST LTD.

File No: 1791E
Page No: 2

RESULTS OF TESTING:

ELEMENT	TOTAL METALS	TURBID METALS
Be	L 0.20	L 3.6
Cd	16.7	130.
Cr	4.8	122.
Cu	28.1	43.7
Mn	564.	122.
Mo	124.	146.
Ni	4.6	30.4
PO_4	2,470.	596.
Pb	100.	140.
Ti	207.	146.
V	20.4	15.8
Zn	632.	280.
Al	7,970.	12,700.
Fe	15,100.	4,320.
Mg	4,510.	3,490.
Ca	25,100	13,700.

L - Less than
- results are expressed as micrograms element per dry gram of sample

CAN TEST LTD.

Rob Deverall

R. W. Deverall

/cs

Government of Canada | Gouvernement du Canada

MEMORANDUM **NOTE DE SERVICE**

TO / À: Fred Claggett, Manager
Pollution Control Group

FROM / DE: Lee Harding, Coordinator
Freshwater & Marine Programs

SECURITY CLASSIFICATION DE SECURITE

OUR FILE - N/REFERENCE

YOUR FILE - V/REFERENCE

DATE: June 30, 1981

SUBJECT / OBJET: AMAX TAILINGS SEDIMENT SIZE DISTRIBUTION

Paul MacGillvary has analysed an Amax tailings sample taken on April 27 for sediment size. This is the same sample from which a subsample was analysed chemically by CanTest, on June 9, for both slurry and suspended solids in the supernatant after 15 hours of settling. The sediment size analysis is a composite of two methods: for particles above μ(=0.044 mm), the material was put through a series of standard sediment sieves, employing a wet sieving technique to avoid agglomeration of particles. Material passing the 44 μ sieve was analysed by sedigraph which measures increasing intensity of an X-ray beam passing through a sample of suspended sediment, based on the principle that different size particles settle at different rates. Preliminary results, combined from the two techniques are as follows:

Size Fraction (μ)*	% by weight
500	0.01
500-350	0.5
350-250	4.7
250-177	9.4
177-125	14.8
125-88	11.1
88-62.5	9.96
62.5-44	9.5
44-31	3.6
31-22.5	6.4
22.5-15.6	8.0
15.6-11.1	5.6
11.1-7.8	8.0
7.8-5.6	2.4
5.6-3.9	2.2
3.9-2.75	1.8
2.75-2.0	1.0
2.0-1.38	1.2
1.38-0.98	0.4

*%passing the larger size and retained by the smaller size. Mr. McGillvary has provided the following precautionary notes regarding interpretation of these results

"Seive and sedigraph results disagree by 20%. From between 40 and 60% of the sample is less than 44 μ. The disagreement may be attributable to non-homogeneity in the tailings sample, i.e., two tailings samples have different distributions of size. It may also be a fundamental inadequacy of the two methods for this sample type. Only further investigation will determine the cause.

The results should be interpreted with care. The accompanied graph is a best-fit between sedigraph and seive results. The micron intervals are the equivalent of Ø-sizes, which is the standard unit in sedimentary work".

Lee Harding

Lee Harding

cc: Dr. J. McInerny - University of Victoria
Howard Smith - Fisheries & Oceans

APPENDIX 4

The following counts are of particles from photographs taken at 1000X with a scanning electron microscope of a 56μ square of filter paper. Some clumping made counting difficult. Most dates unavailable.

<u>L8</u> - taken in plume.

Size range	A.	B.	C.	D.
0.1-1μ	170	120	110	115
1-10μ	35	63	45	64
10-100μ	1	1	1	1

<u>L8</u> - (sample #460) May 26, 1981 - taken in plume.

Size range	A.	B.
0.101μ	obscured	obscured
1-10μ	14	29
10-100μ	11	9

This filter very dense with larger particles which obscured 0.1-1u range.

<u>R14</u> - taken in plume.

Size range	A.	B.	C.
0.1-1μ	140	130	144
1-10μ	94	47	76
10-100μ	1	2	1

<u>Head of Inlet.</u> - taken away from plume at 20 metres depth.

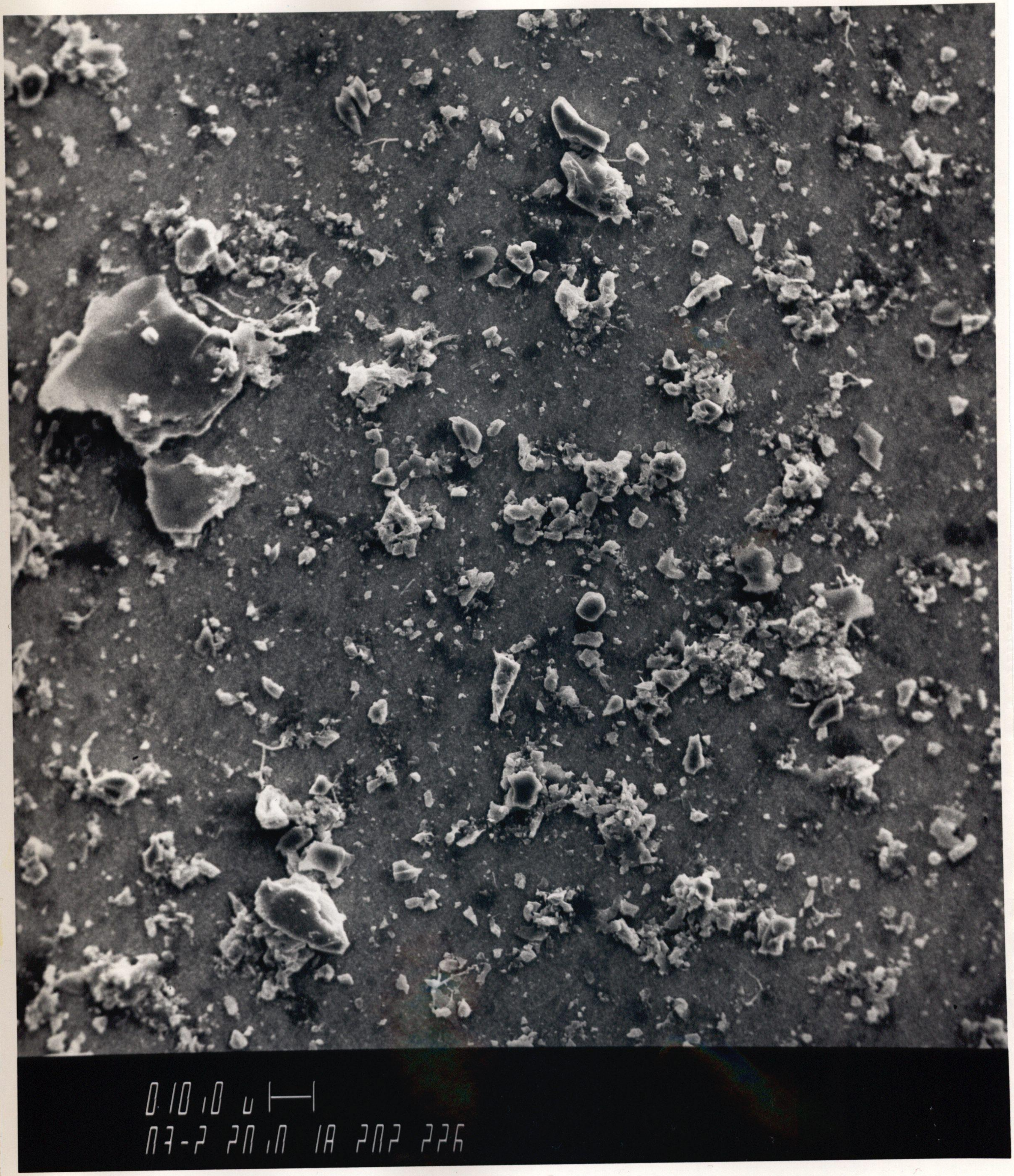
Size range	A.	B.
0.1-1μ	~100 (very hard to count)	~80 (very hard to count)
1-10μ	32	41
10-100μ	1	1

<u>Head of Inlet.</u> - taken at surface

Size range	A.	B.
0.1-1μ	several layers deep	--
1-10μ	several layers deep	--
10-100μ	1	0

This filter very dense. Many particles present in both 1-10μ and 0.1-1μ ranges.

DON DeMILL
Senior Technician
July 7, 1981

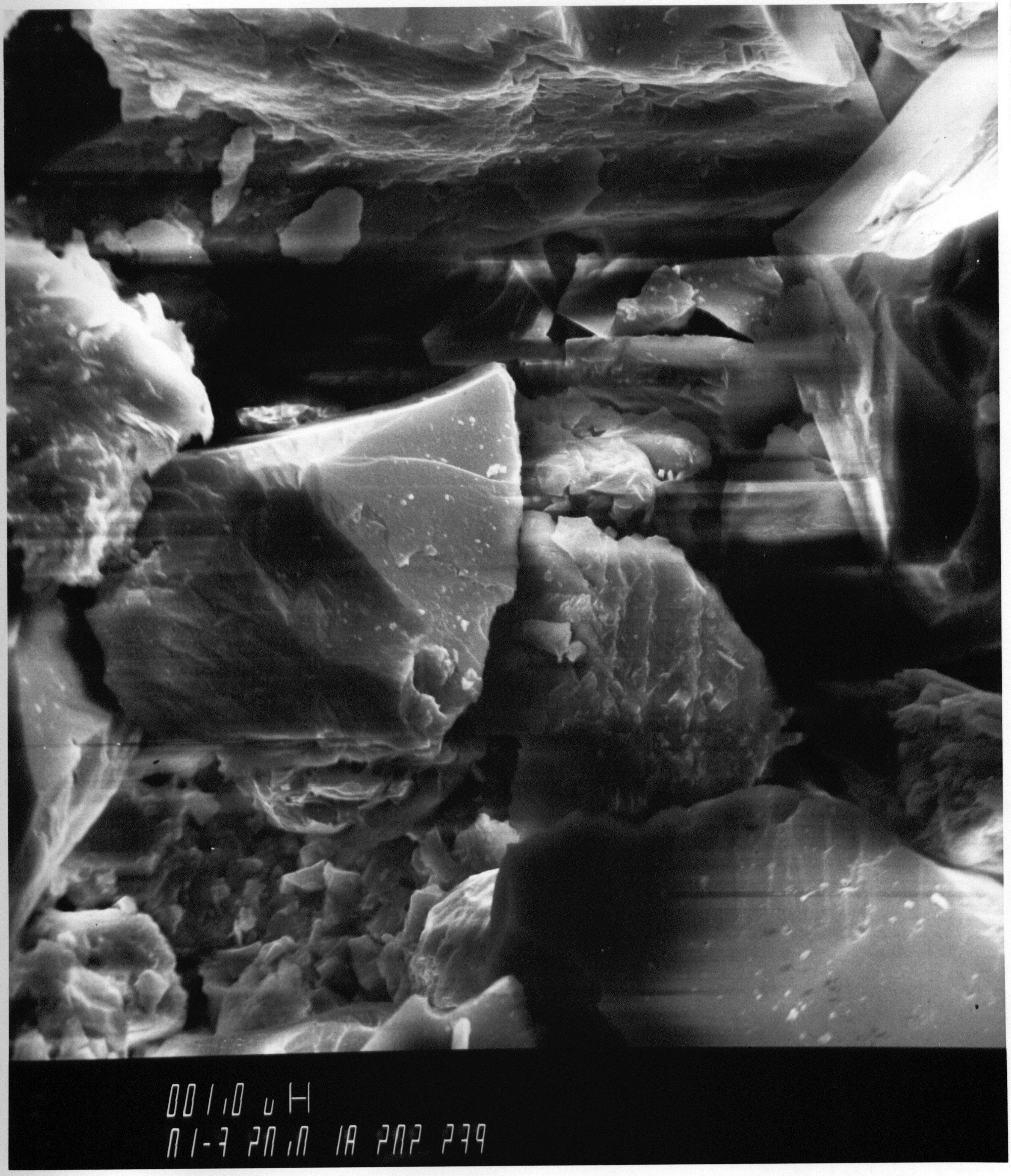

0.10.0 u

R-14 - taken in plume

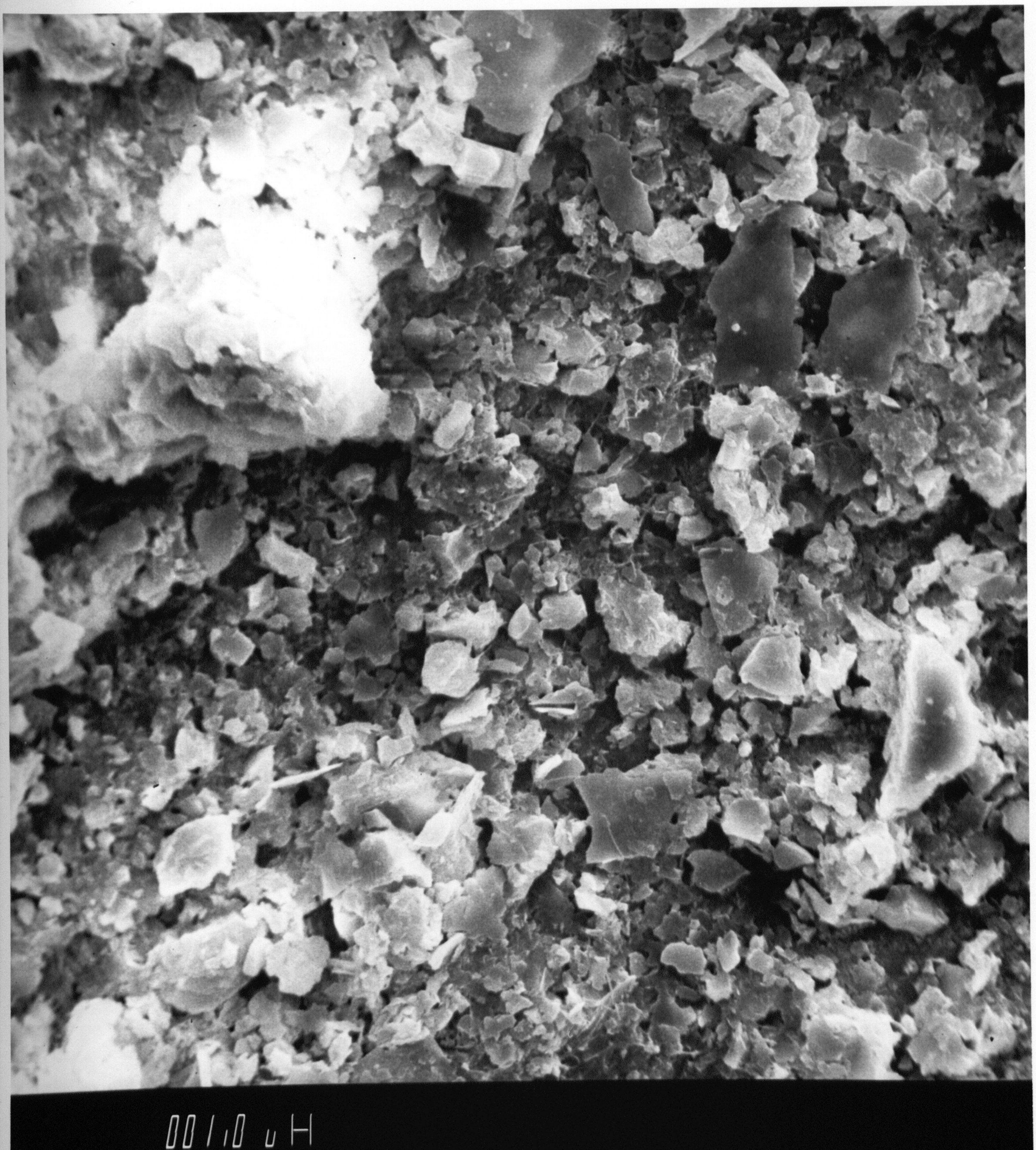
R14 Taken in plume


0 10.0 u
03-2 20.0 1A 202 237

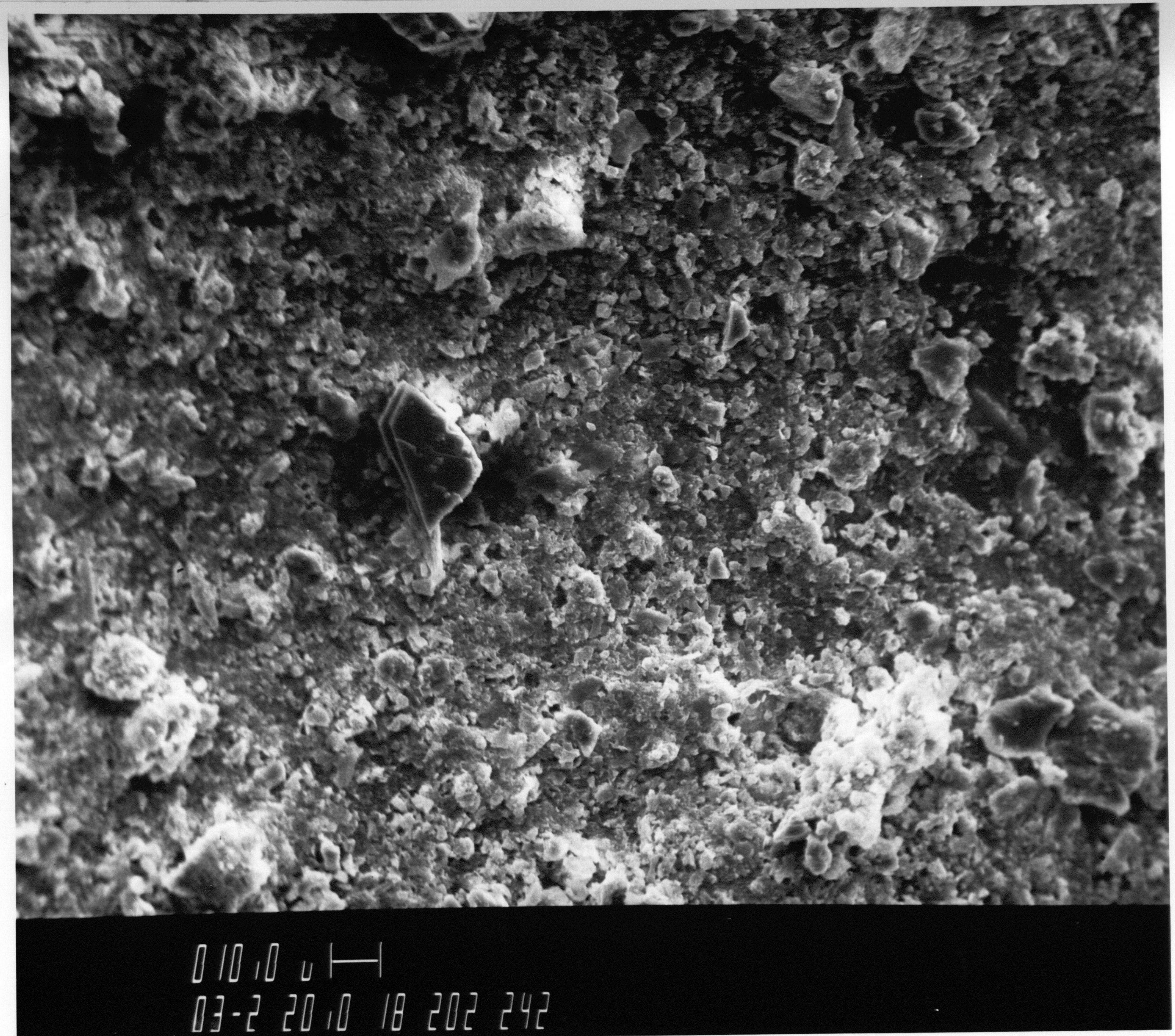
L8 (#460) taken in plane 26 May 81.



L8 (#460) taken in plume 26 May 81.



Head of Inlet-surface



0010.0 u
03-2 20.0 18 202 242

Head of Inlet-surface

Head of Inlet-surface