

84-#309-1222.8  
E

ASSESSMENT REPORT

Based on Metallurgical Research  
by CANMET (DEMR) on Bulk Samples  
from the Coquihalla Nickel Property

OWNER/OPERATOR

BORDER RESOURCES LTD.,  
4547 West 5th Ave.,  
Vancouver, B.C.  
V6R 1S6

PROPERTY LOCATION

New Westminster M.D.  
N.T.S. Grid 92H/6(E)

NORTH GROUP

49°29'00" N. Lat.  
121°16'00" W. Long.

(17 claims)

G 1-2, GWH 2, N 22-27, 28FR, 29FR, TAX 51-56

SOUTH GROUP

49°26'00" N. Lat.  
121°14'00" W. Long.

(9 Claims)

EVE 1-2, TOY 3-9

**GEOLOGICAL BRANCH  
ASSESSMENT REPORT**

**12,228**

REPORT COMPILED BY: P. Hall, BA  
PROJECT SUPERVISED BY: H.E.A. von Hahn, P.Eng., PhD  
COMPONENT REPORTS BY: M.A. Cristovici, PhD. et al  
P.R. Mainwaring, PhD.

DATE: 15 May 1984

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# NORTH GROUP

# SOUTH GROUP

C A S C A D E

BORDER RESOURCES LTD.

## LOCATION MAP

N.T.S. Grid: 92H/6(E)

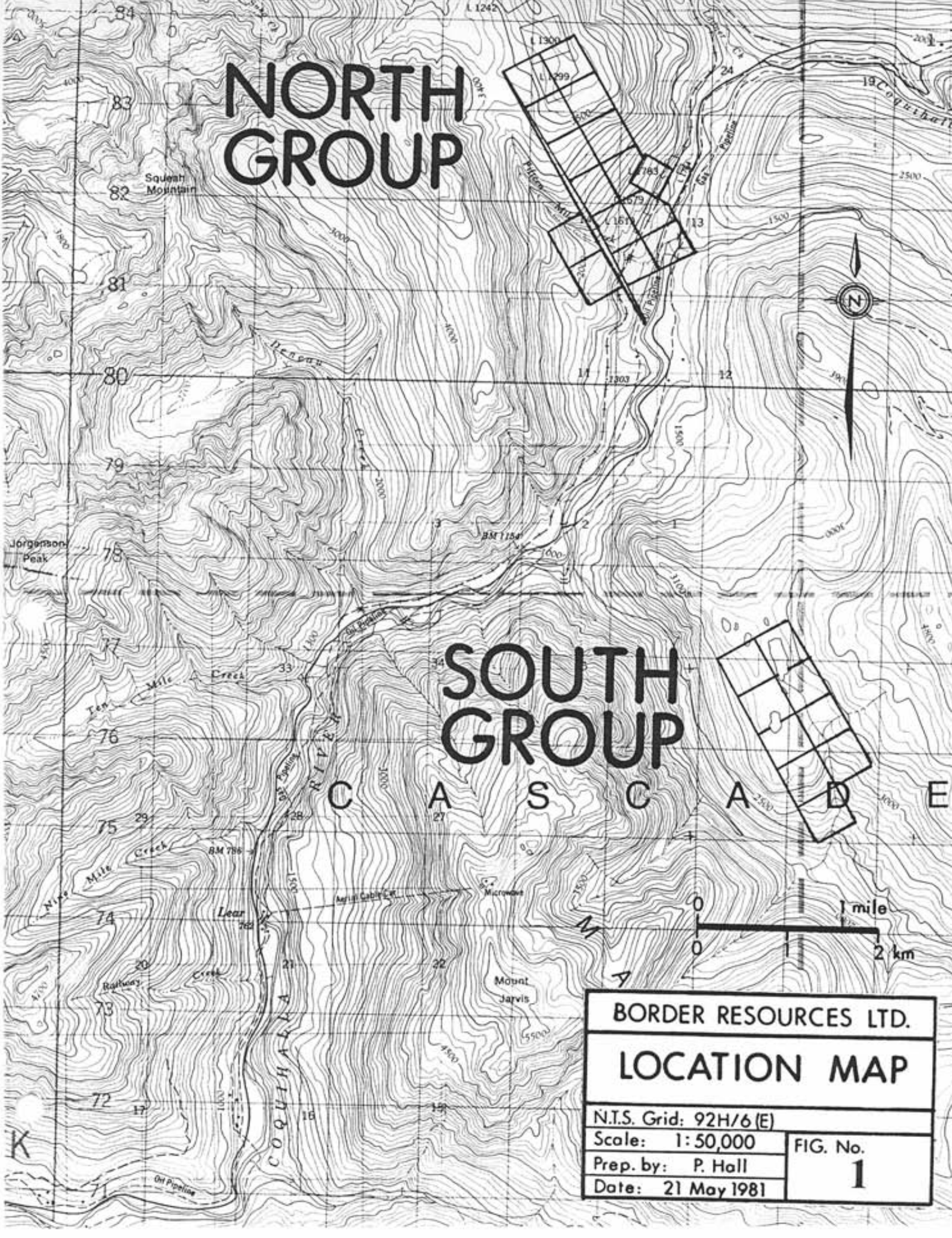
Scale: 1:50,000

Prep. by: P. Hall

Date: 21 May 1981

FIG. No.

1



INTRODUCTION: (by P. Hall)

Work has been done on the Coquihalla property held by BORDER RESOURCES LTD. since 1969 when the claims were originally staked. Over the years the original 153 claims have been reduced in number down to the present twenty-six key claims. These in turn are divided into two discontinuous groups. The North Group (17 claims) is located on the North side of the Coquihalla River at Fifteen Mile Creek, while the South Group (9 claims) lies on the West slope above Sowaqua Creek some 5 km South of its junction with the Coquihalla River.

Following considerable metallurgical research by A-MIN-TECH RESEARCH LTD. of Vancouver as described in the assessment report dated 22 May 1981, it was decided that more detailed work than what could be done in Vancouver with the equipment available would have to be conducted. The CANMET laboratory in Ottawa, run by the Federal DEPARTMENT OF ENERGY, MINES & RESOURCES was selected as the agency to perform this work.

On 16 June 1982, a letter of agreement was signed by BORDER and CANMET to undertake further research designed to discover a method for extracting microscopic needle-like concentrations of nickel mineralization from the serpentized ultramafic host rock.

A field trip was carried out on 5-6 October 1981 led by Dr. J.A. Chamberlain, P.Eng. with the writer as assistant, to locate appropriate sample sites for the future bulk sampling needs. Eleven sites were sampled and assayed, but by the time the review of the data was completed, the year had advanced so far that winter snow conditions rendered the property inaccessible until late Spring of the following year. On 23 July 1982 a helicopter-supported field crew succeeded in obtaining a bulk sample from each of the two selected sites, Nos. 9 and 11, in the range of 350 kg per site. Appropriately detailed location maps of these sites were included in the assessment report filed on this work on 27 July 1982.

On 26 July 1982, these samples were sent to Ottawa where they were stored until laboratory time could be scheduled to work on them. This time became available in January 1983 and continued on through to March 1984. During this period, two reports on the progress of the research were generated. The first report by Cristovici et al, dated July 1983, outlined the investigative metallurgical procedures. The second report dated February 1984 by P.R. Mainwaring tabulates the results of the mineralogical research. Both these reports are contained as part of this present compilation.

The entire project was supervised by BORDER's Vancouver-based consultant, Dr. H. von Hahn of A-MIN-TECH RESEARCH LTD.

This present report tallies assessment credits in the amount of \$23,256.36, equating to 116 unit years, or just over 4 years per claim. Since the metallurgical work described in this report dragged on over a very long period of time and since filing of it could not be done until the results and costs were in, a portion of the expenditure on the work may have to be disqualified as not complying fully with Section 1(4) of the Mineral Act Regulations. Unless Ministerial dispensation can be obtained to waive this requirement, those claims having an anniversary this May will be able only to derive value from those costs recorded after May 1983 and which amount to \$13,176.76. Those claims with a July anniversary can draw upon \$12,386.73, which differs only by the deletion of the June billing of \$790.03. The total claim year credits available is therefore 65 and the \$10,256.36 overall difference between the total expenditure of \$23,256.36 and the \$13,000.00 assessment application should qualify for P.A.C. fund inclusion under the 3-year scope of Section 12(1) Regs.

Despite that the bulk samples used in this research were obtained exclusively from claims 'N25' and 'N27' of the North Group, the continuity and nature of the deposit are such that the results obtained in this study are believed to apply equally to the South Group.

# BORDER RESOURCES LTD.

CLAIMS SCHEDULE  
(New Westminster M.D.)  
Date: 22 March 1984  
NTS 92H/6

NORTH GROUP:

17 claims - 49°29'00"N/121°16'00"W

<u>CLAIM NAME</u>	<u>RECORD No.</u>	<u>ANNIVERSARY</u>	<u>EXPIRY YEAR</u>
G 1-2	29430-31	July 26	1986
GWH 2	28025	July 19	1986
N 22-27	26333-38	July 13	1986
N 28FR-29FR	26339-40	"	1986
TAX 51-56	21629-34	May 26	1987

SOUTH GROUP:

9 claims - 49°26'00"N/121°14'00"W.

<u>CLAIM NAME</u>	<u>RECORD No.</u>	<u>ANNIVERSARY</u>	<u>EXPIRY YEAR</u>
EV 1-2	21703-04	May 22	1986
TOY 3-9	21601-07	May 26	1986

INVESTIGATION TO RECOVER Ni-Co-Fe-Cr FROM ORE SAMPLES  
SUBMITTED BY BORDER RESOURCES

M.A. Cristovici, M.M. Raicevic, P. Lachapelle  
Mineral Processing Laboratory

July 1983

Project: MRP-3.4.9.9.99  
Cost Recovery Mineral Processing Technologies

Job No. 025151

MINERALS RESEARCH PROGRAM  
MINERAL SCIENCES LABORATORIES  
DIVISION REPORT MRP/MSL 83-7 (CR)

**CONFIDENTIAL**

INVESTIGATION TO RECOVER Ni-Co-Fe-Cr FROM ORE SAMPLES  
SUBMITTED BY BORDER RESOURCES

by

M.A. Cristovici\*, M.M. Raicevic\*\*, P. Lachapelle\*\*\*

ABSTRACT

Samples of serpentine ore collected from a deposit located in British Columbia were investigated for the recovery of Ni, Co, Fe and Cr.

The samples exhibited low content in the metals of interest: 0.2% Ni; 0.012% Co; 6.24% Fe and 0.27% Cr.

The recovery of Ni-Co by flotation was difficult to achieve due to the intimate association of the valuable minerals and to their slow response to flotation. Various levels of Ni and Co concentration were obtained by successive flotation cleanings. At 6% Ni and 0.3% Co the recovery in open circuit was 30% for both metals.

The separation of Fe and Cr minerals by magnetic concentration was not possible. Also the upgrading of the Ni flotation tailing or the original ore by magnetic separation to saleable iron concentrate could not be achieved. Concentrates of only 40% Fe and 1.4% Cr were obtained for a recovery of 33% for Fe and 30% for Cr.

Recommendations are made to continue the exploration of the deposit searching for zones of better mineralization. Investigation to upgrade the ore should resume when ore of better quality is found.

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\*Research Scientist, \*\*Supervising Research Technician, \*\*\*Research Technician, Mineral Processing Laboratory, Mineral Sciences Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa, Ontario.



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## INTRODUCTION

Following the request of Border Resources Ltd. of Vancouver, B.C. an investigation was initiated to study the possibility of recovering nickel-bearing sulphides and other valuable minerals of Co, Fe and Cr from a serpentine ore deposit located in B.C.

A company providing consulting services in mineral processing, A-Min-Tech Research Ltd. also of Vancouver, B.C., acted as a technical advisor for Border Resources Ltd.

Previous testwork performed by A-Min-Tech Research on some samples originating from Border Resources deposit was focused on Ni-Co flotation and indicated that the upgrading of the ore to saleable concentrate at a good metal recoveries was difficult to achieve.

CANMET carried out a reduced test program attempting to improve the Ni-Co flotation results obtained by A-Min-Tech and to achieve concentration of the iron and chromium minerals by magnetic separation. Also, the preconcentration of all valuable minerals by gravity separation method was tried.

The best Ni-Co flotation concentrates were assayed for precious metals to determine their possible concentration in the final products.

Finally, microscopic examination was performed in the Mineralogical Laboratory to investigate the nature of Ni-Co mineralization and the association of the minerals. The results of this work will be reported under a separate cover.

The progress and results of the testwork were examined and discussed in frequent meetings and telephone conversations with Dr. H. von Hahn of A-Min-Tech Research Ltd.

OBJECTIVES OF THE TESTWORK

The object of the testwork was to investigate the possibility of obtaining, by mineral dressing methods, from Border Resources serpentine samples the following products:

- Ni-Co concentrate of minimum 6% Ni
- Fe concentrate
- Cr concentrate

HEAD ASSAY OF ORE SAMPLES

Two samples were provided by Border Resources for the testwork. They were identified as:

- Site #9 and
- Site #11

Both were serpentine type ore samples and site #11 contained more fibrous minerals than site #9.

The samples were crushed and prepared for chemical assay and testwork.

All the chemical assays were performed by Bondar and Clegg Company in Ottawa, with the exception of some determinations aimed to isolate the sulphide Ni from total Ni, that were done in CANMET Chemical Laboratories.

The head assay of the samples is presented in Table 1.

Table 1 - Head assay

Element	Site	Site	Element	Site #9		Site #11	
	#9	#11		oz/ton	g/t	oz/ton	g/t
	%	%					
Ni	0.21	0.20	Au	< 0.005	< 0.17	< 0.005	< 0.17
Co	0.012	0.014	Ag	0.02	0.69	< 0.02	< 0.69
Cu	0.003	0.004	Pt	< 0.002	< 0.07	< 0.002	< 0.07
Fe	6.24	5.30					
Cr	0.27	0.25					
S	0.060	0.047					

Table 2 gives the results of CANMET determinations to isolate the sulphide from total nickel. The Ni soluble in ascorbic acid - hydrogen peroxide mixture was reported as sulphide Ni.

Table 2 - Ni assay (CANMET)

Sample	Assay, Ni %		% Dist. Ni Sulph
	Total	Sulphide	
Site #9	0.22	0.17	77.3
Site #11	0.21	0.12	57.1

According to these data, the nickel tied up in a sulphide form is 77.3% and 57.1% of the total nickel for sites #9 and #11 respectively.

#### TESTWORK

The following investigations were conducted:

- Grinding test to determine the conditions for grinding the ore to various sizes
- Gravity concentration tests to recover the heavy minerals
- Flotation tests to recover the Ni and Co
- Magnetic concentration tests to recovery the Fe and Cr

Most of the testwork was carried out with site #9 sample and only few experiments were performed with site #11 which was a material more difficult to process.

#### GRINDING TESTS

Several tests were carried out to determine the conditions under which the ore samples could be ground to -150  $\mu\text{m}$  (100 mesh); -74  $\mu\text{m}$  (200 mesh); -37  $\mu\text{m}$  (400 mesh); -30  $\mu\text{m}$  (500 mesh).

The equipment used to grind the ore was a laboratory steel mill having a grinding balls load of 17,656 g.

The grinding conditions for various sizes are given in Table 3.

Table 3 - Grinding conditions

Site	Grind		Charge g	Slurry % solids	Grind time min.	Ground ore % passing
	µm	Mesh				
9	150	-100	2000	50	30	72.9% - 74 µm
	74	-200	2000	60	57	95.4% - 74 µm
	37	-400	2000	60	150	98.0% - 37 µm
	30	-500	2000	60	300	98.6% - 30 µm
11	150	-100	2000	50	25	71.8% - 74 µm
	74	-200	2000	50	58	96.1% - 74 µm

Two tests were carried out using stage grinding for a total grinding time of 342 minutes for 3-stage grinding and 147 minutes for 2-stage grinding with desliming between stages.

#### GRAVITY CONCENTRATION

Several tests were carried out to examine the possibility of preconcentrating all heavy minerals (Ni, Co, Fe, Cr) by a gravity separation method.

Samples ground to -150 and -74 microns from sites 9 and 11 were processed on a laboratory Wifley table.

The results of the table tests showed no trend of a significant concentration in any of the table products. This method of investigation was not considered appropriate for this type of ore and it was abandoned.

#### FLOTATION

The recovery of Ni and Co in a collective concentrate was tried by flotation.

The flotation tests were conducted in the following sequence:

#### Tests to Reproduce the A-Min-Tech Conditions

Three tests were carried out, two with site #11 and one with site #9, to reproduce the conditions and results previously obtained with this

material by A-Min-Tech. Under similar grinding conditions and reagent regime the results obtained by us with sites #9 and #11 were inferior to those previously reported by A-Min-Tech.

A comparison between the metallurgical data obtained by CANMET and those reported by A-Min-Tech is presented in Table 4.

Table 4 - Metallurgical results, CANMET vs A-Min-Tech

Research unit	Test no	Site no	Products	% Weight	Assay %		% Dist.	
					Ni	Co	Ni	Co
CANMET	1	11	Conc 1-3	8.8	0.45	0.025	19.5	19.4
			Tails	91.2	0.18	0.010	80.5	80.6
			Head	100.0	0.20	0.011	100.0	100.0
A-Min-Tech	BRF-16	11	Conc 1-4	7.3	1.13	0.055	40.7	42.0
			Tails	92.7	0.13	0.006	59.3	58.0
			Head	100.0	0.20	0.010	100.0	100.0
CANMET	2	9	Conc 1-3	7.2	0.83	0.042	28.6	34.9
			Tails	92.8	0.16	0.006	71.4	65.1
			Head	100.0	0.21	0.009	100.0	100.0
A-Min-Tech	BRF-8	4	Conc 1-3	4.8	2.29	0.133	53.7	52.8
			Tails	95.2	0.10	0.006	46.3	47.2
			Head	100.0	0.21	0.012	100.0	100.0

The ore identified as site #4 was similar to that of site #9.

No explanation could be found as to why the A-Min-Tech results were not reproduced by CANMET, except probably that the characteristics of the material were different.

#### Rougher Flotation Tests

Several flotation tests were then carried out to adjust and improve the Ni-Co recovery in the rougher stage. Site #9 ore was used for these tests since this material appeared to be less difficult to upgrade than site #11.

Most of the tests were performed under -74 $\mu$ m (200 mesh) grinding conditions and the best conditions were then applied to -37  $\mu$ m (400 mesh) and -30  $\mu$ m (500 mesh) ground ore.

In an attempt to increase the metals recovery two tests were performed with stage-grinding, flotation being carried out between grinding stages. In one of those tests (Test 19a-b-c) the ore was first ground to  $-74 \mu\text{m}$  and the Ni-Co was floated. Then the tailing was again ground after which another series of Ni-Co concentrates were collected. Finally the second flotation tailings were ground for the third time followed by a third series of Ni-Co flotation. In the other test (Test 22a-b) the ore was ground to  $-74 \mu\text{m}$  and Ni-Co was floated. Then the rougher tails were deslimed twice and the deslimed material was again ground after which Ni-Co concentrates were again collected.

The metallurgical data and conditions of the most significant tests of the rougher flotation are summarized in Table 5. The flotation time for collecting each concentrate was 5 minutes for all tests except test #21 and 22a-b, where the time was 10 minutes.

In one test the flotation products were assayed for total Ni, and total Ni and sulphide Ni, to determine the efficiency of the flotation process as regards the nickel extraction. The results of this test are presented in Table 6.



Table 5 - Summary of rougher flotation conditions and results

Test no. (Site)	Grind	pH	Reagents		Products	Z Wt	Assay %		Z Dist	
			Types	g/t			Ni	Co	Ni	Co
32 (9)	-150 μm (100 mesh)	9.7	C.M.C.*	1500	Conc 1-3	2.3	1.68		18.0	
			Aero-208	100	Tails	97.7	0.17		81.1	
			Aero-3477	55	Head	100.0	0.20		100.0	
			Xanthate-350	55						
			Dow Froth-250	36						
6 (9)	-74 μm (200 mesh)	9.8	Same as test		Conc 1-3	5.0	1.34		33.6	
			32		Tails	95.0	0.14		66.4	
					Head	100.0	0.20		100.0	
16-A (9)	-37 μm (400 mesh)	9.2	C.M.C.	2500	Conc 1-3	7.8	1.03		38.4	
			Collectors as above	210	Tails	92.2	0.14		61.6	
			DF-250	9	Head	100.0	0.21		100.0	
28 (9)	-30 μm (500 mesh)	9.6	C.M.C.	3750	Conc 1-3	15.6	0.63		47.4	
			Collectors as above	210	Tails	84.4	0.13		52.6	
			DF-250	18	Head	100.0	0.21		100.0	
19 a-b-c (9)	3-stage grind -37 μm (400 mesh)	9.6	C.M.C.	4500	Conc 1-9	32.0	0.44	0.021	65.4	71.3
			Aero-208	300	Tails	68.0	0.11	0.004	34.6	28.7
		9.8	Aero-3477	165	Head	100.0	0.22	0.009	100.0	100.0
			Xanthate-350	165						
		DF-250	81							
22 a-b (9)	2-stage grind -37 μm (400 mesh)	9.7	C.M.C.	3000	Conc 1-6	26.0	0.48	0.025	60.3	68.8
			Aero-208	200	Slimes	2.6	0.11	0.006	1.5	2.2
		9.8	Aero-3477	110	Tails	71.4	0.11	0.004	38.2	31.2
			Xanthate-350	110	Head	100.0	0.21	0.009	100.0	100.0
		DF-250	63							
21 (9)	-37 μm (400 mesh)	9.7	Same as test		Conc 1-3	12.9	0.75		48.0	
			16-A, except		Tails	87.1	0.12		52.0	
			longer flot. time		Head	100.0	0.20		100.0	
18 (11)	-37 μm (400 mesh)	9.0	Same as test		Conc 1-3	13.5	0.56		36.6	
			16-A, except		Tails	86.5	0.15		63.4	
			DF-250		81	Head	100.0	0.21		100.0

Carboxymethylcellulose

Table 6 - Flotation results based on sulphides assay

Product	% Weight	Assay %			% Dist.		
		Ni total	Ni Sulphide	Ni non-sulph.	Ni total	Ni Sulphide	Ni non-sulph.
Conc -1	2.0	1.98	1.87	0.11	18.1	23.7	3.6
Conc -2	1.8	0.96	0.89	0.07	7.9	10.1	2.1
Conc -3	2.0	0.57	0.51	0.06	5.2	6.5	2.0
Conc 1-3	5.8	1.18	1.10	0.08	31.2	40.3	7.7
Tails	94.2	0.16	0.10	0.06	68.8	59.7	92.3
Head	100.0	0.22	0.16	0.06	100.0	100.0	100.0

Based on the results presented in Table 5 and 6 the following comments can be made:

(a) The nickel recovery increased with the fineness of grind but even when the size of the particles was 98.6% -30 microns the nickel extraction did not exceed 47.4%.

(b) By using longer flotation time or stage grinding - flotation, the nickel extraction rose in some tests to 65.4% but the concentrate was impurified with a large quantity of gangue which drastically reduced the grade of the Ni product.

(c) The required amount of C.M.C. to depress the gangue minerals increased with the fineness of grind. This reagent seemed to be a very efficient depressant for the serpentine gangue, however the required large consumption (1.5-4.5 kg/t) and its high cost (\$2.03/kg) might be very expensive in industrial application.

(d) The recovery of sulphide nickel was better than that of total nickel but probably because of the intimate association of the pentlandite with the gangue minerals, even the extraction of sulphide nickel was not satisfactory.

(e) The results obtained with site #11 ore were inferior to those resulting by processing site #9 under the same conditions.

#### Cleaner Flotation Tests

Several flotation tests were carried out to determine the possibility of upgrading the nickel product by re-floating the rougher concentrate.

Since the Ni concentration in the original ore was quite low it was necessary to process large amounts of material in the rougher stage to obtain enough quantity of rougher concentrate for the next cleaning stages. The collecting of the rougher concentrate took several days and the concentrate saved during this period in preparation for cleaning might have suffered some aging effects which could, to a certain extent, have affected the results of the flotation in the cleaning stages.

A summary of the conditions and results of the flotation cleaning tests is shown in Table 7.

Table 7 - Summary of cleaning flotation results

Test no.	Grind	Reagent (cleaning)		Product	% weight	Assay % Ni	% Dist. Ni
		Type	g/t*				
29	-74 $\mu$ m (-200 mesh)	CMC (1st Cl. Fl.)	100	3rd Cl. Conc	0.60	9.02	26.0
		(2nd Cl. Fl.)	26	2nd Cl. Conc	1.00	6.35	30.5
		(3rd Cl. Fl.)	3	1st Cl. Conc	2.50	2.73	32.8
				Rougher Conc	11.80	0.72	40.8
		Xanthate 350	2.8	1st Cl. Tails	9.30	0.18	8.0
				Rougher Tails	88.20	0.14	59.2
30	-74 $\mu$ m (-200 mesh)	CMC (2nd Cl. Fl.)	10	4th Cl. Conc	0.24	12.30	14.4
		(3rd Cl. Fl.)	2	3rd Cl. Conc	0.29	11.72	16.6
				2nd Cl. Conc	0.50	8.02	19.6
		Xanthate 350	0.4	1st Cl. Conc	0.99	4.61	22.3
				Rougher Conc	4.42	1.39	30.0
				1st Cl. Tails	3.43	0.46	7.7
				Rougher Tails	95.58	0.15	70.0
31	-37 $\mu$ m (-400 mesh)	Xanthate 350	4	3rd Cl. Conc	0.14	17.06	11.4
				2nd Cl. Conc	0.20	13.50	12.9
				1st Cl. Conc	0.36	8.67	14.9
				Rougher Conc	7.19	0.98	33.5
				1st Cl. Tails	6.83	0.57	18.6
				Rougher Tails	92.81	0.15	66.5
33	-37 $\mu$ m (-400 mesh)	CMC (3rd Cl. Fl.)	5	4th Cl. Conc	0.06	23.25	6.8
		Xanthate 350	8.5	3rd Cl. Conc	0.10	17.00	8.3
				2nd Cl. Conc	0.25	11.44	14.0
				1st Cl. Conc	0.56	6.46	17.7
				Rougher Conc	7.85	0.96	37.0
				1st Cl. Tails	7.29	0.54	19.3
				Rougher Tails	92.15	0.14	63.0
34	3-stage grinding -37 $\mu$ m (400 mesh)	Xanthate 350	22.5	4th Cl. Conc	0.17	11.40	9.3
				1st Cl. Conc	1.56	2.67	20.0
				Rougher Conc	24.06	0.52	60.0
				1st Cl. Tails	22.50	0.37	40.0
				Rougher Tails	75.94	0.11	40.0

\*g/t of ore

Based on the results of the flotation cleaning tests the following comments can be made:

(a) Upgrading the rougher concentrate to a relatively high grade nickel product was possible by successive cleaning stages. Concentrates of Ni content higher than 6% were obtained, for some tests, even in the 1st cleaner stage.

(b) The nickel recovery dropped significantly in the cleaning stages.

The first two flotation cleaning tests were carried out with ore ground to -74 microns. In test 29 an intensive rougher flotation was performed to boost the nickel recovery. A good amount of gangue minerals were entrained in the rougher concentrate but a large addition of CMC in the first cleaner stage (857 g/t of 1st cleaner feed) managed to remove most of the gangue in the 1st cleaner tails, for a nickel loss of 8.0%. The gangue was further controlled by successive additions of CMC without losing too much Ni in the subsequent cleaner tails. Thus the 2nd cleaner concentrate assayed 6.35% Ni for a nickel extraction of 30.5%.

In the next test (#30) where the weight of the rougher concentrate was kept low by reduced addition of frother, there was no need to control the gangue by CMC addition in the 1st cleaner stage. By strict froth control, again a substantial amount of gangue was dropped in the 1st cleaner tails for a nickel loss of 7.7%. The 2nd cleaner concentrate assayed 8.02% Ni but overall nickel recovery was only approximately 20%.

In the subsequent three tests with ore ground to -37  $\mu\text{m}$  (400 mesh) elimination of the CMC addition and avoidance of the entrainment of the gangue minerals throughout the cleaning stages by a careful control of the froth was tried. However, in those tests this was not possible because of a much higher proportion of slimes produced by the finer grind. A substantial amount of material was again dropped in the 1st cleaner tails but the amount of nickel carried along was this time very high 18.6 - 40%.

#### Precious Metals Analysis of Flotation Concentrate

Two flotation cleaner concentrates were assayed for precious metals. The results are given in Table 8.

Table 8 - Precious metals assay

Test	Product	Ni %	Au		Ag		Pt		Pd	
			oz/t	g/t	oz/t	g/t	oz/t	g/t	oz/t	g/t
31	3rd Cl. Conc	17.06	<0.001	<0.03	0.2	6.86				
30	4th Cl. Conc	12.30					0.012	0.41	0.006	0.21

The precious metals content in a nickel concentrate of 12-17% Ni was negligible.

#### MAGNETIC CONCENTRATION

The magnetic concentration of iron and chromium minerals was examined.

First, a series of Davis Tube determinations was carried out to evaluate the possibility of obtaining an iron concentrate, then magnetic separation tests were performed using several magnetic separators.

The conditions and results of these tests follow.

#### Davis Tube Determinations

Samples of original ore and flotation tailing at various grinding sizes were subjected to Davis Tube tests. The results are presented in Tables 9 and 10.

Table 9 - Davis Tube tests with original ore

Test no.	Grind % -74 $\mu$ m	Cond. Amp.	Products	Weight		Assay %		% Dist.	
				g	%	Fe	Cr	Fe	Cr
0-1	95.4	1.8	Mags	6.0	9.6	40.2	1.72	57.6	60.4
			Non-Mags	56.6	90.4	3.14	0.12	42.4	39.6
			Head	62.6	100.0	6.7	0.27	100.0	100.0
0-2	100.0 and 98.0% -37 $\mu$ m	1.8	Mags	3.5	6.8	56.4	2.02	53.8	49.5
			Non-Mags	47.7	93.2	3.54	0.15	46.2	50.5
			Head	51.2	100.0	7.1	0.28	100.0	100.0
0-3	100.0 and 98.6% -30 $\mu$ m	1.8	Mags	2.1	4.5	50.9	1.90	35.8	32.2
			Non-Mags	44.3	95.5	4.30	0.19	64.2	67.8
			Head	46.4	100.0	6.4	0.27	100.0	100.0

Table 10 - Davis Tube tests with flotation tailing

Test no.	Grind % -74 $\mu$ m	Cond. Amp.	Products	Weight		Assay %		% Dist.	
				g	%	Fe	Cr	Fe	Cr
4	95.4	1.8	Mags	5.2	11.1	37.5	1.52	60.0	61.2
			Non-Mags	41.8	88.9	3.12	0.12	40.0	38.8
			Head	47.0	100.0	6.94	0.28	100.0	100.0
16-A	100.0 and 98.0% -37 $\mu$ m	1.8	Mags	3.5	7.8	53.90	1.90	56.7	51.7
			Non-Mags	41.4	92.2	3.48	0.15	43.3	48.3
			Head	44.9	100.0	7.41	0.29	100.0	100.0
28	100.0 and 98.6% -30 $\mu$ m	1.8	Mags	3.0	6.2	59.3	2.00	55.4	50.4
			Non-Mags	45.2	93.8	3.16	0.13	44.6	49.6
			Head	48.2	100.0	6.64	0.25	100.0	100.0

The results of the Davis Tube determinations indicated that even at almost 100% -30 microns grind the separation of iron-chromium minerals was not possible, both following the same trend of concentration. Also, the iron content of the magnetic product could not be raised over 60%. The non-magnetic product remained high in Fe and Cr throughout the tests.

### Magnetic Separation

A series of magnetic separation tests was carried out to confirm the Davis Tube results. All the tests but one were performed with flotation tailing resulting from rougher flotation, under -74, -37 and -30 microns grinding. One test was done with original ore ground to -74 microns.

Various magnetic apparatus were used: Sala permanent magnet, Sala High Gradient Magnetic Separator (HGMS), Jones and Jeffrey. The experiments carried out with Jeffrey were performed by Lakefield Research of Canada while the tests with the other equipment were done in our laboratory.

In tests 4-1 and 16A-1 the Ni flotation tailing was passed through Sala permanent magnet apparatus to separate the magnetite from chromite and other less magnetic minerals. Then the non-magnetic product resulting from this separation was processed in a Sala High Gradient Magnetic Separator at various intensities of the magnetic field to concentrate the chromite.

In tests 4-2, 16A-2 and 16A-3 the Ni flotation tailing was processed by Sala HGMS at the lowest intensity of the magnetic field (approximately 660 Gauss) under various flow rates. In one test, 16A-3, the magnetic concentrate obtained at 660 Gauss was reprocessed at a higher flow to improve its iron content, while the non-magnetic product was retreated at a higher intensity of the magnetic field (21.4 K Gauss) to separate the chromite.

In test 28-1 nickel flotation tailing of very fine grind (98.6% -30 microns) was passed through a Jones separator at zero amperage which corresponded to a residual magnetic field of 3000 Gauss. The purpose of the test was to concentrate the magnetite in the magnetic product.

Nickel flotation tailing at various grinds and original ore ground to 95.4% -74 microns was processed at Lakefield Research Laboratories in a Jeffrey separator for the purpose of producing a magnetite concentrate.

The results of the magnetic concentration tests are summarized in Table 11. Since the separation of iron and chromium minerals could not be



achieved the data presented in Table 11 referred to the magnetic product as resulting from the magnetic concentration process.

Table 11 - Magnetic concentration of flotation tailing and original ore

Flotation tailing								
Equipment	Test no.	Grind	Mag. Field Gauss	% Weight	Assay %		% Dist.	
					Fe	Cr	Fe	Cr
Sala perm. magnet	4-1	-74 $\mu$ m	600	5.7	39.9	1.44	32.9	30.3
	16A-1	-37 $\mu$ m	600	3.4	25.8	0.95	12.1	11.4
Sala HGMS	4-2	-74 $\mu$ m	660	19.0	15.8	0.70	55.6	49.1
	16A-2	-37 $\mu$ m	660	14.8	13.9	0.60	41.0	32.2
	16A-3	-37 $\mu$ m	660	40.6	10.7	0.47	70.0	73.8
Jones	28-1	-30 $\mu$ m	3000	4.8	36.86	1.32	25.1	21.7
Jeffrey	23-1	-74 $\mu$ m	320/1300	6.3	36.0	1.41	35.2	32.3
	17-1	-37 $\mu$ m	600/1300	4.4	14.80	0.60	9.5	8.7
	28-1	-30 $\mu$ m	800/1300	0.9	26.33	0.91	3.4	2.9
Original ore								
Jeffrey	-	-74 $\mu$ m	320/1300	3.4	40.1	1.53	21.6	19.3

Based on the results of the magnetic concentration tests the following comments can be made:

(a) Separate concentration of iron and chromium minerals by magnetic separation was not possible even at a very low magnetic field (320 Gauss) or at extremely fine grinding (98.6% -30 microns). Both Fe and Cr followed the same trend of concentration throughout the tests.

(b) The grade of the magnetic concentrate for both Fe and Cr was far below the level of the saleable products. Contrary to what would have been expected and to what the Davis Tube tests showed the grade of the magnetic concentrate deteriorated with the fineness of grind. The highest Fe and Cr concentrate grade was obtained at 95.4% -74 microns (approximately 40% Fe and 1.5% Cr). Extremely intimate association between magnetite and other

minerals must have been the cause for the poor efficiency of the magnetic separation.

(c) The iron and chromium recovery for the best magnetic concentrates was quite low (below 35%). Sala HGMS gave higher Fe and Cr extraction but the grade of the magnetic product was too low to deserve further attention.

(d) No significant difference was found between the results of the magnetic concentration with flotation tailing or original ore (not subjected to flotation).

#### CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn based on the results of the testwork with Border Resources ore:

(a) The ore exhibited a very low content in valuable metals making the task of upgrading the material to saleable products difficult to achieve.

(b) Extremely intimate association of the minerals among themselves reduced very much the efficiency of concentration for all methods tried in this testwork.

(c) Nickel and cobalt can be recovered by flotation and concentrates of 6% Ni or more were obtained but the nickel extraction, at this level of concentration, did not exceed 30%. Continuous operation with middlings recirculation will probably be able to increase somewhat the nickel recovery but it is unlikely that under the most optimistic conditions a recovery in excess of 50% will be obtained.

(d) Precious metals (Au, Ag, Pt, Pd) concentration in flotation products of high Ni grade was insignificant and therefore little economic benefit should be expected from this part.

(e) Separate concentrates of iron and chromium could not be obtained by magnetic separation. Even at an extreme fine grind and under very low intensity of magnetic field the two constituents remained unseparated, showing at all times similar distribution in the magnetic and non-magnetic products.

(f) The grade of the Fe-Cr product obtained by magnetic concentration was far below that of a saleable concentrate and the recovery in both metals remained very low under all tested conditions. It is unlikely that by mineral dressing methods an efficient separation of Fe-Cr minerals can be obtained.

Although the results of this testwork were not quite satisfactory it must be recognized that some progress in the recovery of nickel minerals was definitely achieved. It was proved that a good part of the nickel minerals showed a positive response to flotation; concentrate of over 20% Ni being produced under strictly controlled conditions. These results deserve further attention and constitute a good ground to continue the investigation for the beneficiation of this ore.

The following recommendations are offered:

1. Develop a scientifically oriented prospecting program to locate zones in the ore body of better mineralization. Apparently there are some scientific grounds to support the idea that such zones of higher nickel concentration does exist in that geological formation.
2. Continue the mineralogical investigation to identify the intimate structure and nature of the mineralization. Ni-Co as well as Fe-Cr minerals should be the main object of this research work.
3. Submit samples of original ore to various manufacturers of magnetic separation equipment to obtain more information about the possibility of concentrating the iron and chromium minerals by this method.
4. When better nickel mineralization is found resume the flotation testing program for the recovery of the nickel, cobalt and other possible constituents including precious metals.

RESULTS OF MINERALOGICAL EXAMINATION OF TAILINGS  
SAMPLE 16-A, SITE #9  
SUBMITTED BY BORDER RESOURCES LTD., VANCOUVER

P.R. Mainwaring  
Mineral Processing Laboratory

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Cost Recovery in Mineral Processing Technologies

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MINERALS RESEARCH PROGRAM  
MINERAL SCIENCES LABORATORIES  
DIVISION REPORT MRP/MSL 84-3 (CR)

**CONFIDENTIAL**

RESULTS OF MINERALOGICAL EXAMINATION OF TAILINGS SAMPLE 16-A, SITE #9  
SUBMITTED BY BORDER RESOURCES LTD., VANCOUVER

by

P.R. Mainwaring

SUMMARY

Border Resources Ltd., Vancouver submitted samples of serpentinized ultramafic rock containing disseminated sulphide mineralization to CANMET for metallurgical testwork. The tailings samples from beneficiation tests conducted by CANMET consist predominantly of serpentine, magnetite and minor pentlandite. Electron microprobe analyses of serpentine show that it contains about 0.07% NiO and that pentlandite contains about 40.0% Ni. There is about 0.25 wt % pentlandite in the tailings, as estimated visually in SEM micrographs. Therefore, about 59% of the unrecovered nickel occurs in pentlandite and 41% occurs in serpentine.

## INTRODUCTION

Samples of serpentinized ultramafic rock were submitted by Dr. H.E.A. von Hahn of Border Resources Inc. to CANMET for metallurgical testwork. The specimens were collected from the Coquihalla ultramafic belt near Hope, B.C. and consist of serpentinized periodotite or pyroxenite. Nickel content of the heads averages about 0.24%. Beneficiation tests have been conducted by M.A. Cristovici, Mineral Dressing Section, MPL, on samples of the serpentinite which contains finely disseminated nickel minerals. Results of these tests have been reported (1). Several samples of products from these tests were submitted for mineralogical examination. The purpose of this examination was to determine the occurrence and distribution of nickel-bearing minerals in the tailings. The particle size of the material was 98%  $< 37 \mu\text{m}$  and it contained 0.14% Ni.

Results of earlier examinations of heads and tailings of this same material indicate that millerite and heazlewoodite, as well as pentlandite, are present in the heads and that as much as 65 - 70% of the nickel occurs in solid solution in mafic silicate minerals. More recent chemical analysis indicates, however, that about 77% of the nickel is in the sulphide form. In addition, magnetite has also been suggested as a carrier of nickel (2).

This report includes, in Appendix A, an outline of a possible model for re-interpretation of nickel mineralization in the Coquihalla Serpentinite belt, from which the samples examined in this study were taken. This model predicts local concentrations of higher grade nickel mineralization which, if found, would significantly improve the economics of the property.

## RESULTS

### MINERALOGY OF SAMPLES

Mineralogy of sample 16-A (Tailings) is given in Table 1. Polished section grain mounts of the tailings and polished thin sections of serpentinite were examined in order to characterize the minerals. Examination was conducted with an optical microscope and with a scanning electron microscope equipped with an energy dispersive X-ray analyser.

Mineral chemistry was determined with a JXA 733 electron microprobe using an electron beam diameter of approximately 0.5 micrometre.

#### Heads

The serpentinite consists largely of serpentine, probably antigorite, with minor chlorite, amphibole, and talc. Opaque minerals are magnetite, hematite, chromite, sparse ilmenite, sphalerite, chalcopyrite and pentlandite. Sinclair estimated total sulphide in some head samples as less than 1% (3). Although head samples were not examined in detail in this study, a visual estimate is in agreement with this figure.

#### Tailings

Tailings sample 16-A is composed of approximately 0.25% pentlandite, 4% chlorite + amphibole, 0.4% magnetite and 95.3% serpentine. Minor talc has also been identified. Photomicrographs of tailings, mounted in polished section, are shown in Figures 1 and 2. Figures 3, 4 and 5 are SEM micrographs of the tailings using a backscattered electron detector. The medium grey particles represent silicate and the brighter particles represent minerals that have a higher average atomic number, such as magnetite, ilmenite, chromite and pentlandite. The general nature and typical distribution of the minerals can be seen in these figures. Due to the low absolute nickel contents, 8 polished sections of tailings were used in this examination. Pentlandite was observed in all samples. No heazlewoodite or millerite was identified in any of the samples.

#### LIBERATION CHARACTERISTICS OF PENTLANDITE

Visual estimates of the volume per cent pentlandite in the tailings are in the order of 0.25%. This pentlandite occurs as free grains and as locked grains in serpentine. About 75% of the pentlandite occurs as locked grains. Free pentlandite is irregular to subrounded in shape as is most of the pentlandite which is locked in serpentine (Fig. 3 and 7). As shown in the SEM micrographs, the free pentlandite is up to about 20 micrometres in maximum dimension while the locked pentlandite may be as large as 15 micrometres. Approximately 1/3 of the locked pentlandite forms acicular or 'blocky' needle-like grains (Fig. 4, 5, and 6). The longest acicular

pentlandite included in serpentine is about 50 micrometres and may be only 2-3 micrometres wide. Since the sizes of locked pentlandite are typically less than 20 micrometres in dimension then liberation of a significant amount of this pentlandite will only be achieved if grinding is carried out to finer than 500  $\mu\text{m}$  (-26 micrometres).

#### DISTRIBUTION OF NICKEL

In the tailings samples studied, nickel is distributed between iron-oxide minerals, silicates and sulphides. Nickel content in the iron oxide minerals is very low, as indicated by electron microprobe analyses (Table 3). Therefore, most of the nickel is distributed between sulfide and silicate minerals, such as serpentine. Quantitative analyses of serpentine and pentlandite show that there is a relative concentration factor of about 300 between nickel in the pentlandite and that in the serpentine.

Since the nickel content of pentlandite is about 40 wt. % (see below) and the tailings contains about 0.25% by weight pentlandite, then the mineral contributes about 0.1% of the nickel. Serpentine has a mean nickel content of about 0.07% (Table 3) and its abundance is about 95%, therefore it contributes about 0.067% nickel to the tailings (Table 2). The total estimated nickel content in the tailings is 0.17% which compares with the assay value of 0.14% total nickel. This agreement is reasonable considering the accuracy of visual estimates of pentlandite and serpentine. The estimate of the nickel content in silicates (0.067%) compares well with that determined by Cristovici (0.06%). These results are summarized in Table 3.

#### MINERAL CHEMISTRY

Pentlandite and serpentine were analysed by electron microprobe in order to confirm identification and to measure the nickel and cobalt content. Compositions are reported in Table 3. Analysis of about 100 grains, by semi-quantitative techniques, resulted in the detection of several grains which contained about 3 - 5% Ni. It is believed that these grains contained small inclusions of pentlandite, lying beneath the surface, which were excited by the electron beam during analysis to produce the spurious nickel radiation from the serpentine. Typically, serpentine ranges in nickel content between about 0.01 and 0.4%. The mean nickel



content is calculated to be about 0.07%. Figure 7 is a composite micrograph of the tailings with a superimposed nickel Ka X-ray dot map. Except for the large, locked grain of pentlandite, there is a relatively even distribution of nickel content of the serpentine.

Pentlandite contains about 40% Ni which is quite high relative to most pentlandite compositions commonly observed in ultramafic rocks. Such a high nickel content normally implies coexistence with either millerite or a nickel-iron alloy in the rocks. Neither mineral was identified in the tailings examined although millerite has been reported (2). Cobalt was detected only in the pentlandite and this confirms the speculation about its distribution as noted in earlier reports.

#### DISCUSSION

Previous internal company reports by von Hahn (4), Chamberlain (2,5), and Sinclair (3) state that millerite, heazlewoodite and pentlandite are present, in variable amounts, in the samples examined by them. Sinclair's determination of millerite was based on optical examination alone while von Hahn's identification of pentlandite was by electron microprobe analysis. Although pentlandite has been confirmed by electron microprobe in the samples supplied for this study, neither heazlewoodite nor millerite was detected.

Chamberlain and Campbell (6) state that "...about 60 - 70% of the nickel is actually locked in the silicate fraction of the rock while the remainder occurs as finely divided pentlandite and millerite". This statement is predicated on the observation that "...microscopic study of the tail samples indicates that the tails are essentially barren of sulphides, therefore it can be reasonably assumed that the silicates of all the samples contain about 0.20% Ni...". Cristovici (1983) interpreted from nickel assays that up to 77.3% of the nickel in the heads is combined as a sulphide mineral (pentlandite). The present examination of the tailings indicates that about 59% of the nickel occurs as pentlandite.

Cobalt content was measured at the same time as nickel because these two elements commonly substitute for each other in minerals. Pentlandite was the only mineral found to contain cobalt and there it occurs at levels of about 2%.

### SUMMARY AND RECOMMENDATIONS

This detailed mineralogical study of Border Resources tailings from Site #9 has shown that:

- pentlandite is the only sulphide carrier of nickel in the samples examined;
- pentlandite occurs as small free grains and as grains locked in serpentine;
- maximum size of free pentlandite is about 20 micrometres and locked pentlandite is considerably finer;
- serpentine accounts for about 41% of the nickel content of the tailings while pentlandite accounts for about 59%;
- liberation of the locked pentlandite will occur only if grinding is carried out to  $-30 \mu\text{m}$ ;
- nickel content of pentlandite (40%) suggests that it may have been in equilibrium with millerite or iron-nickel alloy;
- detailed systematic petrography of the host serpentinite should be undertaken to identify additional nickel-bearing minerals;
- further metallurgical testing should be carried out on any samples which have more economic potential;
- a new model for exploration in the Coquihalla ultramafic belt is based on assimilation of sulphide-bearing shale and greywacke rocks which form the footwall of the serpentinite; this model is discussed in the appendix.

ACKNOWLEDGEMENTS

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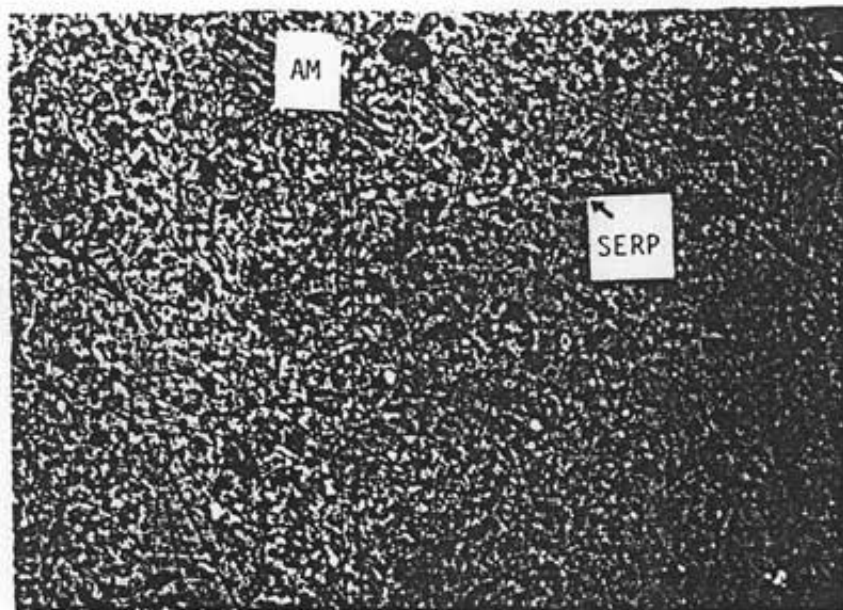


Fig. 1. Polished section of site #9 tailings. Particles are predominantly of serpentine (serp), amphibole (am) and pentlandite (pn). Width of field is 0.05 mm. Mesh size: -400. Plane polarized light.

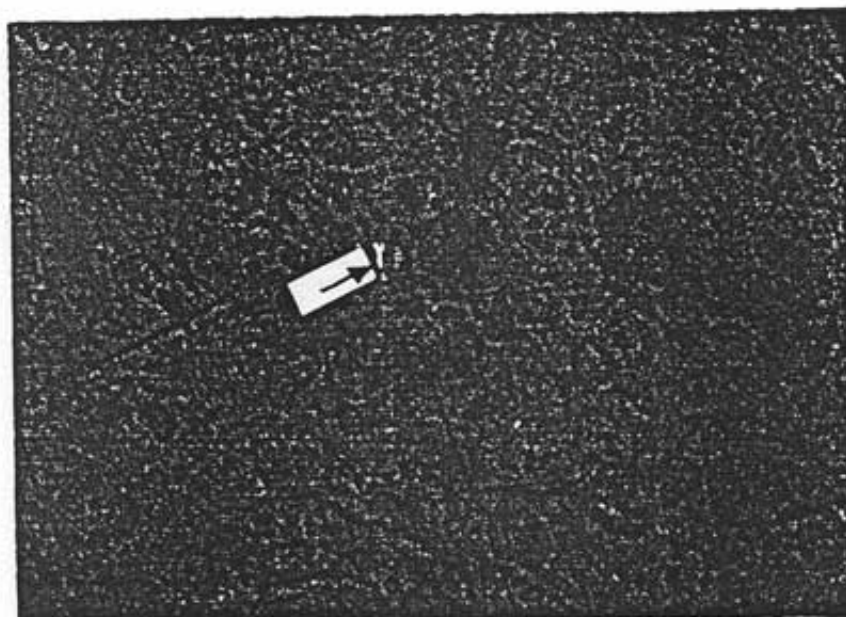


Fig. 2. Polished section of site #9 tailings. Free grain of anhedral pentlandite marked. Width of field is 0.05 mm. Mesh size: -400. Plane polarized light.

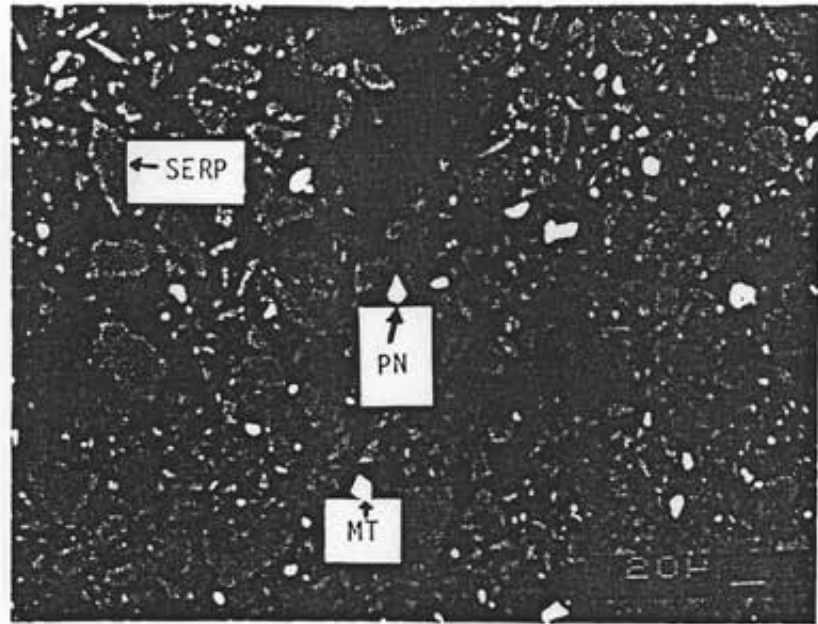


Fig. 3. Back-scattered electron (BSE) SEM micrograph of tailings. Predominantly serpentine particles (serp), pentlandite (pn) locked and free, and magnetite (mt).

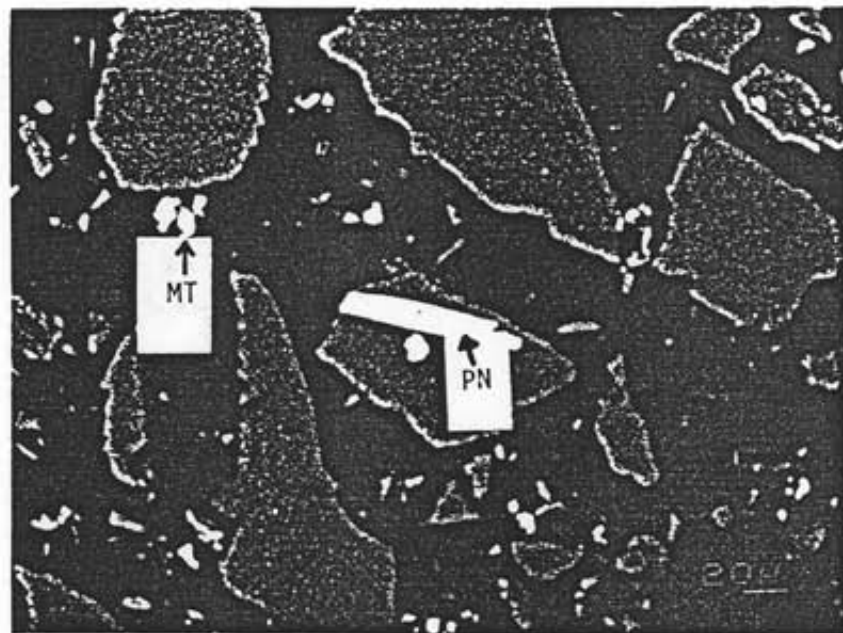


Fig. 4. BSE micrograph of coarser particles of serpentine with elongated grain of locked pentlandite (pn). Other "bright" particles are magnetite (mt).

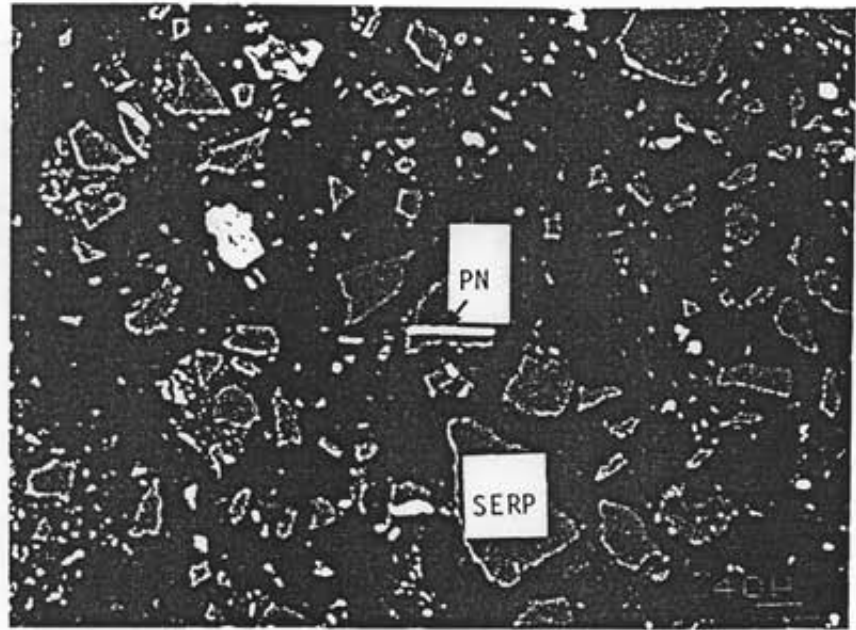


Fig. 5. BSE micrograph of serpentine particles (serp), one with locked, needle-like grain of pentlandite (pn).

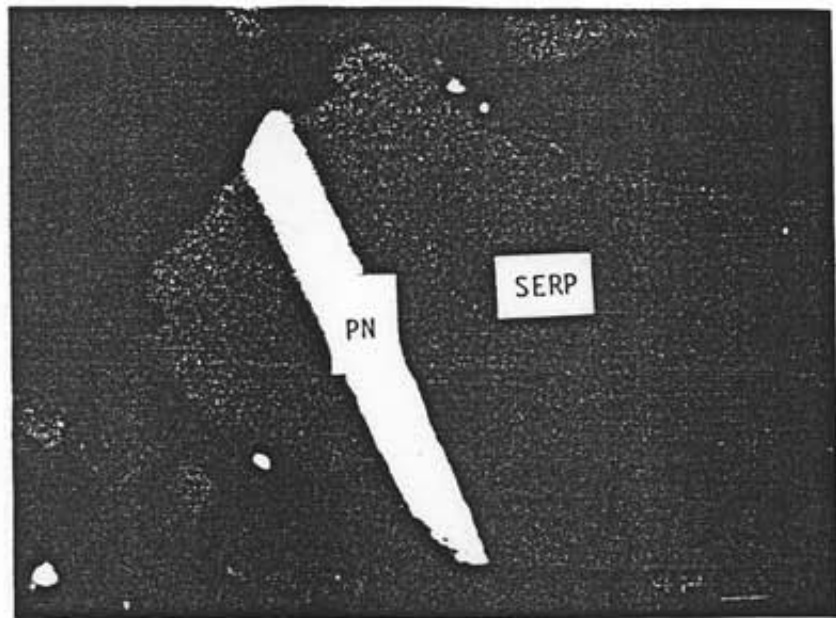


Fig. 6. BSE micrograph of locked needle-like grain of pentlandite (pn) in serpentine grain (serp).

TABLE 1

Mineralogy of Samples Examined

Mineral	Approx wt % (range)	Mineral	Approx wt % (range)
Serpentine	90 - 98	Magnetite	1 - 3
Chlorite	0 - 2	Hematite	Trace
Amphibole	Trace	Chromite	Trace
Talc	Trace	Ilmenite	Trace
		Sphalerite	Trace
		Chalcopyrite	Trace
		Pentlandite	Trace

TABLE 2

Nickel Distribution in Tailings

Mineral	Abundance	Ni content (%)	Total Ni	Distribution Ni %
Pentlandite	0.25%	40.0	0.1%	59
Serpentine	95%	0.07	0.07	41



TABLE 3

A: Selected Serpentine Analyses

	1.	2.	3.	4.	5.
SiO <sub>2</sub>	40.5	40.3	40.3	40.4	40.2
MgO	41.1	41.3	40.4	41.4	41.5
Al <sub>2</sub> O <sub>3</sub>	0.31	0.51	n.d.	-	-
FeO	2.19	2.34	2.36	2.74	2.32
NiO	0.01	0.02	0.03	0.03	0.40
H <sub>2</sub> O (assumed)	<u>15</u>	<u>15</u>	<u>15</u>	<u>15</u>	<u>15</u>
TOTAL	99.11	99.47	98.09	99.57	99.42

B: Selected Pentlandite Analyses

	1.	2.	3.	4.
Fe	23.9	23.2	22.3	23.6
Ni	39.8	41.1	40.4	40.7
Co	2.1	2.10	2.12	2.0
S	<u>32.0</u>	<u>32.3</u>	<u>32.9</u>	<u>31.9</u>
TOTAL	97.8	98.7	97.7	98.2

C: Selected Magnetite Analyses

	1.	2.	3.
FeO*	99.5	98.7	99.2
NiO	0.2	0.1	0.0
Co	<u>0.0</u>	<u>0.1</u>	<u>0.0</u>
TOTAL	99.7	98.8	99.2

\*(Total Fe as FeO)

APPENDIX

A POSSIBLE RE-INTERPRETATION OF NICKEL MINERALIZATION  
IN THE COQUIHALLA SERPENTINE BELT, HOPE, BRITISH COLUMBIA

Background and Objective

The current economic potential of the Border Resources deposit is hampered by its low grade and disseminated nature. Additional mineralization might be present on the property in a higher grade and more concentrated form due to the unique geological conditions of the area. If this higher grade mineralization is found, it should form the basis of any further beneficiation work undertaken on the ores. The objective of this discussion, requested by Dr. H. von Hahn of Border Resources, is to suggest through consideration of previous reports on the property, the nature of this possible increased potential for higher grade mineralization.

Several investigative reports have been completed on samples of low-grade mineralization from the subject property. These reports have focused on property geology, mineralogical characterization of the nickel mineralization, and metallurgical recoveries. This report addresses the possibility of locating more favourable areas for exploration in light of both recent models of nickel mineralization and serpentinization processes as an ore-localizing mechanism.

DISCUSSION

Examination of geological maps and reports of the Coquihalla area supplied by Border Resources indicate that there is incomplete exposure of the Coquihalla serpentine belt. Preliminary mapping by consultants has established the existence of two important rock types in this area: serpentinite and "diorite" which is more likely an associated gabbro. The body as a whole then, would be intrusive by nature into country rocks which have been mapped as slates, cherts and volcanic rocks. Detailed examination of contact relationships, with emphasis on the existence and distribution of country rock xenoliths, would confirm the intrusive origin of the mafic and ultramafic rocks. The nature of the transition between the possible gabbro (mapped as "diorite") and the ultramafic rocks would provide evidence that the two are related by differentiation from a common liquid parent. Chemical compositions of minerals (olivines, pyroxenes) could also provide important information on this aspect.

Although no unequivocal field evidence exists which supports the concept that the mafic and ultramafic rocks were emplaced as solid or largely solid bodies, this appears to be the commonly accepted hypothesis. If it can be shown that the rocks were originally emplaced as magma and not in the solid state, contamination by country rock may have occurred. Country rock contamination has been shown to be an effective process of bringing a magma to sulphur saturation, especially if the included material contains sulphur-bearing minerals. Additional factors that result in sulphur saturation and production of sulphide minerals are the rapid cooling of the magma by the xenolith and the addition of silica. One example of this process has been described by Mainwaring and Naldrett in Minnesota (1).

The Coquihalla serpentinites occur in an assemblage which includes slates and graphitic argillites with pyrite according to the report by Chamberlain (1) (sample #1525). There is, therefore, a possibility that contamination of the melt has taken place and the formation of nickel-bearing sulphides has occurred. Mainwaring and Naldrett describe in detail the formation of iron and nickel sulphides under these conditions. On the assumption that the samples supplied are representative of the serpentinites, the following two points can be made. Firstly, the absence of pyrrhotite strongly suggests that contamination by sulphur-bearing country rocks has not affected the samples and secondly, there was however, sufficient nickel in the system to dissolve in the magnetite and to form millerite.

#### EFFECTS OF SERPENTINIZATION

Serpentinization results in pronounced changes in both silicate and sulphide mineralogy. The effects of serpentinization differ in rocks that were originally either moderately or weakly mineralized. In ultramafic rocks, such as the Coquihalla samples, that were originally poor in sulphur, nickel that was combined in olivine is liberated and enters solid solutions in magnetite and serpentine. In rocks that contained small amounts of sulphur or in which sulphur was introduced by the serpentinizing fluids, the strongly chalcophile nature of nickel dictates that the vast majority of the nickel will be combined as a sulphide phase. Millerite, with a high Ni:S ratio will combine with all the available sulphur to form fine-grained sulphides disseminated throughout the rock. This process will, of course, be more important in ultramafic rocks in which there is little original sulphide and most of the nickel remains in the olivine or pyroxene.

If the large quantities of sulphides had been formed by contamination then serpentinization might have released nickel from the mafic minerals and further upgraded the tenor of the sulphides. Due to the increased sulphur content in this situation the grade of the sulphides would be expected to be lower although occurring in much greater quantities.

## RECOMMENDATIONS FOR EXPLORATION

Sulphides associated with serpentized ultramafic rocks are commonly fine-grained as in the case of the Dumont nickel deposit (Ekstrand) (3), however they would not of necessity be if sulphurization of the parent ultramafic or gabbroic melt had occurred. As stated above, no evidence exists in the samples examined to date that sulphurization has occurred. However, the abundance of nickel in the system implies that coarse-grained nickel sulphides may be the products of country rock contamination. These areas of contamination might form reasonable exploration targets that could be expected to be of more appropriate economic significance. If pyrite and graphite are characteristic of the country rocks that might be associated with the formation of sulphides in the Coquihalla intrusion then geophysical techniques such as EM or IP might outline local targets.

## REFERENCES

1. Chamberlain, J.A. "Nickel Distribution in the Coquihalla Ultramafic Complex", Progress Report #2 to Mountain Pass Mines Ltd., 1971.
2. Eckstrand, O.R. "The Dumont Serpentinite: A Model for Control of Nickeliferous Opaque Mineral Assemblages by Alteration Reactions in Ultramafic Rocks", *Economic Geology*, Vol. 70, pp. 83-201, 1975.
3. Mainwaring, P.R. and Naldrett, A.J. "Country-Rock Assimilation and the Genesis of Cu-Ni Sulphides in the Water then Intrusion, Duluth Complex, Minnesota", *Economic Geology*, Vol. 72, pp. 1269-1284.

STATEMENT OF COSTS

CANMET INVOICES:

Jan. 25/83	#E125285 - Outside chem. anal. . . . .	\$1,354.00
Jan. 25/83	#E125286 - Laboratory charge . . . . .	4,855.32
Sept. 16/83	#E133340 - Lab. Chg. (Jan.1-July 31) . . . . .	4,432.48
Sept. 20/83	Lakefield Research - mag./sep. test. . . . .	627.04
Sept. 29/83	#E133376 - Lab. Chg. & Outside anal. . . . .	2,361.04
Apr. 12/84	#E137711 - Mnlgl. res. . . . .	1,919.56
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		\$15,549.44

(Since May 1983 = \$9,340.12)

A-MIN-TECH INVOICES:

Sept. 31/82	Consulting fees/disbursements/travel . . . . .	\$862.20
Nov. 30/82	" " " " " " " " " " " "	1,168.41
March 30/83	" " " " " " " " " " " "	1,839.67
June 30/83	" " " " " " " " " " " "	790.03
Aug. 31/83	" " " " " " " " " " " "	1,441.10
Oct. 27/83	" " " " " " " " " " " "	417.65
Nov. 30/83	" " " " " " " " " " " "	356.32
Feb. 29/84	" " " " " " " " " " " "	198.04
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		\$7,073.42

(Since May 1983 = \$3,203.14)

ADMINISTRATION COSTS:

May 1984 - Report assembly (3 days X \$200.00/day) . . . . .	\$600.00
Stationery . . . . .	8.50
Xeroxing . . . . .	25.00
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	\$633.50

TOTAL: 

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\$23,256.36

(Total since May 1983=\$13,176.76)

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August 28, 1971.  
Geochemical Programme, Coquihalla Property  
September 2, 1972.
- Hall, P. Assessment Report - Based on Costs of Sample Collection for Metallurgical Research by A-MIN-TECH RESEARCH LTD. of Vancouver.  
May 22, 1981.  
Assessment Report - Based on Costs of Bulk Sampling and Metallurgical Research by A-MIN-TECH RESEARCH LTD. of Vancouver.  
May 21, 1982  
Assessment Report - Based on Costs of Bulk Sampling for CANMET Metallurgical Research.  
July 27, 1982

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## Statement of Qualification and Certification.

I, Hardwin E.A. von Hahn, of Vancouver, British Columbia, do hereby state as follows:

1. I am a consulting metallurgical engineer.
2. I am graduate of the University of British Columbia: BAsc in metallurgical engineering, 1958; MAsc in metallurgy, 1960; PhD in metallurgy, 1963.
3. I am a registered professional engineer of the Province of British Columbia.
4. I have, on behalf of Border Resources Ltd., supervised and directed the work done as described and contained in the following two reports, and I am familiar with the contents of these reports:
  - (i) "Investigation to Recover Ni-Co-Fe-Cr from Ore Sample submitted by Border Resources" by M.A. Cristovici, M.M. Raicevic, P. Lachapelle, Mineral Processing Laboratory, July, 1983 and
  - (ii) "Results of Mineralogical Examination of Tailings Sample 16-A, Site 9, Submitted by Border Resources Ltd., Vancouver", by P.R. Mainwaring, Mineral Processing Laboratory, February, 1984.

Both reports produced by the Mineral Sciences Laboratories, Energy, Mines and Resources, Ottawa, Ontario.

5. I hereby certify that the costs charged pertaining to the work in these two reports and ancillary costs, all listed in the detail cost summary of the Border Resources Ltd. Assessment Report for the period SEPT. 1982 - Apr. '84 and amounting to the total sum of \$23,256.36, are reasonable and correct.

Dated this 19 PROFESSIONAL OFFICE 1984, at Vancouver, British Columbia.

Signed: H. E. A. von Hahn  
H.E.A. ENGINEER Eng.