Open File Report OF85-8

Chromite Reserves of the Bird River Sill

By D.M. Watson

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Prospecting for asbestos and other minerals lead to the initial discovery of the Bird River Sill (BRS) chromite deposits in the 1920s. Early descriptions of the deposits were published by de Wet (1942), Brownell (1942) and Bateman (1943). Since then the area has been the subject of theses, papers and general reports by company and government geologists. The most recently published works include a general description of the chromite deposits (Bannatyne and Trueman, 1982) and the detailed geology of the chromitite layers (Scoates, 1983).

Most of the reports have been written on the regional geology or on the geology of individual properties, and very little attention has been directed towards the geology of individual layers. Company reports have concentrated on specific chromite occurrences and only a limited effort has been made to elucidate detailed stratigraphic correlations between individual properties.

In this study the individual chromite-rich layers from several different sections are described in detail. New analyses for chromium are presented and compared with previously reported analyses. These data are used in calculating geologically inferred reserves of chromium for the BRS.

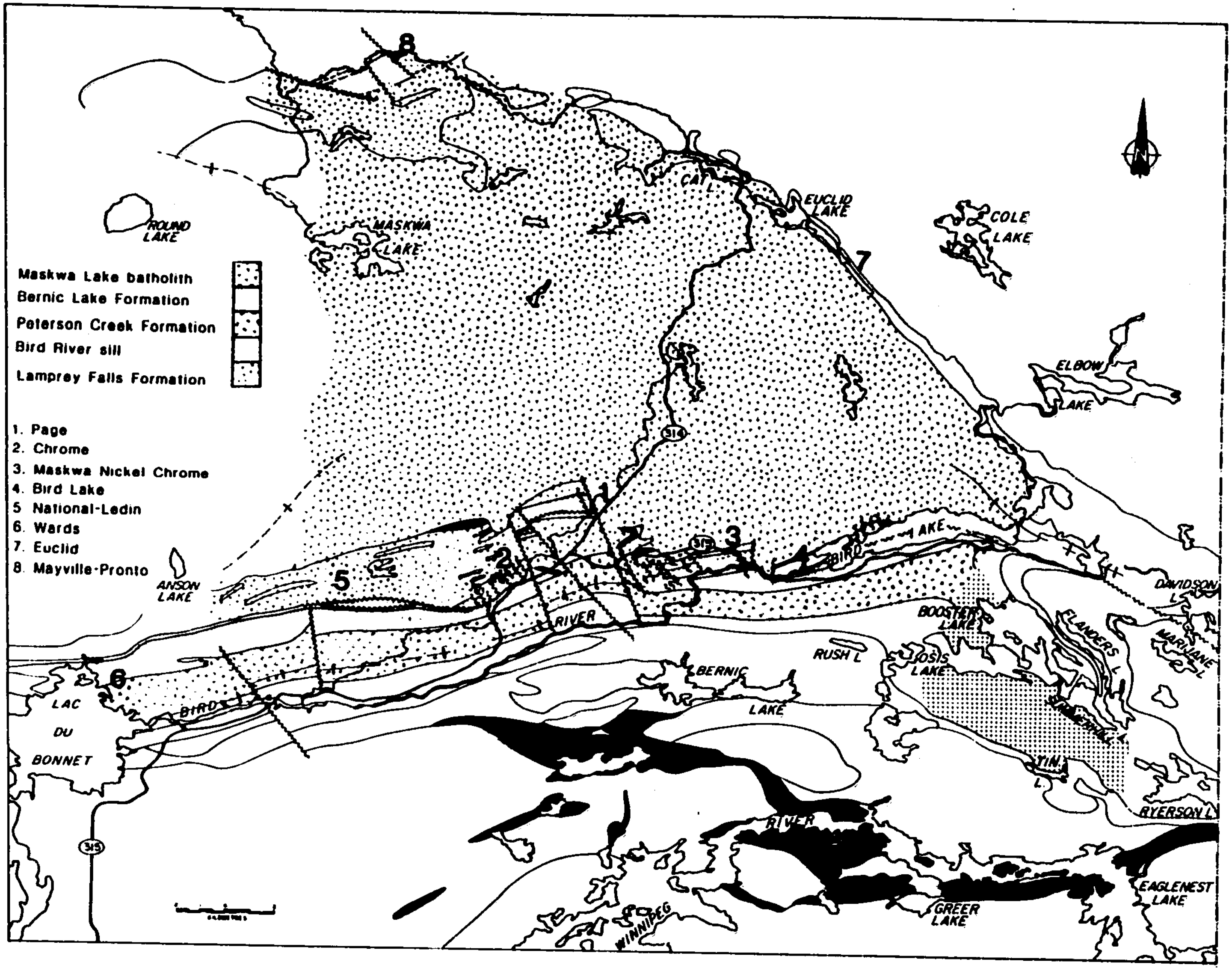

Figure 1: General geology and locations of the areas studied.

GENERAL GEOLOGY

The Bird River Sill (BRS) (Fig. 1) is a layered intrusive complex emplaced along the contact between the Lamprey Falls and Bernic Lake Formations of the Rice Lake Group (Bannatyne and Trueman, 1982). It consists of a lower series of ultramafic rocks and an upper series of gabbroic rocks. Chromite occurs near the top of the lower series over a stratigraphic thickness of approximately 60 m. The geology of the BRS and associated rocks has been detailed by Trueman (1971), who considered it to be the product of a single pulse of magma, with the layering being the result of fractional crystallization and gravitational settling.

Trueman's model for the BRS, although adequate in its explanation of the observed differentiation and layering, does not explain the absence of particular rock types or layers in certain parts of the BRS. Instead of the entire BRS having been injected with a relatively uniform thickness, it appears from detailed field observations that it was originally somewhat wedge-shaped and dipped toward the thicker southern end (Watson, 1983).

Crystallization of olivine and pyroxene resulted in formation of dunite and peridotite in the lowermost portion of the wedge-shaped intrusion at the same time that crystallization of feldspars was taking place. These feldspars, being less dense than the magma, rose to the top of the magma chamber. As crystallization continued, chromite crystallized and formed chromitite layers on the floor of the chamber. In the lower portion of the chamber, these chromitite layers were deposited on a relatively level base and these early layers have been preserved. Disturbed and disrupted layers of chromite similar to those described by Scoates (1983) occur both between chromitite layers and elsewhere as discrete pods and lenses. It is envisioned that the chamber floor at the margins of the intrusion would have had a steeper slope than the central portion of the chamber. Transport of chromitite layers downslope from the margins of the chamber would account for the distorted and disrupted chromitites occurring between continuous individual layers. It might also account for scattered lenses and small pods of chromite found included within sheared gabbros elsewhere.

Contemporaneous with chromitite and ultramafic layer formation on the floor of the magma chamber, plagioclase crystals were accumulating near the roof. Blocks of anorthositic gabbro trapped in the ultramafic cumulate rocks are now represented by rodingite-type inclusions. At some time in the evolution of the sill, magma in the upper chamber reached the surface and formed pillowed flows that can be traced back to massive gabbro. Cobbles of granitic and various gneissic rocks were noted at one locality near the Mayville property; these rocks occur within pillowed flow rocks adjacent to massive gabbro. The ultramafic rocks and chromitite layers were not found in this part of the BRS.

CHROMITE-RICH ROCKS WITHIN THE BIRD RIVER SILL

Concentrations of chromite occur in the upper portion of the ultramafic part of the BRS. The chromite occurs as chromitite layers containing over 85% chromite, disseminated layers containing 25 - 85% chromite and as scattered grains in concentrations of up to 25%.

Chromite has also been found as scattered blebs and stringers within the gabbroic rocks of the upper series.

The individual chromite layers and their relationships to each other and the intervening ultramafic layers have been described recently by Scoates (1983). They may be considered to occur as a series of suites or sets of layers with distinctive lithologies and modes of occurrence (Fig. 2). From the bottom upwards these suites are: 1 - Lowermost Chromitites (LC), 2 - Disrupted Layer Suite (DL), 3 - Lower Main Suite (LM), 4 - Banded-Diffuse Layer Suite (BL), 5 - Upper Main Suite (UM), and 6 - Upper Paired Chromitites (UP). Minor amounts of chromite occurs below the lowermost chromitites as irregular lenses and blebs that cannot be characterized as a distinctive suite.

Lowermost Chromitites

Two, and in places three, thin chromitite layers occur approximately 110 m above the base of the BRS. The layers of this suite range in thickness from 2 to 7 cm and are discontinuous along strike. Below these layers, chromite only occurs as irregular blebs and as disseminated grains without any degree of regularity. Analyses of several continuous cuts across this suite are given in Table 1. Locations of the sampled sites are shown in Figure 3; copies of this figure at a scale of 1:1000 are available upon request.

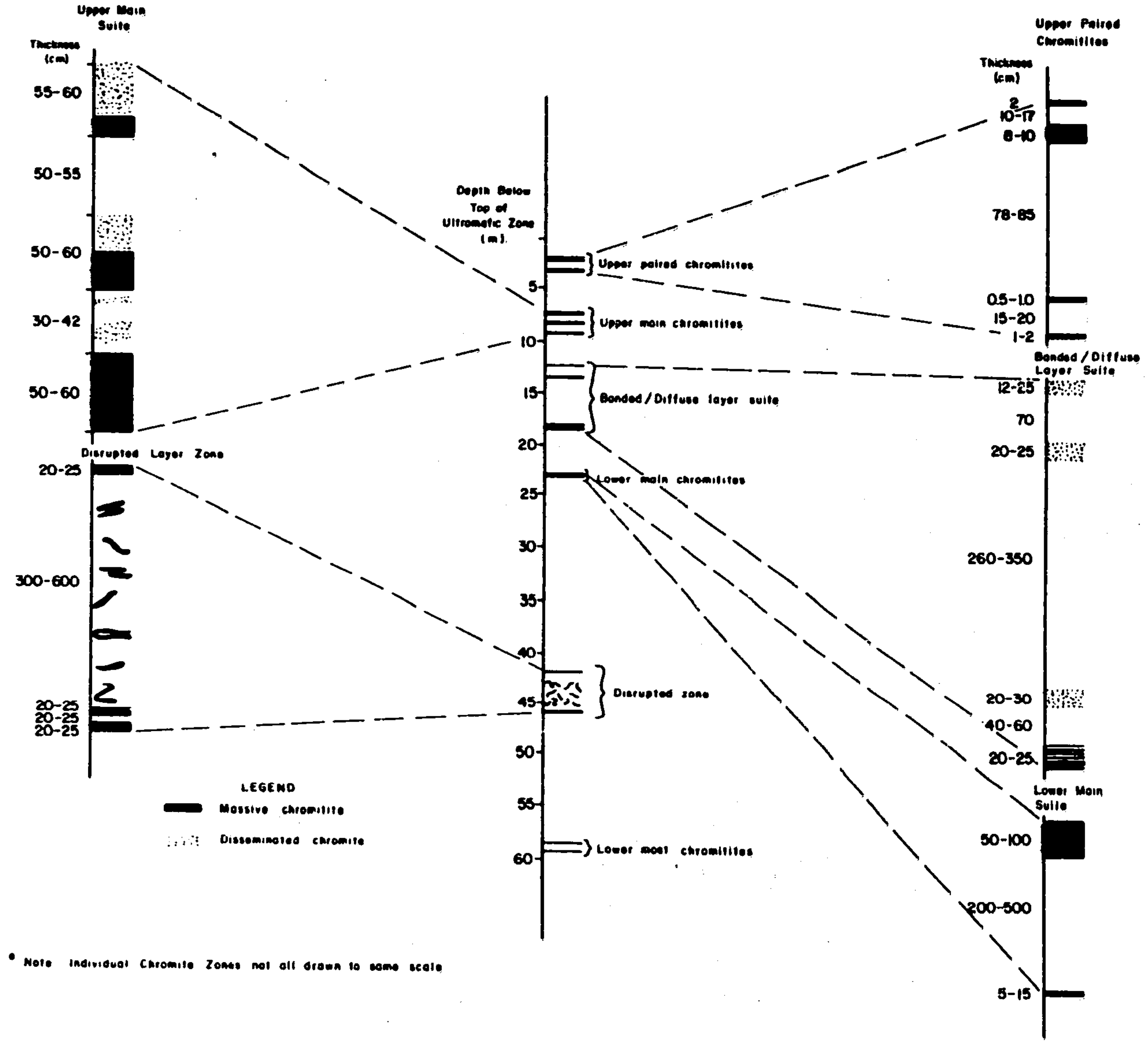

Figure 2: Schematic stratigraphic section through the Bird River chromitites.

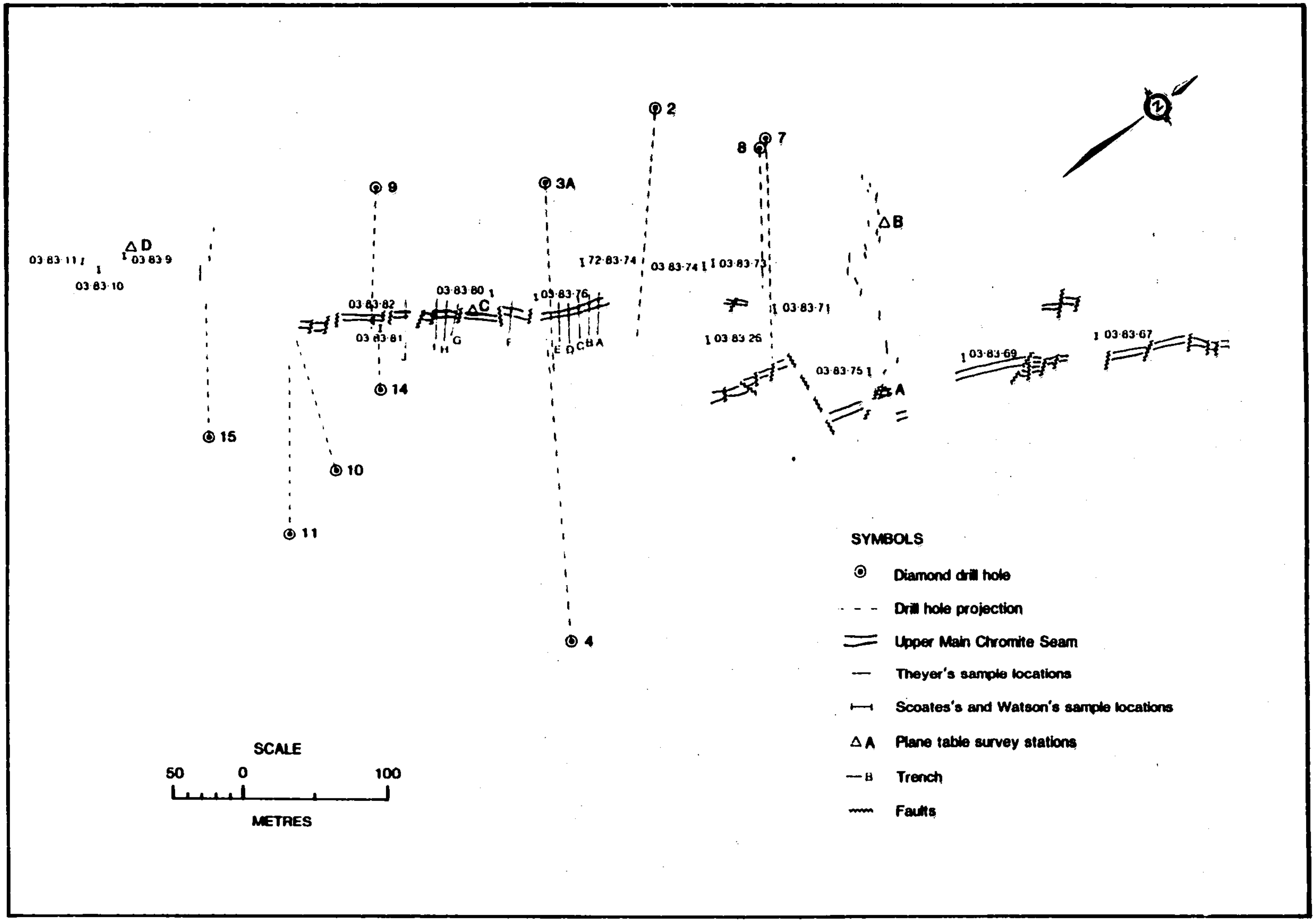

Figure 3: Location of samples analyzed from the Chrome Property.

TABLE 1

Cr and Fe analyses of Lowermost Chromitites
(Chrome Property)

Sample	Cr%	Fe%	Comments
03-83-73.2	1.94	8.81	Lowermost chromitite
03-83-73.3	6.60	10.67	Upper chromitite
03-83 9.4	0.83	8.16	Lowermost chromitite
03-83-9.5a	9.95	11.55]	Two samples from Upper
03-83-9-5b	2.45	8.78.]	pair of chromitites

Disrupted Layer Suite

The Disrupted Layer Suite occurs about 5 m above the Lowermost Chromitites. This unit consists of an upper and a lower bounding chromitite layer, each approximately 25 - 30 cm thick and separated by 3 to 6 m of fine grained olivine cumulate containing numerous broken and disrupted chromitite layers (Fig. 4). Due to the heterogeneous nature of this zone, analyses of sections across it may vary greatly. Analyses of several sawn sections across the suite are given in Table 2.

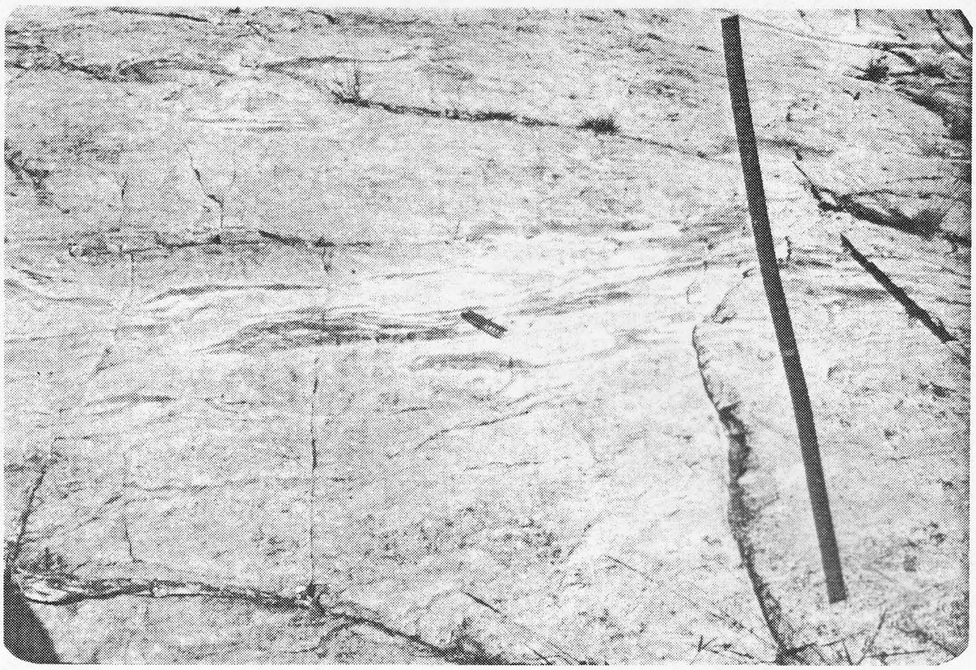

Figure 4: Disrupted Layer Suite. Distorted and disrupted chromitite layers in central portion of suite. Note the continuous lower bounding chromitite in upper right of photo. Black bar indicates width of chromite concentration.

TABLE 2

Cr and Fe analyses of Disrupted Layer Suite
(Chrome Property)

Sample	Cr%	Fe%	Comments
03-88-10.1a	9.76	11.84	Lower bounding layer
03-83-10.1b	8.02	11.55	" " "
03-83 10.2a	10.34	10.74	Middle of disrupted layer
03-83-10.3	10.03	12.22	Upper bounding layer
03-83-74.1a	7.58	11.41	
03-83-74.1b	6.40	11.13]	
03-83-74.1c	0.25	8.16]	
03-83-74.1d	9.22	11.76]	2.6 m section across disrupted zone
03-83-74.1e	1.58	7.48]	
03-83-74.1f	6.06	10.44]	
			Average 5.18% Cr across 2.6 m
03-83-74.2a	7.75	9.75]	1.5 m section across disrupted zone
03-83-74-2b	5.32	10.41]	

Lower Main Suite

The base of the Lower Main Suite lies from 17 to 20 m above the upper bounding layer of the Disrupted Layer Suite. A single 5 - 15 cm thick layer (Fig. 5) lies at the base of this zone and is separated from an upper 0.5 - 1.0 m thick chromitite layer by 1.5 to 5 m of coarse grained olivine cumulate. This upper layer of chromitite is the thickest single chromitite layer in the BRS. Analyses of samples from several saw cuts across this layer are given in Table 3.

TABLE 3

Cr and Fe analyses of the Lower Main Chromitites
(Chrome Property)

Hole	Cr%	Width	Comments
3A	16.45	0.73 m]	
9	20.09	0.70 m]	Average of all holes 17.03% Cr across 0.76 m.
7	16.58	0.98 m]	
8	15.02	0.64 m]	

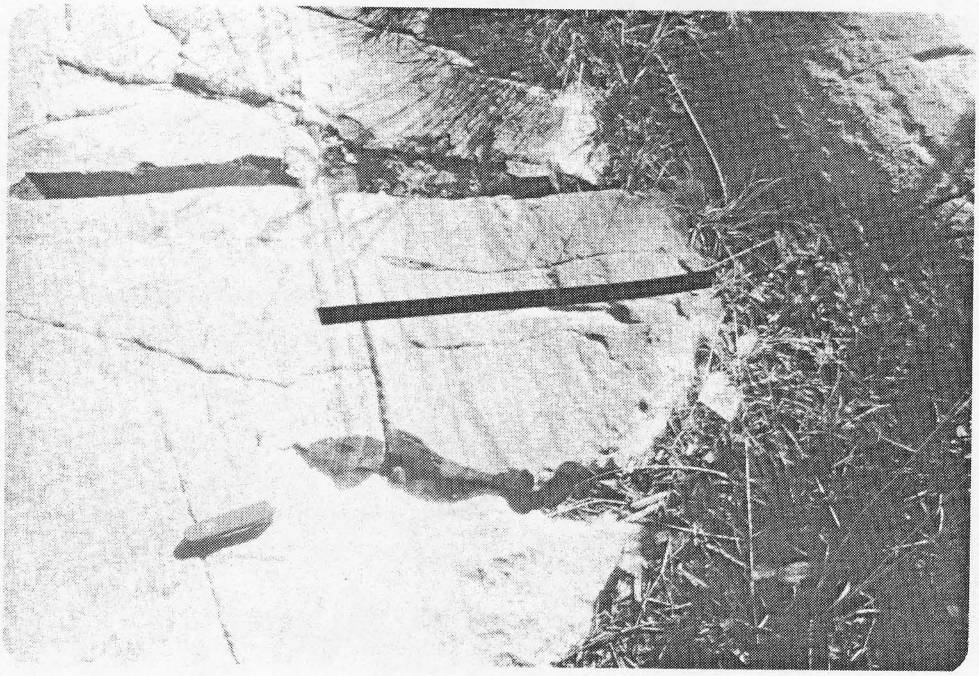

Figure 5: Lower Main Chromitites.

In addition to this sampling program, analyses are available from drill hole data on file. These analyses and the reported (uncorrected) widths are given in Table 4.

TABLE 4

Cr and Fe analyses of the Lower Main Chromitites - data from drill holes (Page Property)

Sample	Cr%	Fe%	Comments
03-83-77.a	17.82	12.36]	Average 17.34% Cr across 0.75 m
03-83-81.b	14.26	13.22]	
03-83-80.a	8.91	11.55]	Average 10.13% Cr across 2.15 m
03-83-80.b	6.68	9.01]	
03-83-80.c	10.12	10.86]	
03-83-80.d	1.02	8.19]	
03-83-80.e	17.82	12.36]	
03-83-80.f	17.42	14.90]	
72-83-34.a	18.21	12.98]	Average 18.79% Cr across 0.50 m
72-83-34.b	19.37	13.09]	

Banded-Diffuse Layer Suite

The base of this suite, a single chromitite layer 5 - 15 cm thick, lies from 3 - 6 m above the top of the lower main chromitites. The other elements of this suite are (from base upwards): a banded layer consisting of 10 - 14 layers of chromitite from 0.5 - 1.0 cm thick, and three diffuse layers each from 20 - 25 cm thick (Fig. 6). The entire suite occupies approximately 6 m of stratigraphy. The chrome content of various sawn sections through these layers is given in Table 5.

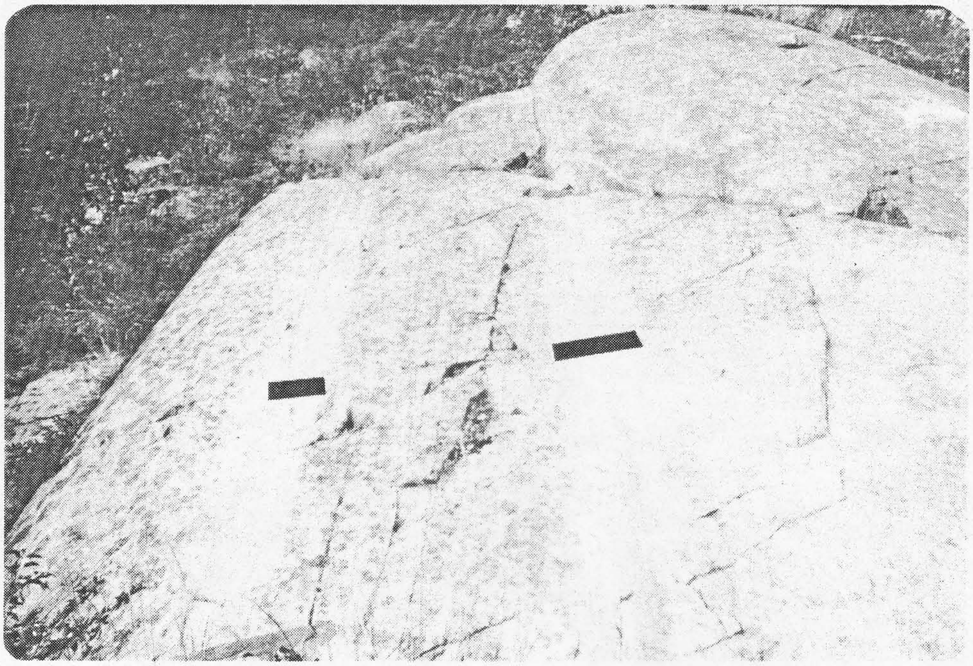

Figure 6: Banded Diffuse Layer Suite. The banded layer (left) and one of the diffuse layers are shown.

Upper Main Chromitites

The base of the Upper Main Chromitites lies from 2.0 to 2.5 m above the top of the Banded-Diffuse Layer Suite (Fig. 7). The upper main suite consists of two lower chromitites each 50 cm thick and separated by 30 - 40 cm

TABLE 5

Cr and Fe analyses of the Banded-Diffuse Layer Suite (Chrome Property)

Sample	Cr	Fe	Comments
03-83-79.1	0.87	8.09	2.6 m below Lower diffuse layer
03-83-79.2a	6.60	9.54	Middle and Upper diffuse layer
03-83-79.2b	5.49	9.03	" " " " "
03-83-79.2c	3.30	8.07	" " " " "
			Average 5.13% Cr across 1.35 m
03-83-76.1	10.16	12.05	Lower dense chromitite
03-83-76.2a	3.84	8.78	Banded layer and Lower diffuse
03-83-76.2b	1.74	5.47	" " " " "
03-83-12.1a	6.77	10.68	Banded layer
03-83-12.1b	4.50	9.58	" "
03-83-12.2a	0.23	7.55	Lower diffuse
03-83-12.2b	3.12	9.12	Middle diffuse

of olivine cumulate. The upper chromitite is also underlain by 30 - 40 cm of olivine cumulate which separates it from the uppermost chromite-rich layer of the suite. This upper layer varies from 55 - 60 cm thick and is a diffuse type layer. The entire suite has a uniform thickness and chemical composition from place to place in the BRS. Analyses of the Upper Main Chromitites are given in Tables 6 to 9.

TABLE 6

Cr and Fe analyses of the Upper Main Chromitites (Chrome Property)

Sample	Cr%	Fe%	Comments
03-83.82.2a	13.16	13.19]	Middle chromitite of UM
03-83.82.2b	9.76	10.73]	
03-83.82.3a	10.43	11.07]	Upper chromitite of UM
03-83.82.3b	10.61	10.81]	

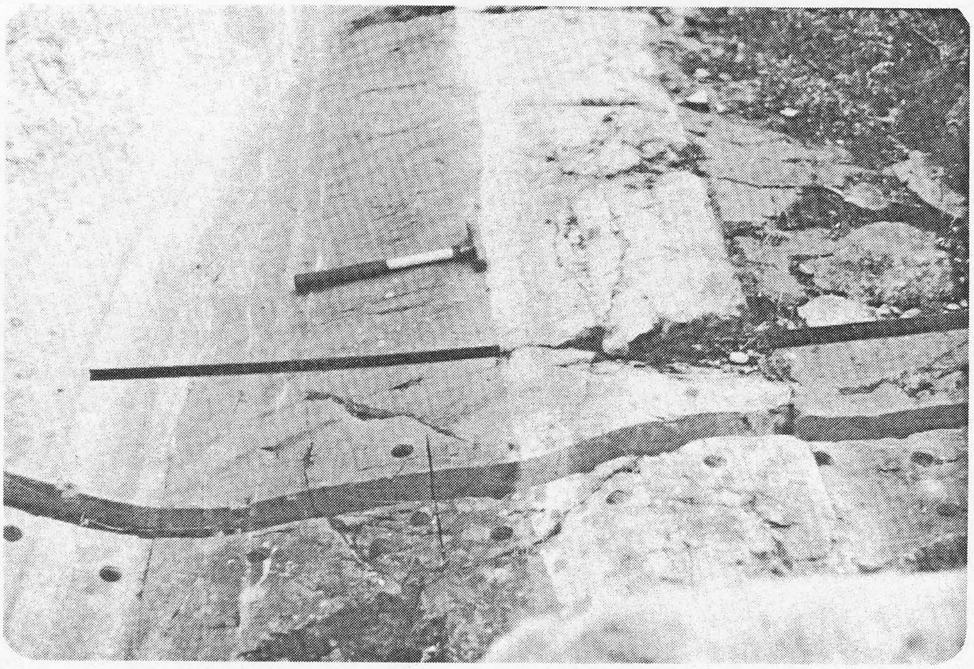

Figure 7: Upper Main Chromitites. Note sample cut and drill holes for paleomagnetic analysis.

TABLE 7

Cr and Fe analyses of the Upper Main Chromitites - data from drill holes (Chrome Property)

Hole	Width cm	Cr%	Hole	Width cm	Cr%
2	60	17.73	10	58	16.05
	37	0.27		24	0.00
	64	17.87		52	11.81
	70	3.43		34	0.00
	94	13.84		46	15.40
3A	49	18.18	11	27	10.75
	21	9.17		104	4.75
	27	18.75		85	16.41
	73	8.36		58	0.63
	88	19.45		82	16.21
4	76	13.70	14	48	10.51
	131	0.00		176	0.00
	112	15.14		49	15.18
9	61	18.96	15	85	12.67
	40	0.00		49	7.58
	46	17.84		43	14.64
	61	6.14		58	0.38
	113	13.21		82	17.59

The highest analysis obtained for one of the main chromitites in this sampling program is 19.16% Cr. This corresponds to 28.0% Cr_2O_3, which is comparable to the 25.5% reported by Bateman (1943) as an average for the zone. Analyses for selected holes drilled on the Chrome Property are given in Table 7; analytical results from the trenches across the UM suite are shown in Table 8 (Manitoba Energy and Mines Files). The lengths shown in the tables are measured lengths and are not corrected to true thickness since in most cases the dip of the chrome layers and/or drill holes are not known.

TABLE 8

Cr and Fe analyses of the Upper Main Chromitites - samples from trenches (Chrome Property)

Trench	Width cm	Cr%	Trench	Width cm	Cr%
A	24	14.46	F	85	14.01
	40	15.31		43	5.20
	58	5.44		79	18.05
	48	18.73		18	0.00
	33	0.00		58	19.21
	48	19.77			
			G	61	13.76
B	52	12.82		52	6.33
	55	3.85		67	5.98
	58	17.67		43	0.00
	30	0.00		43	19.27
	43	17.32			
			H	92	13.15
C	64	18.60		67	5.98
	55	5.49		64	19.23
	52	20.13		33	0.00
	43	12.60		52	20.03
D	58	13.62	I	85	14.25
	43	6.02		61	6.41
	43	19.10		58	19.76
	40	0.00		43	0.00
	40	19.40		48	18.48
E	64	14.08	J	48	14.01
	48	6.50		55	6.06
	37	18.05		46	20.95
	43	0.00		33	0.00
	58	17.14		46	19.64

In most cases the chrome values follow roughly the same pattern: one value of 12 - 15% Cr, followed by a lower value of 5 - 8% Cr, then by two bands of higher value (15 - 20% Cr) separated by a zone of low to zero per cent Cr. No record exists of how the trenches and drill holes were sampled for analysis. During the present study, no samples were obtained with zero per cent chromium even though they are common in the assay values on record. It is probable that some low grade zones were not sampled in previous studies, and their values have been entered as zero.

The Upper Main Zone is also exposed on the Page Property and was sampled as part of the investigation of that area. The character of the chrome mineralization on this property is identical to that on the Chrome Property in spite of the distance of more than 5 m separating the two occurrences. The chrome analyses for some sawn samples from the Page Property are given in Table 9.

TABLE 9

Cr and Fe analyses of the Upper Main Chromitites (Page Property)

Sample	Cr%	Fe%	Comments
73-83-Pla	1.23	8.66]	
73-83-Plb	8.75	12.41]	
73-83-Plc	8.53	9.38]	Average 10.56 across 2.4 m.
73-83-Pld	12.03	10.51]	
72-83-Ple	19.45	13.84]	
72-83-Plf	13.29	10.55]	

This average is comparable to the average of the assays obtained from the various drill holes and trenches sampled on the Chrome Property. Analyses of the same zone at Euclid and Bird Lakes also yield approximately the same figures (Bannatyne and Trueman, 1982).

Upper Paired Chromitites

This uppermost suite of chromitites lies from 4 to 5 m above the top of the upper main suite and consists of two pairs of chromitite layers. The

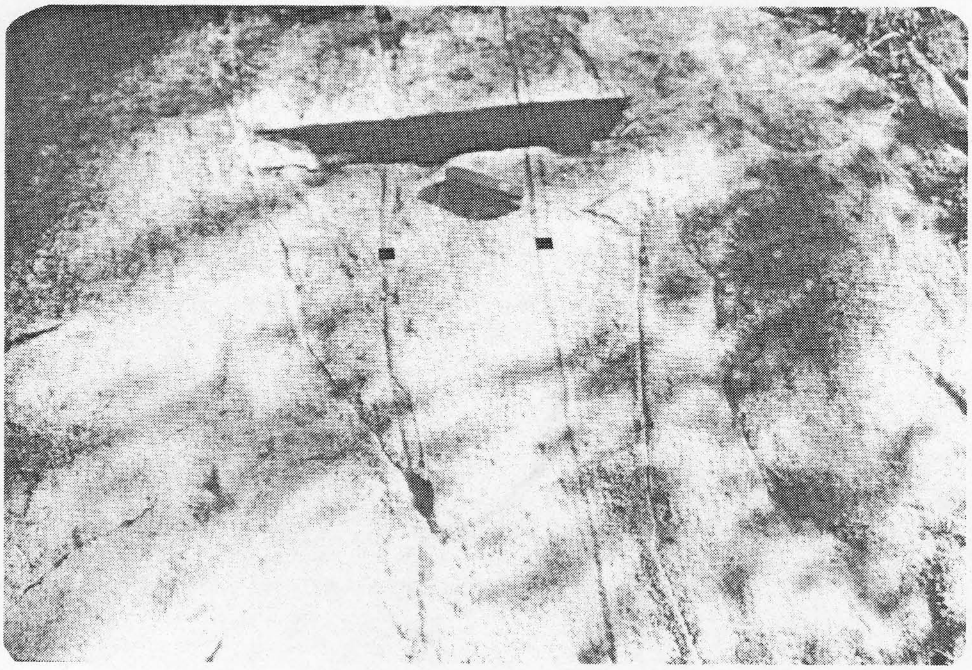

Figure 8: Lower chromitite pair of Upper Paired Chromitites.

lower pair of layers consists of two 1 cm thick layers separated by 15 - 20 cm of olivine cumulate (Fig. 8). Approximately 75 cm above this pair is the lower 8 - 10 cm thick layer of the upper pair (Fig. 9). This layer is separated from the upper 2 - 3 cm thick layer by 15 - 20 cm of olivine cumulate.

Analyses of sawn cuts across this section are given in Table 10.

TABLE 10

Cr and Fe analyses of the Upper Paired Chromitites

Sample	Cr%	Fe%
03-83-81.1a	2.00	7.66
03-83-81.1b	0.69	8.78
03-83-81.2a	1.22	11.01
03-83-81.2b	10.29	15.05

The average analysis for this section is 2.85% Cr or 4.01% Cr_2O_3 over 1.45 m.

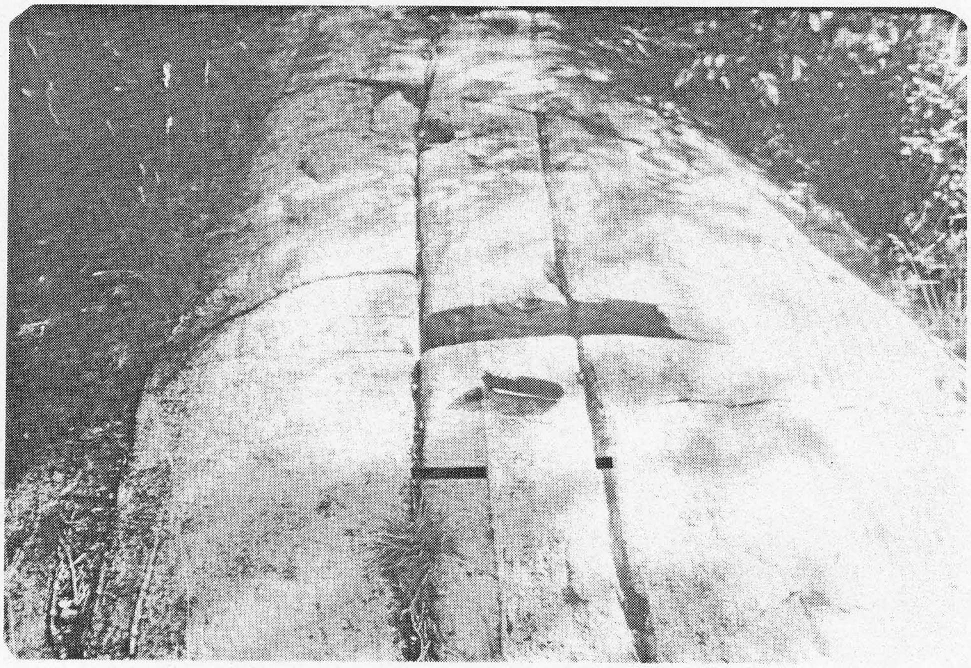

Figure 9: Upper chromitite pair of Upper Paired Chromitites.

OTHER ROCKS OF THE LOWER PORTION OF THE BRS

Although the majority of the chrome contained in the rocks of the Bird River Sill occurs in the chromitite layers, significant amounts are contained in the ultramafic rocks between the chromitite layers. In many cases these rocks have been overlooked during sampling and have not been assayed. However, their chrome values would contribute to the overall chrome returned from any mining operation and should therefore be included.

Table 11 contains analyses of various rocks from the ultramafic portion of the BRS on the Chrome Property.

TABLE 11

Cr and Fe analyses of the other rocks of the lower portion of the Bird River Sill

Sample	Cr%	Fe%	Comments
03-83-69.1a	0.17	8.19	Transition zone gabbro: 2.25 m
03-83-69.2a	0.07	5.85	Gabbro, 2.25 m above 03-83-69.1
03-83 68-2a	0.93	8.29	Coarse grained olivine cumulate 1.2 m above lower chromitite of Lower Main
03-83 68.2b	0.49	8.47	
03-83 68.3	0.52	8.55	1.5 m above 68.2
03-83-68.4a	0.96	8.60]	olivine cumulate below LM
03-83 68.4b	0.93	7.73]	
03-83-68.4c	1.76	8.87]	
03-83-9.1	0.23	8.26	Dendritic peridotite below lowermost Cr
03-93-9.4	0.45	9.69	

CHROMITE RESERVE CALCULATIONS

Chromite reserves for the various areas of the BRS were calculated using information gathered in this study along with data from previous work. Chemical values and section widths used in these calculations are from this study; lengths and depths are from Bannatyne and Trueman (1982). Widths and chromium values used are given in Table 12.

TABLE 12

Zone thicknesses and chrome values used in reserve calculations

Zone	Width m	Cr%
1. Upper Paired	1.45	2.85
2.	6.0	0.75
3. Upper Main	2.5	10.65
4.	8.75	0.70
5. Diffuse/banded	1.35	5.13
	1.15	2.79
6.	6.75	0.90
7. Lower Main	2.15	10.13
8. Olivine cumulate	13.50	0.95
9. Disrupted layer	2.6	5.18
10.	7.75	0.45
11. Lowermost Chromitites	0.3	5.50

These values yield an average of 2.04% Cr over 54.3 m. However, if the section from the top of the Upper Main to the bottom of the Disrupted Layer is used, the grade is 2.43% across 37.75 m. The highest grade section (consistent with maintaining a reasonable mining width) would be from the top of the Upper Main to the bottom of the Lower Main; this zone averages 3.12% Cr (or 4.56% Cr_2O_3) over 22.65 m. Although the specific gravity of the rock varies slightly from place to place due to variations in chromite content and other mineralogical variations, a value of 0.30 cubic metres per tonne will be used for all calculations of tonnage.

The average width of 22.65 m yields 75.5 tonnes of ore per metre of strike length for each metre of depth, and using an average chromium value of 3.12% Cr yields 2.3556 tonnes of chromium per metre of strike length and depth. Calculated tonnages for various properties are given in Table 13.

TABLE 13

Chrome reserves for individual properties

Deposit	Page	Chrome	Bird Lake	Euclid
A <u>Measured</u>				
Length	762 m	640 m	1 646 m	373 m
Depth	0-99 m	0-198 m	0-61 m	0-122 m
Width	22.65 m	22.65 m	22.65 m	22.65 m
Cubic m	1,708,670	1,870,208	2,274,196	1,030,711
Tonnes ore	5,695,566	9,567,360	7,580,653	3,435,703
Tonnes Cr_2O_3	259,718	436,271	345,678	156,668
Tonnes Cr	177,701	298,502	236,516	197,194
B <u>Indicated</u>				
Length	2,286 m	725 m	488 m	373 m
Depth	0-99 m	0-198 m	0-61 m	122 m (122-244 m)
Width	22.65 m	22.65 m	22.65 m	22.65 m
Cubic m	5,126,012	3,251,408	674,345	1,030,171
Tonnes ore	17,086,707	10,838,025	2,247,484	3,435,703
Tonnes Cr_2O_3	779,154	494,214	102,485	156,668
Tonnes Cr	533,105	338,146	70,122	107,194
<u>TOTAL</u>				
Tonnes ore	22,782,273	20,405,385	9,828,137	6,871,406
Tonnes Cr_2O_3	1,038,872	930,485	448,163	313,336
Tonnes Cr	710,806	636,648	306,638	214,388

The chrome contents determined in this study for the Chrome and Page properties differ significantly from those previously reported by +146% and +157%, respectively. The values for lengths and depths are those used by Bannatyne and Trueman (1982); however, the widths used are based on the measured chrome-bearing section (Scoates, 1984; Watson, 1984).

The chrome contents for the relatively unexposed Bird Lake and Euclid Lake properties differ by only +9% and -25%, respectively, from those reported by Bannatyne and Trueman. The widths used in the study for these two properties are interpreted from the stratigraphic studies conducted on the Chrome and Page properties and do not differ greatly from the values traditionally used for the Bird Lake and Euclid Lake properties.

In view of the uncertainty involved in correlation of chromite layers in the limited amount of drilling done to date, these geologically inferred chrome contents are considered to represent a reasonable minimum value for these properties.

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