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THE CHROMITE DEPOSITS OF THE EASTERN TOWNSHIPS OF THE PROVINCE OF QUEBEC

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Énergie et Ressources naturelles
Québec

PROVINCE OF QUEBEC, CANADA

BUREAU OF MINES

Honourable J. E. PERRAULT, Minister of Mines

J. L. BOULANGER, Deputy-Minister A. O. DUFRESNE, Director

ANNUAL REPORT

OF THE

QUEBEC BUREAU OF MINES

FOR THE CALENDAR YEAR

1931

JOHN A. DRESSER, Directing Geologist

PART D

The Chromite Deposits of the Eastern Townships of the Province of Quebec, by Bertrand T. Denis.

QUEBEC
PRINTED BY R. PARADIS
PRINTER TO HIS MAJESTY THE KING
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THE CHROMITE DEPOSITS OF THE EASTERN TOWNSHIPS OF THE PROVINCE OF QUEBEC

by Bertrand T. Denis

INTRODUCTION

General Statement

Although chromium is one of the less common metals, recognition of its valuable properties has led to its use in an ever-increasing variety of industries. This growing demand has, in turn, led to the search for new deposits of chromite, the only commercial ore of the metal, and to a revival of interest in known deposits of low-grade ore.

Virtually the whole of Canada's production of chromite has come from deposits in the Eastern Townships of the Province of Quebec. Mining of chromite in this district was more or less continuous from the early 'nineties' until 1923, and was especially active during the war and in the years immediately following. There has, however, been no comprehensive official report on the industry since 1909, when the Mines Branch of the Federal Department of Mines issued a report by Fritz Cirkel ①, which has long been out of print. It was therefore considered opportune that an investigation be made of the present situation in the industry, and that all available information be embodied in a report covering the various aspects of the subject as completely as possible. Accordingly, during the field season of 1931, the writer, ably assisted by Mr. J. T. Williamson of McGill University, visited practically all the known deposits and occurrences of chromite in the Province with a view to ascertaining their economic possibilities and geological relationships. The results of this work are embodied in the following report.

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① *Report on the Chrome Iron Ore Deposits in the Eastern Townships, Province of Quebec*, by Fritz Cirkel; Mines Branch, Dept. of Mines, Ottawa. 1909.

It is desired to acknowledge gratefully the co-operation of the Asbestos Corporation of Canada, who furnished plans and much valuable information concerning those deposits of which they own the mining rights. Thanks are also due to the Director of the Geological Survey of Canada, who made available for study Dr. Robert Harvie's unpublished report on his investigations of these deposits. Dr. Carl Faessler, Professor of Mineralogy at L'Ecole Supérieure de Chimie in Quebec, rendered great assistance in the preparation of the samples for analysis. Courteous assistance in securing information was also given by numerous property owners and individuals.

World Sources of Chromite

Vauquelin, a French chemist, is generally credited with the discovery of the element chromium, at the end of the eighteenth century. Although the metal was first isolated in the course of an investigation of the rare mineral crocoite ($PbCrO_4$), the discovery, in Russia, of deposits of chrome-iron ore, or chromite, followed within a year of the publication of the first description of chromium. Although other chromium minerals have since been found, chromite has remained the only commercial ore of the metal.

The beautiful colouring properties of the chromiun salts and oxides were immediately appreciated, and attention was directed towards their application in the arts and in industry. Prior to 1827, however, the known sources of ore supply were remote from points of use, and the methods of manufacturing the chromium salts were crude and very costly. As a result, although their adaptability as textile and ceramic pigments was well established, the cost restricted their industrial use.

In the year 1827, the status of the industry was completely altered by the discovery in eastern North America of bodies of chrome iron ore. From that time until 1860, deposits in Pennsylvania and Maryland furnished the bulk of the world's chromium requirements and the United States controlled the industry. Throughout this period, however, consumption was very small, as the most valuable property of chromium, *i.e.*, the qualities it imparts to the alloys in which it is incorporated, had yet to be discovered.

In the meantime, large deposits of chromite had been found in Turkey in 1848, and, although their development was slow, their full importance began to be felt shortly before 1860, and from then until 1897 this country led the rest of the world in chromite production.

From 1897 to 1902, Russia, where, a century earlier, the first discovery of chromite had been made, became the greatest producer, but in 1902 lost the lead in turn to New Caledonia. The extensive deposits of chromite in Southern Rhodesia first began to be exploited in 1906, and by 1910 their output was equal to that of New Caledonia. These two countries alternately held the leading place from 1910 to 1916, when the disturbance of economic conditions caused by the war necessitated the exploitation of more accessible, though lower-grade, bodies of ore on the North American continent, with the result that the United States again took the lead temporarily.

With the cessation of hostilities, however, Southern Rhodesia resumed its position as the foremost producer, and has, in fact, so far outstripped the other producing countries that at present roughly one-half of the world's total annual chromite requirements are mined in that country.

As will be seen from Table I, Canada has produced some 175,000 tons of chromite, practically the whole of which has come from mines in the Eastern Townships of the Province of Quebec. A historical review of the industry in Quebec is given in a subsequent section of this report.

Production Statistics

The world production of chromite, by countries, for the years 1890 to 1929 is shown graphically in Figures 1 and 2, reproduced from the United States Bureau of Mines Information Circular 6566.

The total world production of chromite for the 103 years, 1827 to 1929, inclusive, is estimated at about 7,100,000 long tons, distributed as shown in Table I. Details of production from the Province of Quebec, for the years 1894 to 1923, are given in Table II.

TABLE I

WORLD PRODUCTION OF CHROMITE, 1827 TO 1929, INCLUSIVE, BY COUNTRIES *

COUNTRY	PRODUCTION (long tons)	PER CENT OF TOTAL
Southern Rhodesia	1,912,000	26.9
New Caledonia	1,346,000	19.0
Turkey	832,000	11.7
Russia	650,000	9.2
India	616,000	8.7
United States	478,000	6.7
Greece	336,000	4.7
Cuba	213,000	3.0
Canada	175,000	2.5
Union of South Africa	139,000	2.0
Japan	112,000	1.6
Other Countries	282,000	4.0
Totals	7,091,000	100.0

* U. S. Bureau of Mines Information Circular 6566. These figures are stated to be subject to revision at a later date.

TABLE II

CHROMITE PRODUCTION OF THE PROVINCE OF QUEBEC, 1894-1923 *

YEAR	QUANTITY (short tons)	VALUE	YEAR	QUANTITY (short tons)	VALUE
1894	1,000	$20,000	1909	2,470	$26,604
1895	3,177	41,300	1910	299	3,734
1896	2,342	27,004	1911	197	2,469
1897	2,637	32,474	1912 to 1914	none	none
1898	2,021	24,252			
1899	2,010	21,842	1915	14,397	245,297
1900	2,335	27,000	1916	27,952	312,901
1901	1,247	16,744	1917	36,186	498,031
1902	900	13,000	1918	36,131	770,955
1903	3,509	51,121	1919	8,184	223,331
1904	6 074	67,146	1920	10,585	247,730
1905	8,575	93,301	1921	1,893	22,696
1906	9,035	91,859	1922	767	11,503
1907	7,196	72,901	1923	3,558	52,650
1908	7,225	82,008	Grand Total	201,902	$3,099,853

* Annual Reports on Mining Operations in the Province of Quebec.

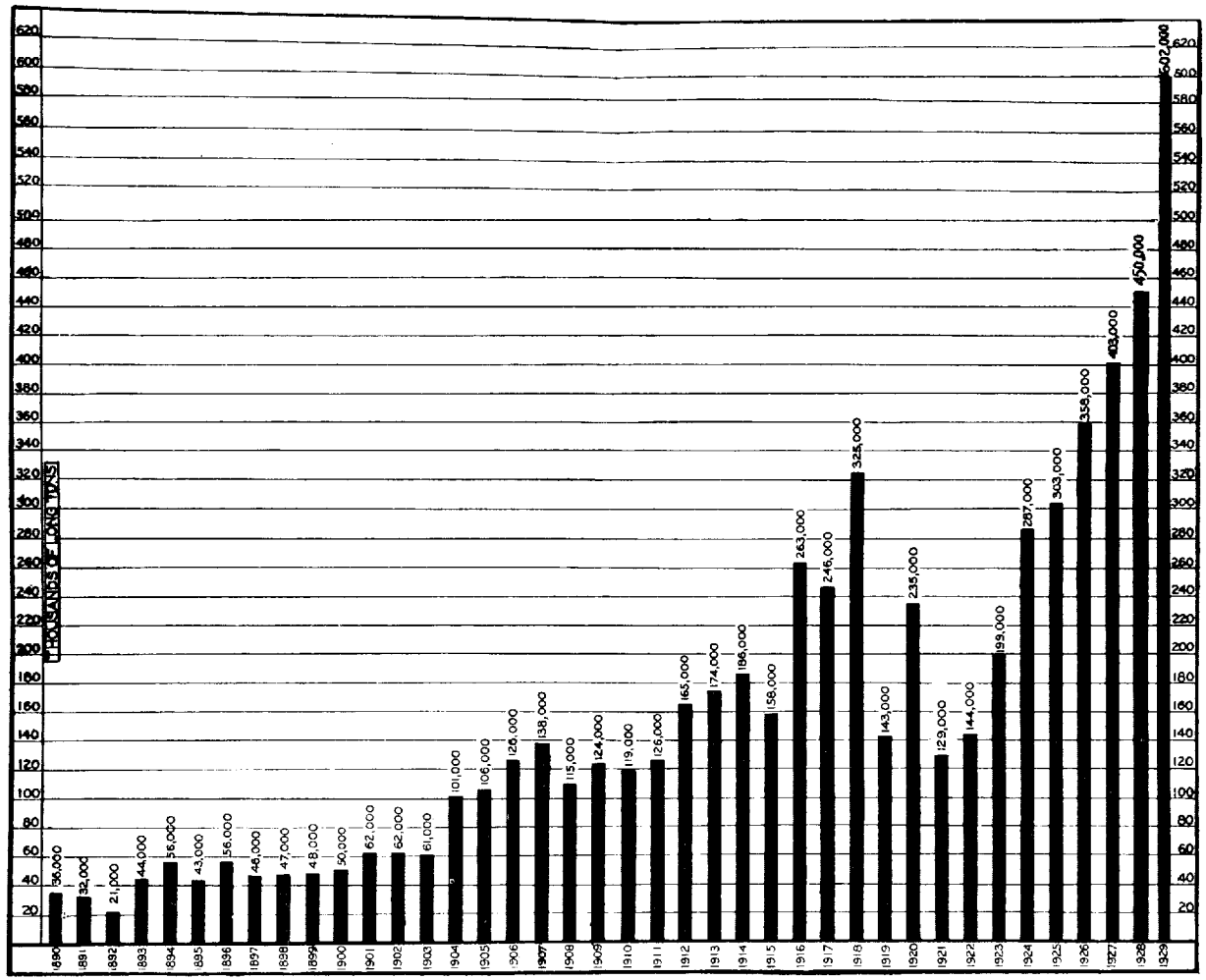


FIGURE 1.—World production of chromite, 1890-1929.
(Reproduced from Information Circular 6566, United States Bureau of Mines)

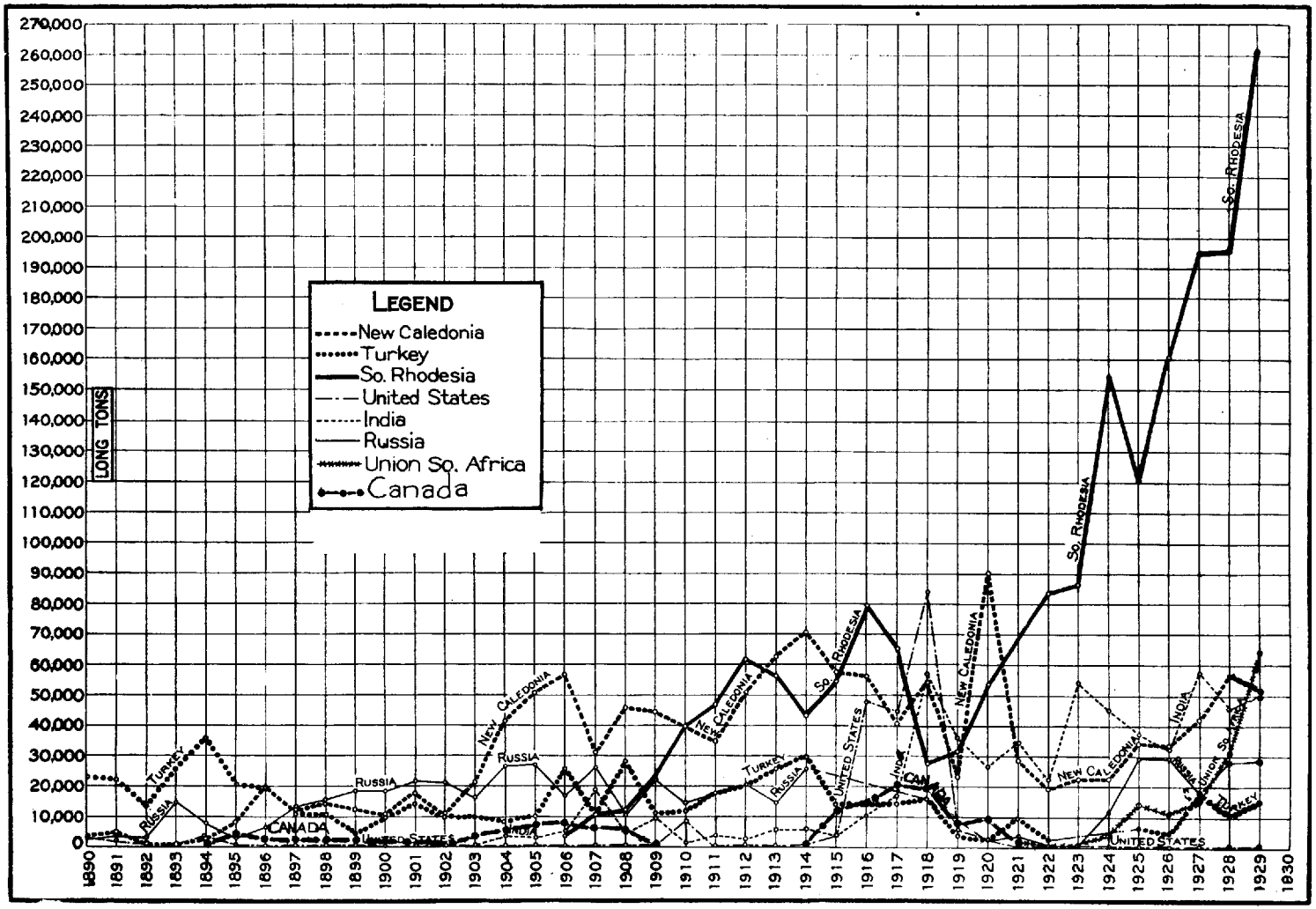


FIGURE 2.—Production of chromite in principal producing countries, 1890-1929.
(*Adapted and reproduced from Information Circular 6566, United States Bureau of Mines.*)

Mineralogy of Chromite

Chromite is an iron-black to brownish-black mineral with a metallic to pitchy sub-metallic lustre. The colour of the powder (streak) is brown, and very thin fragments of the mineral may be translucent, showing a yellowish-red colour. Crystals are usually simple octahedra and quite small. Commonly, the mineral is massive, fine-granular to compact. It is tough, breaks with an uneven fracture, and is sometimes feebly magnetic. The hardness is 5.5 and the specific gravity ranges from 4.32 to 4.57.

Chromite is infusible before the blowpipe in the oxidizing flame. In the reducing flame, splinters may be slightly rounded, and the mineral may become magnetic or have its magnetism increased; this is particularly the case after fusion with sodium carbonate. It is not appreciably acted on by acids, but is decomposed by fusion with sodium or potassium bisulphate. The chromium content is most easily detected by the green colour this metal imparts to a borax or microcosmic salt (salt of phosphorus) bead.

In the field, chromite is distinguished by its brown streak from magnetite and ilmenite, both of which have a black streak. Magnetite, also, is always very strongly magnetic, whereas chromite, if magnetic at all, is but feebly so.

Although, as noted below, all chromite has not exactly the same chemical composition, the mineral may be represented essentially by the formula $FeO.Cr_2O_3$. Chromite of this composition would contain 32 per cent iron protoxide (FeO) and 68 per cent chromium sesquioxide (Cr_2O_3). Actually, the mineral seldom, if ever, contains such a high percentage of chromium as this.

Mineralogically, chromite belongs to the 'spinel group' of minerals, whose general formula may be written $R''O.R'''_2O_3$, in which R'' = Mg, Fe'', or Zn, and R''' = Al, Fe''', Cr, or Mn. As a large proportion of zinc or manganese is not commonly present in the chrome-bearing members of the group, these constituents may be neglected for the purpose of the present discussion and the group formula may be written $(Mg,Fe)O.(Al,Fe,Cr)_2O_3$. Three of the commonest members of the spinel group, with the essential formulae assigned to them, are: spinel ($MgO.Al_2O_3$), magnetite ($FeO.Fe_2O_3$), and chromite ($FeO.Cr_2O_3$).

Minerals such as these, which have similar chemical formulae and the same crystal symmetry, are said to be 'isomorphous'; and it is characteristic in a group of isomorphous minerals to get intermediate types or 'isomorphous mixtures'. Thus, most specimens of spinel are found, on analysis, to contain both MgO and FeO, and both Al_2O_3 and Fe_2O_3. The ratio of total protoxides to total sesquioxides remains 1:1, however, and the formula might be written $(Mg,Fe)O.(Al,Fe)_2O_3$. The mineral then contains all the constituents both of pure spinel and of magnetite. It is not, however, a mechanical mixture of the two, but a homogeneous compound.

Similarly, chromite seldom, if ever, contains only FeO and Cr_2O_3. Almost invariably there is present some MgO, taking the place of an equivalent amount of FeO, and both Fe_2O_3 and Al_2O_3 are usually present similarly replacing a portion of the Cr_2O_3. Thus, ordinary chromite may be represented by the formula $(Fe,Mg)O.(Cr,Fe,Al)_2O_3$. Sometimes varieties containing a relatively high percentage of MgO are called 'magnesio-chromite', while those types in which the content of Cr_2O_3 falls below 10 per cent are designated 'picotite'.

The problem of establishing the true composition and nature of any sample of chromite is singularly complicated. Owing to its relative insolubility in acids and fluxes, great difficulties are encountered in the chemical analysis of the mineral, particularly in the accurate determination of the ferrous and the ferric iron. Any error in this determination is necessarily reflected in the ratio of the total protoxides to the total sesquioxides, and, in fact, the calculation of this ratio from the majority of the published analyses of chromite reveals wide variations from the 1:1 ratio required by the formula. Moreover, even though the analysis be accurate, the material analyzed may not be homogeneous, since microscopic examination, either of thin sections or of polished surfaces, of practically any specimen of Quebec chromite shows it to consist of two or even more constituents, usually so intimately intergrown that their separation in a pure state for individual analysis would be hardly, if at all, possible. The same is doubtless true of chromite from other localities.

The fact that chromite belongs to a group of isomorphous minerals, and that the ferrous iron and the chromium, respectively, may be replaced in any proportion by magnesium and by ferric iron and aluminium, is of paramount importance to the producer of chromite,

for it means that not only does the ore as extracted from the mine only contain a certain proportion of chromite, but the percentage of Cr_2O_3 in the chromite itself is, in practice, always below the maximum of 68.0 per cent which is contained in the ideal chromite of composition $FeO.Cr_2O_3$. It is, moreover, evident that while improvements in mechanical processes of separation and concentration may raise the proportion of chromite in the product, no mere mechanical method may be devised to improve the quality (chromium content) of the chromite itself.

It is therefore essential, when considering the exploitation of a body of chromite-bearing rock, to take into account not only the chromium content of the ore, but also to determine carefully the chromium content of the chromite mineral in the ore, for this latter factor is at least equally important to the success of the venture. Reliable data on possible variation in composition of the mineral within a single ore-body seem to be unobtainable, but it is reasonable to presume that if there is any variation it will not exceed the range permitted in usual specifications for commercial requirements. On the other hand, it is certain that in different occurrences within the same general district the chromite may vary considerably in composition and include both marketable and unmarketable grades.

The market requirements for chromite ore are dealt with in a subsequent chapter. It may be said at this point, however, that chromite ore containing 40 per cent Cr_2O_3 may be regarded as the lowest marketable grade, and that the composition of the bulk of the ore sold falls within the following limits:

Cr_2O_3	40 to 55	per cent
FeO	12 to 21	"
Al_2O_3	6 to 21	"
SiO_2	1 to 9	"
MgO	9 to 16	"

Uses of Chromium

The chief uses of chromium may be grouped under the following general headings:

1.—Metallurgical
2.—Refractory
3.—Chemical and chrome plating

METALLURGICAL USES:

In recent years, chromite has found its most extensive use in the metallurgical industry, and today slightly more than one-half of the world's output of chromite is absorbed in the manufacture of various chrome-iron alloys. As indicating the increasingly widespread use of these alloys, it may be pointed out that in the year 1930, despite the great curtailment of activity in the iron and steel industry, there was an increase of 10 per cent in the production of chrome-iron alloys in the United States.

The use of chromium steel, containing from one to six per cent of chromium, or of chromium alloyed with other metals, is indicated where great resistance to wear and to violent stress is required. These alloys can also be welded to iron Steel of this type is suitable for the manufacture of armour-plate, projectiles, rails, axles and springs, and the wearing parts of rock-crushing machinery. Welded to iron, it is used in the manufacture of burglar-proof safes, as cores for prison bars, etc., being impenetrable by the finest drilling and cutting tools.

Although steel containing as little as six per cent of chromium is known commercially as 'non-rusting', true stainless steel, whose widespread application is a comparatively recent development, contains up to 20 per cent of chromium. Such steel effectively resists ordinary atmospheric oxidation, as well as the corrosive action of salt water and certain acids, and as a consequence it is employed in a very wide range of products, embracing such diverse utilities as cutlery and structural beams. The advantages of durability and economy of maintenance of non-rusting steel are so obvious that only its high cost has prohibited its use in general construction work; but improvements in metallurgical processes, with consequent reduction in prices, have greatly enlarged its field of application within the last few years.

Chromium also enters into the manufacture of a certain class of machineable casting-alloys, and likewise into a number of high-temperature-resisting alloys. Of these latter, 'stellite', a chromium-cobalt alloy containing also tungsten or molybdenum has properties which allow it to take a good cutting edge, and to retain its hardness at a temperature approaching red heat, thereby permitting very high speeds in lathe-work. Other high-temperature-resisting alloys con-

taining chromium are used for annealing boxes, retorts, and for the manufacture of machinery subjected to high temperatures during operation.

The chromium is incorporated with the iron or steel in the form of ferro-chrome, containing between 60 per cent and 70 per cent of metallic chromium. In order to produce ferro-chrome of this composition, the manufacturers require chromite containing at least 45 per cent Cr_2O_3 and it is, moreover, desirable that the ratio of iron oxide to chromic oxide should not exceed one to three. For example, an ore containing 51 per cent Cr_2O_3 would not be regarded as suitable for the manufacture of ferro-chrome unless the iron oxide content were less than 17 per cent. Low sulphur and phosphorus are also essential.

The United States, Russia, Germany, the United Kingdom, Norway, and Switzerland are the principal producers of ferro-chrome. It is made in the electric furnace by a reduction process, using either carbon or aluminium as the reducing agent. As the ferro-chrome obtained by aluminium reduction has the lower carbon content, this process is to be preferred if the alloy is to be used for the manufacture of high-class steel.

It is, of course, quite out of the question to deal at length with the subject of chromium-iron alloys in a report of this nature. They have been the subject of much research in recent years, and the results achieved have greatly extended their use and have caused a corresponding increase in the demand for chromium While this demand may, with the development of a feasible direct-smelting metallurgical process, be partially satisfied by the exploitation of the huge bodies of chromium-bearing iron ores such as are known to exist in Cuba, the high chromium content essential to such alloys as the stainless steels necessitates the use of chromite as the raw material for their manufacture. An increasing demand for high-grade chromite may therefore be anticipated.

Refractory Uses:

Raw chromite, because of its refractory properties, *i.e.*, infusibility and resistance to corrosion and to assimilation in slags, is extensively employed in metallurgical operations for the lining of

open-hearth furnaces. While, in 1918, it was estimated that only 17 per cent of the chromite imported into the United States was employed for this purpose, in 1929 this proportion had increased to 40 per cent. The crude lump-ore may be used in the form of a dry wall, the interstices being filled with fine ore, or, if necessary, the crude fine-ore is manufactured into a chromite cement.

Chromite bricks are now extensively employed, not only in steel works and in other high-temperature metallurgical operations, but also for the lining of alkali recovery furnaces in the sulphite process for pulp manufacture. It has been found that they are suitably resistant to the corrosive action of the gases and liquors involved in this process. Chromite brick has, within recent years, been replacing magnesite brick to a very large extent in the United States. In fact, while, in 1923, there were about three magnesite bricks manufactured for each chromite brick, in 1927 approximately equal numbers of the two were made.

The chromite to be used in bricks or as refractory linings generally may contain as little as 38 to 40 per cent Cr_2O_3, but, on the other hand, a low proportion of silica, less than eight per cent, is demanded. The physical characters of the ore—that is, the grain, tenacity, size of lumps, etc.—may likewise determine the adaptability of a particular ore to the requirements of the individual consumers. Typical specifications of manufacturers of refractories in the United States are as follows:

	No. 1	No. 2
Chromic oxide	40 to 50 per cent	40 per cent (minimum)
Iron oxide	15 per cent (maximum)	15 per cent (maximum)
Silica	8 per cent (maximum)	6 per cent (maximum)

CHEMICAL USES :

A considerable amount of chromium is absorbed by the chemical industry, for use as a pigment, as a mordant for fixing dyes, in leather tanning, and in chromium plating.

The raw chromite is used for the manufacture of bichromates of sodium and of potassium, in which form the chromium is used in the leather-tanning industry. Bichromates have been used since 1884 for this purpose, and in such steadily increasing quantity that an assured supply of chrome salts has become of vital importance to the industry.

The principal countries manufacturing chromates are Germany, the United States, the United Kingdom, and Russia. Of these, Russia alone produces chromite, but the disadvantage to the other countries in having to import the raw ore is more than compensated by their resources in the necessary limestone, alkali carbonate, and coal, as well as in power and machinery.

Chromium salts are used in the textile industry, as dyes and as mordants to fix other dyes, and also to some extent in printing, as, for example, in the printing of bank notes, for which chromic oxide has been found to be the only suitable indelible pigment.

An increasingly large proportion of the chromite consumed in the chemical industry is ultimately marketed as chromium-plated articles. Great difficulty was at first experienced in plating chromium directly on iron, but recently a process has been perfected which makes unnecessary a preliminary nickel plating. Chromium plate is used for cooking utensils, automobile parts, plumbing fixtures, and numerous other articles, where resistance to oxidation, corrosion, and abrasion, combined with ability to take a high polish, are desired. The advantages claimed for chromium plating over nickel plating include the greater resistance of the former to abrasion, so that the surface of the article is less readily scratched and therefore retains a high polish more effectively.

For the chemical industry, the highest grade of chromite is desirable, over 50 per cent Cr_2O_3 being usually specified. Uniformity of composition and low resistance to pulverisation are also required. The iron content may be slightly higher than the maximum acceptable in ore used for the manufacture of ferro-chrome, but a low percentage of both aluminium and silica is demanded.

According to the figures given in the "Statistical Summary of the Mineral Industry of the British Empire and Foreign Countries" which is published annually by the Imperial Institute, London, the

following countries were the principal consumers of chromite in 1930, in order of importance: United States, Germany, Sweden. Norway, Great Britain and France.

Specific information on local markets should be sought from organizations such as the departments of Trade and Commerce of these countries. They usually can furnish lists of buyers of chromite at the time of inquiry.

CHROMITE DEPOSITS OF QUEBEC

Historical

The first recorded references to the occurrence of chromite in the Province of Quebec are to be found in the reports of the Geological Survey of Canada for the years 1846, 1847, and 1848, where attention is drawn to deposits, stated to be of possible economic importance, which had been discovered in Bolton township on lot 23, range VIII, and lot 26, range VII. There is also mention of a boulder of chromite, weighing some 600 pounds, which had been found near the outlet of lake Memphremagog.

The first actual shipment of ore was made in 1861 from lot 4, range II, of South Ham township, in Wolfe county. About 25 years later, some ore was shipped from lot 24, range III, of Wolfestown township, and again, in 1887, from lot 1, range X, of Leeds township. The possibility of the discovery of larger bodies or marketable ore was kept before the prospectors by government officials, but it was not until 1894, practically 50 years after the first discovery of chromite within the Province, that Mr. Provençal, of Black Lake, found an important body of ore in Coleraine township. Mr. J. Obalski, at that time Superintendent of Mines for the Province, identified the mineral as chromite, and preparations were immediately made for the development of the deposit, with the result that about 1,000 tons was shipped from the property in that year. Other discoveries followed within a short time, and a steady production of chrome ore from the district was maintained until the year 1910, when the competition of the higher grade and more cheaply mined ores which had been discovered in New Caledonia and Rhodesia forced the Quebec operators to suspend their activities.

During this period, however, many of the important known chromite deposits of the Province were located. It was quickly realized that the success of the industry was dependent upon the utilization of the relatively large amounts of low-grade ore which, as a rule, accompany the high-grade or 'crude'; the latter found a ready market without other preliminary treatment than hand sorting. In 1898, the first concentrating mill was erected, on the shore of Black lake, by the Coleraine Mining Company. This mill did not give the satisfaction anticipated, but in 1901 the American Chrome Company commenced the operation of a concentrating mill on lot 9, range XIII, of Coleraine township, which gave, from the first, reasonably satisfactory results, and served as a model to subsequent designers.

The period up to 1894 may be regarded as one of discoveries and trial shipments. The annual production figures for the years that followed reflect a steady expansion of the industry until the year 1908. The highest production of that period was recorded in 1906, when 9,035 tons of chromite was shipped. In the year 1908 this figure had already been slightly reduced, to 7,564 tons, valued at $83,740. Of this production, a little more than half in tonnage, and slightly less than half in value, was 'crude' ore, while the remainder consisted of concentrates resulting from the treatment of lower grade ores.

At this period the Black Lake Chrome and Asbestos Company was the owner of most of the productive chromite properties in the Province. Their holdings comprised the parcel of land designated as Blocks *A* and *B* of the township of Coleraine, which included all the mines formerly belonging to the Coleraine Mining Company, and they were also owners of the Montreal pit on lots 25 and 26, range II, Coleraine township. The Company was mining chromite at the following places: (1) Pit No. 1, close to the road leading from Black Lake village to Coleraine village; (2) Pit No. 2, or Caribou pit, near the lake of that name; and (3) Pit No. 3, or the Montreal pit. Underground working at pit No. 1 was well advanced, while the other mines were being worked by the open-cast method. Concentrating mills were operated by this Company at pits No. 1 and No. 3. The Company employed about 100 men in all.

The Canadian Chrome Company was operating a mine (the Hall mine) on part of lot 16, range *A*, Coleraine. The ore was treated in

a mill located on the property. A third operator was the American Chrome Company, on lots 6 and 7, range *B*, Coleraine. They, also, had their own concentrating mill, adjacent to the mine.

The whole of the output, crude or concentrate, was exported to the United States. By the year 1910, however, competition in this market with ore from New Caledonia and Rhodesia became so acute that the production from the Province of Quebec had fallen to 299 tons, and from 1911 until 1915 mining was completely suspended, although some shipments were made from stock-piles in 1911. The total production of chromite from the Province up to that time had amounted to slightly more than 60,000 tons.

The exigencies of the war, which greatly reduced shipping facilities (and hence, also, sea-borne importations of chromite into the United States) and at the same time produced an increased demand for chromium for armament purposes, resulted in an unprecedented activity in the North American chromite industry. At this period the United States turned to its normally unprofitable deposits of chromite, and actually led the world in production of that material until the cessation of hostilities.

In the Province of Quebec, also, encouraged by the high prices engendered by the increasing demand, and stimulated by the co-operation, and even the insistence, of the government, every effort was made to expand the chromite-mining industry to the utmost. The principal producers resumed their operations, and careful investigation of these long abandoned properties was rewarded by the profitable extraction of previously known low-grade ore and also of newly discovered ore. Intensive prospecting throughout the region brought to light the important ore-bodies of the Reed-Bélanger property, in Coleraine township, and of the Sterrett property near St. Cyr, in Cleveland township. Chromite ore or concentrate containing as little as 30 per cent Cr_2O_3 was accepted by the consumers, and at the time of the signing of the armistice the activity in the industry was at its peak.

Although the mining consisted to a great extent in somewhat haphazard open-pit 'gophering' by contractors on a royalty basis, underground development work and stoping was also carried on at the Caribou pit; on the Mutual Chemical Company's Reed property, adjoining the Bélanger mine; at the Ross property on lot 26, range *B*,

Coleraine township; and on the newly discovered Sterrett mine on lots 7 and 8, range X, Cleveland township.

The capacity of old concentrating plants was increased where possible, and new mills on the Bélanger property and at the Sterrett mine, near St. Cyr, were put in operation.

The production and value of the chromite mined in the Province during the war-years was as follows:

Year	Tons	Value
1915	14,397	$245,297
1916	27,952	312,901
1917	36,186	498,031
1918	36,131	770,955

The production of chromite during these four years, totalling 114,666 tons, was thus considerably greater than that in the fourteen-year period of earlier activity which had been brought to a close in 1909-1910. The 1918 production consisted of 14,934 tons of 'crude' and 21,197 tons of disseminated ore which was reduced by milling to 6,388 tons of concentrate. The value per ton of the crude was about one-half that of the concentrate. It is, of course, certain that much of the chromite sold during the war years was of low grade, only marketable because of the abnormal situation.

The reaction at the end of the war was immediate, both in the United States and in Canada. It was realized that the future of the domestic industry depended upon the ability of the producers to meet once more the competition of ores from outside sources. Development work was continued on the Caribou and the Reed-Bélanger ore-bodies, and for the next three years chromite was mined and shipped, but in rapidly decreasing amount. Since 1923, however, no production whatever has been recorded, though a certain amount of exploration work has been carried on from time to time.

Geology

The 'Serpentine belt', in which the chromite deposits occur in the Province of Quebec, lies entirely within the folded and disturbed Appalachian region, and consists essentially of basic to ultra-basic igneous rocks which are exposed at intervals in a long narrow zone,

the trend of which corresponds with that of the axis of the regional folding. The folds have a general northeast-southwest direction, and the rocks of the Serpentine belt form a discontinuous band or zone which has been traced from the Carolinas, in the United States, to Gaspé peninsula, a distance of about 1,500 miles. Although the name 'Serpentine belt' has been given to this development of igneous rock, serpentine itself constitutes but a small proportion of it. The name, however, aptly emphasises the great economic importance of the serpentine. The predominating rock in the belt has approximately the composition of a diabase and is most conveniently designated as 'greenstone'. Associated with this, and presumed to have been formed by gravitative differentiation from the same parent magma, are ultra-basic rocks, dunites, peridotites and pyroxenites, which have locally been more or less completely serpentinized.

The serpentine, and the ultra-basic rocks from which it is derived, are normally found near the margins of the relatively long, narrow greenstone bodies, and as a rule near that margin which structurally represents the base of the mass of the igneous rock.

The greatest difficulty has been experienced by geologists who have studied the area in assigning a definite geological age to the rocks of the Serpentine belt. This is not due to the inaccessibility of the zone, which lies for the larger part within settled country, and, moreover, its economic importance has attracted to it the attention of geologists practically since the earliest application of that science to mining in North America. The problem is, however, complicated by the structural features of the region, by the lack of fossils which would provide the necessary palaeontological correlation to assist the stratigraphical study of the associated rocks, by the existence of at least one older series of greenstones presenting lithological similarities to those of the Serpentine series, and, finally, by the complex mutual relations of the rocks within the Serpentine belt itself. It is generally agreed, however, that the rocks of the Serpentine series intrude rocks of Ordovician age, and that they are therefore post-Ordovician. Burton ① places the age of intrusion as post-Lower-Devonian. The conflicting evidence brought to light in the various areas where these rocks have been studied suggests that they may not have been intruded at the same time over the entire length of the belt.

① "*Vicinity of Lake Aylmer, Eastern Townships*"; Que. Bur. Mines, Ann. Report, 1930, Part D.

The numerous isolated masses of rock which form the Serpentine belt present great variation in size and in distribution, but on the whole the direction of the longer axis of the different bodies is conformable to the axis of the Appalachian folds. In the Thetford-Black Lake area, in which most of the important producing chromite mines are located, there are, broadly speaking, two parallel bands of these rocks, each about two miles wide. The prevailing direction of these bands is northeast-southwest. Foliation within the rocks in this area is not pronounced, but small faults are numerous, particularly in the serpentine. The serpentines themselves are frequently very much shattered.

No definitely accepted explanation of the relation of the two bands of intrusive rock to one another, and to the surrounding sediments, has been put forward. It has been suggested that they represent the eroded remnants of a single sill or laccolithic body; also, and more frequently, that they are separate intrusions of a series of isolated stocks. Geological studies in the region indicate that they were injected after the folding of the enclosing rocks was largely completed.

In the Black Lake-Thetford region, the rocks which constitute by far the greater part of the Serpentine belt are basic in composition. Dunites, peridotites, and pyroxenites occupy nine-tenths of the area underlain by these intrusive rocks, and the field study reveals that not only is it impossible to differentiate them completely on the map, but that it is even very difficult to estimate the relative abundance of each. Where serpentinization is incomplete, the cleavage faces of the pyroxene crystals are readily apparent, and afford a means of classifying the rock; but even in single outcrops, the variation in composition and grain, and the mutual relations of the different types of rocks, are often very bewildering.

The less basic rock-types include gabbro, diabase, porphyrite, granite, and aplite, the dyke equivalent of granite. All these rocks constitute, in the Thetford-Black Lake area, a small proportion of the intrusive masses, but they are important in that they support the view that differentiation has played an essential part in the course of the intrusion of the series as a whole. These less basic rocks (exclusive of the granites and aplites) usually occupy the marginal portions of the masses. This is, of course, to be expected, whether the masses are remnants of a single sill-like body, or separate intrusions

connected at depth; moreover, these rocks do not form a continuous zone between the basic rocks and the intruded sediments, but share in the general complexity of the intrusions as a whole.

A very striking feature of the ultrabasic rocks of the serpentine series is the widespread development of aplitic dykes. These dykes are normally light coloured, very fine grained, and seldom contain ferromagnesian minerals. They have been noted by the writer and others in the great majority of both asbestos and chromite mines and prospects throughout the Serpentine belt, and it has been suggested① that they are the result of acidic segregations within the magma, rather than due to the gravitative differentiation which explains the disposition of the ultrabasic and intermediate, diabasic, components of the series. These dykes vary from a few inches to more than 75 feet in width, and a noteworthy characteristic which has been observed is the frequency of the occurrences in which the dykes 'pinch out' before reaching the upper limit of the exposure (Pl. III-B). This would tend to support the view that they represent individual segregations of no very great magnitude, which have occupied, or been forced into, small fissures within the scarcely solidified magma. Serpentinization is usually complete in the rock immediately adjacent to these dykes, although the zone of complete serpentinization is often only a few inches in width. Successive pinches and swells have been observed in these dykes, or a succession of lenses *'en chapelet'* without any apparent connecting feeder between them.

Despite the contention of some of the operators that there appears to be some interdependence between these aplites and the chromite, the evidence indicates that the latter was solidified before the intrusion of the granites, and that the mutual relations between the two are merely those of accidental proximity.

Mode of Occurrence and Origin of the Deposits

Cirkel, in his study of the chromite deposits of the Province, remarked that ②: "Most of the serpentine in the chrome iron ore region contains a very small percentage of chromite, disseminated through the mass in an exceedingly fine state of division. Samples

① Dresser, J. A., *Granite Segregations in the Serpentine Series of Quebec*; Trans. Roy. Soc. Can, Vol. XIV, Sec. IV, 1920.

② *Op. cit.*, p. 19.

of the rock were granulated for the purpose of determining whether there could be any chromite extracted, but it was found that no grains or specks could be detected with the naked eye. These samples were then tested for chromite, and it was found that they contained from 0.73 to 6.32 per cent . . .

"A typical serpentine of the chrome iron ore region was subjected to analysis and gave the following percentage composition:

Al_2O_3	1.84
Fe_2O_3	0.57
FeO	6.04
Cr_2O_3	0.04
NiO	0.20
CaO	0.18
MgO	38.18
SiO_2	39.82
H_2O	13.27
	100.14

Analyst: M. F. Connor, Laboratory of Mines Branch, Ottawa.

Dresser ① speaks of "the general occurrence (of chromite), in traces at least, in all the rocks of the series". Harvie, in his unpublished report on the Black Lake-Thetford area, mentions that chromite was found in every thin section of dunite or peridotite examined, and the present writer has observed the presence of grains of this mineral in serpentine from very widely separated sources within the Serpentine belt.

The chromite ore-bodies are, however, invariably associated with the basic members of the Serpentine series, usually with dunite, peridotite, and pyroxenite, or, to be more correct, with the serpentine resulting from the alteration of one or other of these rocks, for the serpentinization of the wall-rock of the ore is a characteristic, possibly only accidental, of the deposits.

In his description of the form of the ore-bodies, and of the relations of the ore to the surrounding wall-rock, Cirkel states ②: Chromite does not occur in Canada in what is generally termed veins, but is found as a rule in irregular masses and pockets, that is, in bodies having no definite form, and no tendency to adhere to dimensions in a special direction. They appear to have no relation to each other . . .

① Dresser, J. A., *Preliminary Report on the Serpentine and Associated Rocks of Southern Quebec*; Geol. Surv. Can., Mem. 22, 1913, p. 90.

② *Op. cit.*, pp. 22-25.

The contacts of the deposits with the serpentine present the most irregular features. Sometimes there is a selvage between the rocks, thus facilitating the extraction of the mineral; at other times, both serpentine and chromite are so intermingled, or 'frozen' to each other, that much difficulty is experienced in separating them... In a general way, the irregularities of the chromite deposits may be summed up as follows: the very pockety nature; the apparent non-relation or non-connection of one pocket of chromite with another; the shooting-off of stringers from the main masses of the chromite into the serpentine; the widening and the pinching of the chromite lodes; the intimate mixture of serpentine and chromite... and the gradation from the nearly pure masses of chromite through a mixture of chromite and serpentine to the pure serpentine...

"In some cases are found so-called 'crude', or high-grade, ore; in other cases, tongue-like apophyses, from a few inches up to two feet or more in width, as offshoots from solid ore-bodies; again as knolls or kidney-like accumulations distributed through crack fillings in the solid serpentine formation, and also close to the contact of the granite intrusions; and again in the form of disseminations of the ore through the rock mass.

"In the case of the 'crude' ore deposits, the ore at the contact with the rock, as a general rule, does not easily separate from the latter; it is frozen to it and requires cobbing by hammer to free it from impurities. Where the formation is highly fissured, as a result of displacement and faulting after its deposition, the ore itself shows fine cracks and fissures, and sometimes highly polished surfaces, admitting easy spalling. In a few isolated cases, some of the ore lenses... exhibit distinct demarcation lines on the contact, and the ore separates readily from the serpentine, while in most deposits a gradual transition from the pure ore to disseminated ore, and pure serpentine, is observed...

"In this disseminated form, chromite occurs as scattered grains, the size of a pea and smaller, through the serpentine... It often appears in cracks and fissures in the serpentine formation, and may be noticed frequently in the vicinity of granitic dykes, in conjunction with the pure ore.

"As to the shape of these disseminated ore-bodies, it must be stated that, in some mines, a banded arrangement can be noticed,

while at others, lens-shaped, pockety accumulations are the principal features. The outcrops of this low-grade, disseminated ore are of peculiar appearance, the grains have a brown tarnish, the serpentine in some cases becomes rust coloured, while in others, especially in the softer variety, white or grey colour predominates; however, in all cases the outcrops of the disseminated ore are easily discernible, and no difficulty is experienced in their location".

At the period when the foregoing summary was written, the chromite industry was flourishing and the working faces of the various mines were accessible; unfortunately, any additional information concerning the mode of occurrence and origin of the chromite which may have been disclosed by subsequent operations is, in the majority of cases, lost, the long disused workings being so effectively concealed by water or by caving as to preclude the possibility of direct observation.

The importance of the banded, disseminated ores has, however, been more clearly recognized since the discovery and development of the Reed-Bélanger ore-bodies in Coleraine township, and the Sterrett mine near St. Cyr. In each of these deposits, the banded character of the ore, and the length of the ore-bodies, are striking features. In these bodies, the ore-bearing zone has been traced over lengths of about 1,500 feet and the width in the Reed-Bélanger attains 60 feet, as compared with a usual width in such deposits of from 6 to 20 feet. The ore usually grades quite rapidly into basic country-rock, but there is never a sharp contact between the two. The regularity of these deposits is, nevertheless, only relative, for the workable portions consist in a series of lens-like concentrations, the longer axes of which parallel the longer axis of the serpentine body in which they occur. In detail, also, the disposition of the ore shows irregularities. Plate IIA, reproduced from the photograph of a large block of ore on the Bélanger property, illustrates well the irregular character of the banding which is such a conspicuous feature in these deposits. It shows how the individual bands vary in width, and, also, how they may be interrupted by sections of practically barren rock, which, however, do not differ in texture or composition from the rest of the rock. Other examples, no less remarkable, may be seen, in which, instead, the continuity of a band is a feature. In these latter, narrow bands of ore, one-quarter to one-sixth of an inch in width, may be followed for lengths of several feet, and although locally they may

be reduced merely to single grains of chromite, spaced up to three-quarters of an inch apart, the distinct continuity of the mineralized horizon is striking. Parallel bands within an inch of one which thus suddenly thins out may continue with undiminished width. Minor folds in the ore bands, on a scale visible in hand-specimens, are occasionally noticeable in the material on the mine dumps.

Sampson ① has suggested an origin by replacement for ore of this type. Plate IIB, reproduced from his paper, represents a specimen of chromite ore from Wood's mine, Lancaster Co., Pa., and it will be noted how strikingly similar it is to the specimen of Bélanger ore shown in Plate IIA. It is, however, very difficult to picture a process of replacement which would produce this remarkable banded appearance in an apparently uniform massive rock. On the other hand, the specimens in which minor folding was noted, and made apparent only by the contrast of chromite and country rock, are strongly suggestive of alignment of the particles prior to complete solidification of the enclosing rock—that is, of primary flow structure. The highly shattered condition of the serpentine rocks in zones which have been subjected to stress, indicates clearly that these rocks yield by fracture rather than by flow. Cirkel, in his description of the chromite bodies, pointed out that the fracturing is later than the ore, a fact which has been repeatedly verified in specimens collected by the writer during the past field season.

No less remarkable than the banded ores are the 'grape' ores which are conspicuous in the deposits on lot 28, range I, of Ireland township, and in the Standard pits near Black Lake. In these two deposits, the disseminated chromite is accompanied by small regular nodules of practically solid chromite. These nodules are surrounded by a very narrow rim of completely serpentinized rock, slightly different in appearance from the normal country rock. In size, they range from a quarter of an inch to about two inches, and they commonly include a very small amount of serpentine, filling tiny fracture planes. The serpentine immediately surrounding the nodules is normally poor in chromite. These 'grape' ores are not important economically, as they constitute only a small proportion of the few deposits in which they occur; but they furnish very strong evidence in support of the theory that the chromite deposits are of the segrega-

① Sampson, Edward, *May Chromite Crystallize Late?*; Econ. Geol., Sept.-Oct., 1929, Vol. XXIV, No. 6.

A.—Banded chromite in serpentine in the Reed-Bélanger ore-body

From Econ. Geol. Vol. XXIV, No. 6, 1929.

B.—Vein of chromite in serpentinized dunite at Wood's mine, Lancaster county, Pennsylvania

tion type. The natural inference of the origin of these 'grapes' would appear to be that they represent centres to which the chromite was attracted from the surrounding rock during its solidification.

Cirkel, in the summary quoted above, states that the disseminated chromite frequently occurs in cracks and fissures in the serpentine. This feature was borne in mind during the examination of the properties throughout the field season, and evidence was carefully sought which might support the view that this chromite had been introduced by hydrothermal action or by solutions. It was found, however, in the few instances in which chromite was seen filling fractures in the serpentine, that it had a fine, brown, earthy appearance, and that it was obviously crushed chromite which had been mechanically introduced along small fault planes. On the other hand, examples were noted, particularly at the Hall mine (on lot 16, range *A*, Coleraine township), where the complex relations of the chromite and serpentine suggest interpenetration of two immiscible portions of a partially solidified rock mass. In ore of this type, the chromite contains fragments of serpentine, and small tongues of chromite penetrate into the rock. The boundaries between the serpentine and the chromite are sometimes graded and sometimes remarkably clean-cut. While, in such deposits, the chromite may appear, locally, to be later than the serpentine, the deposit as a whole exhibits characters which justify Dresser's ① conclusions that "the ore-bodies are the result of differentiation from the magma of the original rock; that they have been modified in shape by mechanical deformation which they, as well as the enclosing rock, have undergone; and that this deformation may have taken place in part while the country rock was still in a partially plastic condition".

In size, the occurrences of chromite range from segregations measuring but a few inches in diameter up to ore-bodies which have yielded thousands of tons. The largest so far discovered is a lens in the Reed-Bélanger deposit, which, according to dimensions reported in the Annual Report of the Bureau of Mines for 1920, is estimated to contain at least 150,000 tons of milling ore; other data indicate a much higher tonnage than this. At least three other properties have produced between 15,000 tons and 30,000 tons each. The dimensions of the ore-body of No. 1 pit of the Black Lake Asbestos and

① *Op. cit.*, p. 90.

Chrome Company, from which approximately 30,000 tons of ore have been extracted, were 80 feet in length, 5 to 50 feet in width, and 340 feet in depth. Besides these large bodies there are a great number of smaller deposits, which have contributed anywhere from a few tons up to several hundred tons each to the Province's total production of chromite.

Chemical Composition of Quebec Chromite

Work by Dresser:

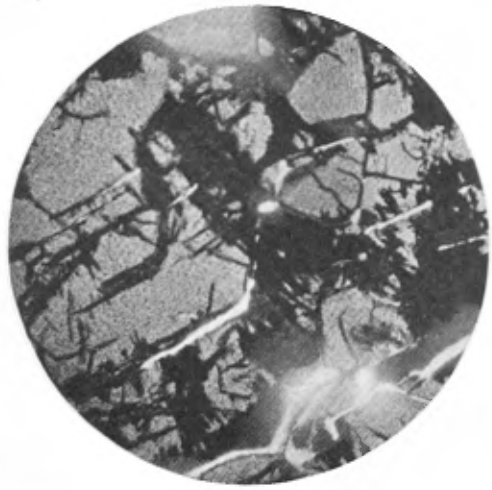
Dresser ①, in discussing the mineralogy of Quebec chromite, distinguished two varieties of the mineral, which he described as follows:

"On examining microscopic sections of chromite from Black Lake, it has been found to consist of two parts: a reddish-brown, translucent substance, and a black, opaque material (Pl. III A). In specimens selected from the high-grade ores, the reddish material was found to make up as much as 90 per cent of the whole; while in specimens of poor ores the black portion was greatly in excess. Specimens of medium grades of ore show the two portions in the thin section to be definitely distinct from each other, though often intricately intergrown. In a few cases they had the appearance of interlocking octahedral crystals, but, in general, crystal outlines cannot be well distinguished in either. In reflected light, the two kinds of material are absolutely indistinguishable.

"An attempt was made to etch a specimen in thin section, but unsuccessfully. The cover glass being removed, the section was treated with hydrochloric acid at boiling temperature for twenty minutes, but no perceptible effect was produced on either of the substances.

"A quantity of rock was crushed, and sized, and a magnetic separation attempted. With an electric current of 2.5 amperes on a Wetherell separator, no part of the mineral proved magnetic; at 6 amperes, all was taken up. After repeated trials, a fairly good separation was effected with an amperage of 3.8—the belt moving at 20 feet per minute, the first magnet standing $^{7}/_{32}$ of an inch from the belt, and the second $^{9}/_{32}$, and with a slow feed. Microscopic examination showed that the heads consisted of the black opaque portion of the

① *Op. cit.*, pp. 76-80.



A.—Photomicrograph of chromite from Black Lake. The opaque portion, high in iron, sends off arms into the translucent reddish-brown substance (see p. 32)
(From Dresser's Memoir 22, Geol. Surv. of Can.)

B.—Termination of aplite dyke, Gagné prospect, lot 25, range III, Coleraine township.

ore, and that the red translucent part formed the tails. Separate treatment of each of the products, made several times, yielded very clean heads, but the separation of the tails was not quite so satisfactory.

"One-fourth of the crushed material which passed through the 150-mesh screen and remained on the 200-mesh, was treated in an experimental hydraulic separator, using an ascending current. By this means a tolerably good separation was also effected. The difference in the density of the two products was not determined, but the red portion proved the lighter.

"Another feature that evidently has a bearing of some importance on the concentration of chromite is the fact that the reddish-brown portion is the more friable. On screening the products of a single crushing, it was found that the proportion of red to black grains increased directly with the fineness of the material. Practically all that passed through the 200-mesh screen was red, and the greater part that lay on 80-mesh, black; while that remaining on the 150-mesh screen was intermediate in composition. In the mill concentration, chromite, after passing through jaw crushers, is stamped to about $^{1}/_{20}$ inch, and separated from the gangue by means of Wilfley tables. There is a notable loss of fine particles, or float, which, it is evident from this investigation, consists of a valuable portion of the ore, and not a waste product.

"In view of the correspondence in formula between chromite and pitchblende, a specimen of chromite was tested for radium by Dr. A. S. Eve, of the Department of Physics, McGill University. It proved to be so feebly radioactive that no examination of the separate products for this purpose was thought necessary.

"The two kinds of ore obtained by the magnetic separation described above were submitted for chemical analysis. The following are the results:

"(*A*) is the reddish-brown, less magnetic, lighter, and more friable portion;

"(*B*) is the black, opaque, magnetic part.

	A		B	
		Molecular ratio		Molecular ratio
SiO_2	6.54	0.109	4.10	0.068
Al_2O_3	10.34	0.101	11.34	0.110
Cr_2O_3	45.30	0.300	48.20	0.320
FeO	13.94	0.193	15.66	0.217
MnO	0.32	0.004	0.36	0.005
CaO	2.50	0.045	1.50	0.027
MgO	16.70	0.417	15.66	0.341 ①
CO_2	2.46	0.056	1.45	0.033
TiO_2	0.12	0.001	0.12	0.001
H_2O	0.12	....	0.08	....
	2.03	....	1.97	....
	100.37		100.44	

"Assigning to CO_2 in the above analyses all the CaO, and an additional amount of MgO to satisfy it; and to SiO_2 enough MgO to make bronzite, the results may be regarded as impurities. Combining the remaining constituents in the three molecules, $FeO.Cr_2O_3$ (MnO being added to FeO), $MgO.Cr_2O_3$, and $MgO.Al_2O_3$, there is only left an excess of MgO in *A*, of 85 molecules; and in *B*, of 49. In other words, the ratios of the protoxide to the sesquioxide bases (exclusive of amounts entering into the impurities, calcite and bronzite) are as follows: in *A*, 494:401, and in *B*, 489:430 ②.

"The difference in composition of these two specimens, which seems to account for their difference in optical and physical character, is that magnesia is higher in *A* than in *B*; while ferrous iron is higher in *B*. Dr. Wadsworth, who made a microscopic study of chromite

① Poitevin and Graham have pointed out that this figure should be 0.391.

② Poitevin and Graham have pointed out that, in the absence of a separate determination of FeO and Fe_2O_3, the calculation of these ratios involves assumptions not specified in the original report.

and picotite in peridotite ①, has suggested that chromite may be an altered form of picotite, a variety of spinel in which chromium occurs to as much as seven per cent. To this, Pratt (*op. cit.*) takes exception, and considers it probable that chromite consists of three isomorphous molecules, $FeO.Cr_2O_3$; $MgO.Cr_2O_3$; and $MgO.Al_2O_3$. He says: 'With the increase of the ratio of the molecule $MgO.Al_2O_3$, and a corresponding decrease in the molecule $FeO.Cr_2O_3$, the more translucent the mineral will become'.

"It is a well known fact that pure chromite, answering the formula $FeO.Cr_2O_3$, has not yet been found in nature, except in meteorites. But the FeO is replaced in part by MgO, and the Cr_2O_3 by Al_2O_3. This it is that has suggested an isomorphic relation of these molecules. The following are analyses of chromite from (I) Bolton, and (II) lake Memphremagog, Que., given by Hunt ②:

	I	II
Cr_2O_3	45.90	49.75
Al_2O_3	3.20	11.30
FeO	35.68	21.28
MgO	15.03	18.13
	99.81	100.46

"The analysis of specimen *A* clearly shows that the translucent portion of the sample in question cannot be picotite, even in somewhat altered form, since it has more than six times as much chromic oxide as that mineral contains. In some sections, the relative positions of the translucent and opaque portions are such as to suggest that the opaque might be an altered form of the other, but in others both appear to be primary. It, therefore, seems more probable that they are intergrowths, and, as Pratt has suggested, that Cr_2O_3 may have for its protoxide base either FeO or MgO, and that the two molecules are commonly both present in an isomorphic relation".

RECENT WORK BY POITEVIN:

The mineralogy of the chromite of the Province of Quebec has been more recently studied in detail by E. Poitevin, chief of the Division of Mineralogy, Geological Survey of Canada ③. The essential features of his report are reproduced in full below:

① *Lithological Studies*, Cambridge, Mass., 1884, p. 184.
② *Geology of Canada*, 1863, p. 504.
③ *Chemical and Mineralogical Studies of some Quebec Chromites*; Geol. Surv. Can., Summ. Rept., 1930, Part D.

"The chromite, as a rule, does not occur in well-defined crystal individuals, but in finely granular aggregates or apparently compact masses, having a black or slightly brownish-black colour, pitchy submetallic lustre, and brown streak. The compact ore often has a platy structure and breaks along ill-defined parting planes, that, in some cases, are coated with a thin film of a white, flaky, biaxial mineral, chromiferous clinochlore. The partings may be highly polished or slickensided, due to differential movements. At the Hall chrome pit, a granular chromite was observed, which is so friable that it can be readily crumbled in the hand.

"Forty specimens of chromite from as many localities and occurring in different varieties of peridotite or in pyroxenite were examined in thin sections. The chromite of thirty-six specimens in thin section was transparent and red to orange, according to the thickness of the section. The chromite of four specimens was opaque. The country rocks of these four specimens hold abundant pyroxene. Many of the chromite specimens hold a few idiomorphic crystals of picotite spinel and of olivine. The crystals of olivine are, as a rule, quite fresh.

"The chromite specimens were investigated by means of a small magnet and it was found that chromites with the same physical appearances differed in their magnetic properties.

"Eight of the chromite specimens were studied in more detail. Chemical analyses of them are presented on a following page. The localities from which the specimens were obtained are listed below.

"Specimen No. 2.—Chromite pit (Bennett Martin chrome) on the road to Vimy, Ireland tp., lot 28, range I, Megantic county, Que.

"Specimen No. 462.—Chromite pit on south slope, near summit of Caribou Mountain, Ireland tp., Megantic county, Que.

"Specimen No. 432.—Chromite pit on north slope of Kerr hill at 1,300 feet elevation in bottom of a draw, Coleraine tp., Megantic county, Que.

"Specimen No. 501.—Woolsey's pit on west slope, 1,540 feet elevation, Quarry hill, Coleraine tp., Megantic county, Que.

"Specimen No. 1.—Chromite pit (Caribou chrome) on southeast slope of Quarry hill, 1,200 feet elevation, near lake Caribou, Coleraine tp., Megantic county, Que.

"Specimen No. 518.—Ross chromite pit on south slope, 1,555 feet elevation, Murphy hill, Coleraine tp., Megantic county, Que.

"Specimen No. 494.—Old Greenshields chrome pit on west slope, 1,000 feet elevation, Provençal hill, Coleraine tp., Megantic county, Que.

"Specimen No. 487.—Chromite pit (American chrome) east of Morin hill, at 1,300 feet elevation on trail to Peach lake, Coleraine tp., Megantic county, Que.

Specimen No. 2

"The specimen consists largely of nodular chromite, the interstices being occupied by dunite as gangue. Grains of this chromite are easily picked up by an ordinary magnet.

"In thin section under the microscope, the chromite is reddish and semi-translucent. Minute idiomorphic crystals of picotite lie in it. The slide is full of geometrical holes, which represent picotite crystals, removed during the grinding of the slide. The olivine of the dunite has been transformed to antigorite and the few pyroxenes originally present are now bastite. The chromite is somewhat fractured and the fractures are filled with antigorite bearing showers of ultra-microscopic crystals of magnetite close to the walls of the fractures. The chromite along the edges of the fractures is generally darker than elsewhere, as the result of oxidation.

"The country rock of the chromite deposit represented by the specimen was a dunite. The rock is now 75 per cent serpentine of the antigorite variety, with a few bastite individuals. The rest of its constituents are residual olivine and a little magnetite due to serpentinization.

Specimen No. 462

"In thin section, the chromite is translucent and red-brown. It is much fractured and the fractures are filled with antigorite serpentine. The matrix was originally olivine. Many fresh and altered olivine inclusions are scattered through the massive chromite. No magnetite nor picotite is visible in thin section.

"The country rock of the chromite deposit represented by this specimen was originally wholly olivine low in iron. The rock now consists of 55 per cent antigorite serpentine. The rest is olivine with traces of chromite. No magnetite is visible.

Specimen No. 432

"The chromite, in thin section, is reddish-brown and translucent. The gangue is antigorite serpentine. Inclusions of fresh and altered olivine are common. No picotite nor magnetite is visible.

"The country rock of the chromite deposit represented by this specimen was originally composed of 96 per cent olivine low in iron, and of 4 to 5 per cent enstatite pyroxene. Now the rock is 66 per cent antigorite serpentine (mesh type) with the other constituents more or less altered.

Specimen No 501

"The chromite, in thin section, is red and translucent with a little black oxidized chromite along fissures. The gangue is lattice and mesh serpentine. The mesh serpentine is somewhat colloidal. There are a few olivine inclusions. No magnetite is visible.

"The country rock of the chromite deposit was a dunite. The olivine has low indices of refraction and, therefore, belongs to the variety low in iron. The rock is now 60 per cent mesh antigorite-serpentine with probably one to two per cent chromite. A little brucite was identified.

Specimen No. 1

"The chromite is of the massive type, with a tendency to cleave in one direction. It is non-magnetic (to the hand magnet). No serpentine can be seen under the binocular microscope. In thin section under the microscope, this chromite exactly resembles the chromites described above. A small amount of picotite is present. A little serpentinized dunite is present as gangue, but there is no trace of magnetite, and the chromite along fractures traversing it shows no sign of oxidation. Many of the picotite crystals are altered to serpentine.

"The country rock of the chromite deposit consists of 60 per cent mesh antigorite-serpentine with remnants of fresh olivine cores. Bastite serpentine indicates that a few enstatite pyroxene crystals were associated with the olivine. Refractive indices of the fresh olivine point to a low-iron-bearing variety.

Specimen No. 518

"Chromite in thin section is seen to be translucent, red, and much fissured. Some dark zones along the fissures are due to the high indices of refraction of chromite and not to black oxidized ore. The gangue is mesh antigorite-serpentine. No magnetite is visible. No inclusions are present in the chromite. On thin edges of the slide, the reddish colour of the chromite grades to orange.

"Although the physical character of this chromite does not differ from those of previously described specimens, chemical analysis shows a great difference in composition. The country rock of the deposit in this case was typical lherzolite, now 75 per cent serpentine. The fresh rock was composed of 90 per cent low-iron-bearing olivine and of 10 per cent diallage pyroxene, with a few enstatite and chromite crystals visible. The olivine has altered to mesh antigorite-serpentine and the pyroxenes to bastite and a little chlorite.

Specimen No. 494

"The chromite, in thin section, is translucent and red. There are appreciable quantities of black oxidized chromite along joints and cracks. Olivine is present as inclusions. Lattice, mesh, and colloidal serpentine without magnetite occur as gangue.

"The country rock of the chromite deposit is a dunite now 60 per cent serpentinized. The remaining olivine is low in iron. The serpentine is antigorite with mesh structure. A few veinlets of chrysotile asbestos are visible. Some brucite and magnetite grains are present. The olivine was in large individuals.

Specimen No. 487

"The chromite, in thin section, is brownish-red. The edges of partings are oxidized to black ore. Olivine inclusions are absent, but idiomorphic crystals of picotite are present. The matrix is largely

a low birefringent chlorite derived from diallage. Chromiferous pennite is also present. It is interesting to note that when much black chromite is observed, chromiferous pennite is an associated mineral. Many occurrences studied, but not described here, show this phenomenon.

"The country rocks at this locality vary much. They range in composition from dunite to pyroxenite, but in the immediate vicinity of the chromite deposit the rock is a lherzolite.

"The samples of chromites analysed were carefully prepared to eliminate the gangue minerals. With care and patience, using heavy liquids, pure chromite with less than 0.5 per cent silica was obtained. The chemical work was performed by Mr. M. F. Connor, formerly of this division, and by R. J. C. Fabry. In many instances, FeO was determined by tests.

"The results of the analyses are as follows:

ANALYSES OF QUEBEC CHROMITES

SPECIMEN No.	2	462	432	501	1	518	494	487
SiO_2	....	0.53	0.47	0.50	....	1.00	0.40	0.30
TiO_2	....	trace	0.08	0.15	0.22	trace	0.15	0.17
Al_2O_3	12.30	14.32	14.23	14.36	15.63	23.63	12.61	20.29
Cr_2O_3	57.31	56.30	53.95	56.00	52.21	45.00	56.81	45.16
MgO	16.13	12.27	12.80	10.45	17.62	12.18	13.66	11.78
CaO	....	0.70	0.50	0.60	trace	0.40	0.40	0.70
Fe_2O_3	6.99	0.44	4.16	0.59	6.56	1.12	3.68	5.07
FeO	8.80	14.95	14.51	17.51	8.70	16.69	12.92	16.92
MnO	trace	0.12	0.20	0.20	nil	0.20	0.16	0.18
NiO	0.06	0.20	0.20	0.14	0.13	0.20	0.15	0.50
	101.59	99.83	101.09	100.50	101.07	100.42	100.94	101.07

"Chromites may be considered as being constituted of a series of salts wherein aluminium, chromium, and iron, functioning as acids, are in chemical combination with magnesium and iron as bases. Thus, the iron may exist in them as an acid as well as a base; but it is to be remembered that aluminium and chromium may exhibit basic as well as acidic properties, depending entirely upon the conditions involved in any given chemical reaction. It is to be noted that the

order of acidity of the acids is Al, Cr, Fe, and that magnesium has stronger basic properties than iron. (These properties are also indicated by the position of the elements in the Periodic Table). In other words, chromites are mixtures in various proportions of several terms of an isomorphus series of spinels $R''O.R'''_2O_3$. To establish these proportions, the above analyses were reduced to total 100, CaO was added to MgO and TiO_2 to SiO_2. To simplify calculations, enough SiO_2 and MgO to combine to form olivine, Mg_2SiO_4, was subtracted, and the remainder recalculated to total 100. Then all the alumina was combined with MgO to form $Al_2O_3.MgO$; the remaining MgO was combined with Cr_2O_3 to form $Cr_2O_3.MgO$; the rest of Cr_2O_3 was united with FeO to form $Cr_2O_3.FeO$; and what was left of FeO was combined with Fe_2O_3 as $Fe_2O_3.FeO$.

"The results obtained are given in the following table ①.

Recalculated Compositions of Quebec Chromites

Specimen No.	2	462	432	501	1	518	494	487
$Al_2O_3.MgO$.	22.81	27.44	26.87	27.62	22.00	42.30	23.80	37.57
$Cr_2O_3.MgO$.	54.00	32.05	34.55	23.15	50.33	15.20	42.03	17.83
$Cr_2O_3.FeO$..	14.88	39.73	33.40	48.63	18.30	39.02	29.37	38.52
$Fe_2O_3.FeO$..	8.31	0.78	5.18	0.60	9.37	3.48	4.80	6.08
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

"All these chromites are characterized by their high proportions of magnesia spinel and by their relatively low content of $Fe_2O_3.FeO$.

"The country rocks of Nos. 2, 462, 501, and 494 are true dunites, whereas those of Nos. 432 and 1 are dunites with a little orthorhombic pyroxene (enstatite), that is, the country rocks in all these cases did not contain aluminium-bearing minerals. Moreover, the olivine of all these rocks is relatively low in iron. Because of the essential similarity existing between the country rocks, one would expect that

① The writer (B. T. D.) was unable to reach these same results, and it is to be presumed that some assumption not specifically indicated was made in order to reach these figures. In the same report analyses of Russian chromites are recalculated in the same manner and although the analyses do not give values for Fe_2O_3, the recalculated molecular ratios give large percentages of magnetite.

the associated chromites would be nearly the same in composition, yet no two are alike, although their Cr_2O_3 contents, and in a lesser degree their Al_2O_3 contents, are about the same. As shown in the above analyses, the value Cr_2O_3 of pure chromite from dunite is always above 50 per cent.

"The country rock of No. 487 is a lherzolite—a rock containing appreciable quantities of aluminium-bearing diallage pyroxene, and in this case the associated chromite is relatively high in Al_2O_3, the Al_2O_3.MgO salt forming, as seen by the table, at least 10 per cent more of the chromite than in the case of any chromite directly associated with dunite. Moreover, the Cr_2O_3 content is several per cent below 50 and the Cr_2O_3.MgO content is comparatively low.

"Chromite No. 518 came from a lherzolite carrying about 10 per cent diallage, that is, from a rock much richer in Al_2O_3 than the dunites and, accordingly, the Al_2O_3.MgO content of the chromite is high, higher even than in chromite No 487, although the chromium spinels in the two are about the same in amount

"Thus the analyses seem to indicate a direct relationship between the composition of the chromites and that of their enclosing rocks. The chromites from the dunites are comparatively high in Cr_2O_3 and comparatively low in Al_2O_3, whereas the chromites from the lherzolites (rocks richer in Al_2O_3) are comparatively low in Cr_2O_3 and high in Al_2O_3. On the other hand, the chromites from the dunites, from rocks presumably very nearly alike in composition, exhibit a considerable variation in composition".

Discussion of New Analyses:

Before the publication of Poitevin's mineralogical study of Quebec chromites, the writer had decided to choose for analysis a number of representative samples of chromite from widespread localities in the Province, and including ores occurring in different types of serpentinized rocks. It was hoped that the comparison of the composition of these samples would reveal some relation between the composition of the chromite and that of the enclosing rock and thus contribute to the solution of the problem of the genesis of these deposits. On the receipt of Poitevin's report on his work, it was decided to continue the research along the same lines. Twelve samples were chosen; they came from the following localities:

Sample *A*.—Caribou pit, block *A*, Coleraine township.

Sample *B*.—Mutual Company's pits, lot 19, range X, Coleraine township.

Sample *C*.—Bennett-Martin Chrome pit, lot 28, range I, Ireland township.

Sample *D*.—Hall mine, lot 16, range *A*, Coleraine township.

Sample *E*.—Southeast slope of the hill to the northwest of Morin hill, lot 12, range *B*, Coleraine township.

Sample *F*.—Pits of the American Chrome Company, lot 10, range IV, Coleraine township.

Sample *G*.—Prospect on the southeast slope of Nadeau hill, lot 7, range IV, Coleraine township.

Sample *H*.—Gagné's prospect, lot 25, range III, Coleraine township.

Sample *I*.—Brousseau mine, lot 37, range V, Garthby township.

Sample *J*.—Montreal pit, lots 25 and 26, range II, Coleraine township.

Sample *K*.—Sterrett mine, lots 7 and 8, range X, Cleveland township.

Sample *L*.—Sterrett mine, lots 7 and 8, range X, Cleveland township.

Sample A

Caribou pit, Block A, Coleraine

The Caribou mine lies towards the southeast boundary of the large dunite-peridotite mass which constitutes the greater portion of the northwest band of rocks of the Serpentine series in Coleraine township. The deposit is, however, about 2,000 feet (horizontally) from the margin of the mass.

The ore is massive. No thin section was made of the ore.

Sample B

Mutual Chemical Company's pits, lot 19, range X, Coleraine

The deposit lies near the southeast boundary of the large dunite-peridotite mass which constitutes the greater portion of the northwest band of rocks of the Serpentine series in Coleraine township. The enclosing rock is serpentinized dunite.

Both massive and disseminated ore occur in this deposit. A thin section in massive ore reveals coarse-grained chromite and a little interstitial serpentine; some of the irregular chromite grains are fractured and the fissures are filled with serpentine similar to that which occupies the spaces between the grains.

Sample C

Bennett-Martin Chrome pit, lot 28, range I, Ireland

The deposit lies near the southeast margin of the large dunite-peridotite mass which constitutes the greater portion of the northwest band of rocks of the Serpentine series in Coleraine township.

Massive or crude ore, disseminated chromite, and the 'grape ore' referred to on page 30 occur in this mine. The enclosing rock is serpentinized dunite.

Sample D

Hall mine, lot 16, range A, Coleraine

The deposit lies towards the southeast margin of the northwest band of rocks of the Serpentine series in Coleraine township.

The surrounding rocks are indicated on the map as pyroxenites. It may be seen, in a thin section of the ore, that the chromite occurs in euhedral to subhedral grains, showing well-developed chain structure, *i.e.*, contiguous grains exhibit a tendency to a lineal arrangement in a manner suggesting links of a chain. The gangue is a felt of fibrous serpentine. Fractures in the chromite grains are filled with serpentine.

Sample E

Lot 12, range B, Coleraine

This occurrence of chromite lies in a small outlying body of serpentinized dunite, between the northwest and the southeast bands of rocks of the Serpentine series in Coleraine township.

The chromite is massive and has rather a dull lustre; its mode of occurrence, in small irregular bodies, is essentially similar in appearance to the small segregations of ilmenite found in masses of anorthosite.

Sample F

American Chrome Company, lot 10, range IV, Coleraine

The deposit is situated on the north slope of Nadeau hill in the contact zone between serpentinized dunite and serpentinized pyroxenite, in the southeast band of rocks of the Serpentine series in Coleraine township.

The ore is of the disseminated type, the chromite occurring in rather coarse grains evenly distributed throughout the rock. It may be seen in a thin section of the ore that the chromite occurs in reddish-brown translucent grains with irregular to subhedral outlines. The gangue is a brown semi-transparent aggregate composed largely of serpentine. Fractures in the chromite and in the adjacent grains are filled by a colourless transparent mineral which could not be determined.

Sample G

Nadeau Hill, lot 7, range IV, Coleraine

The deposit lies on the southeast slope of Nadeau hill in the southeast band of rocks of the Serpentine series in Coleraine township. Although the rocks are indicated on the map as serpentinized dunite, the outcrops in the immediate vicinity show especially well the variations in composition and in texture of the intrusive rocks, and the complexity of the mutual relations of the different phases of the intrusion to one another.

The ore is of the banded type and is exposed over a width of about 24 inches in which chromite constitutes about 30 per cent of the rock. The length of the exposure is six feet.

The chromite is magnetic to a degree suggestive of magnetite. A thin section of the ore reveals that the chromite occurs in small irregular subhedral grains which are brown and translucent. These grains exhibit a poorly developed chain structure. The gangue is serpentine.

Sample H

Gagné's prospect, lot 25, range III, Coleraine

The deposit lies practically in the middle of the southeast band of rocks of the Serpentine series in Coleraine township. The surrounding rocks are pyroxenite and serpentinized pyroxenite, but the

deposit is near the northern margin of these rocks, a short distance from the dunite-peridotite portion of the band.

The ore is of the disseminated type, and it may be seen in a thin section of the ore that chromite occurs in irregularly rounded anhedral grains. The gangue is serpentine derived from pyroxenite, and contains a few partially serpentinized remnants of enstatite. Fractures in the chromite grains are filled with serpentine.

Sample I

Brousseau mine, lot 37, range V, Garthby

The deposit lies in an outlier of the southeast band of rocks of the Serpentine series in Coleraine township. This outlier is mainly serpentinized pyroxenite with irregular patches of serpentinized dunite and peridotite.

The ore is of a disseminated type and is remarkable especially for the brecciated structure or certain portions in which angular fragments rich in chromite are included in the serpentinized rock. The examination of a thin section made in such a portion reveals that the chromite occurs in irregularly rounded grains and that interstitial material between the grains cannot be distinguished from the material which constitutes the mass of the rock. The rock was of the pyroxenite type and is now altered to an aggregate of serpentine and other secondary minerals of the carbonate and epidote groups.

Sample J

Montreal pit, lots 25 and 26, range II, Coleraine

The deposit lies near the southeast margin of the southeast band of rocks of the Serpentine series in Coleraine township. The surrounding rock is serpentinized pyroxenite.

The ore is typical disseminated chrome iron ore and the examination of a thin section reveals grains of chromite with irregular rounded anhedral contours. Fractures in the chromite grains are filled with serpentine. The gangue is also serpentine.

Sample K

Sterrett mine, lots 7 and 8, range X, Cleveland

The deposit lies within a long narrow body of serpentine rocks which crosses Cleveland and Shipton townships. The direction of the ore-bodies parallels that of the enclosing rock mass.

The ore includes both massive and disseminated varieties. A thin section was made in a specimen of ore of intermediate quality, that is, one in which the chromite is predominant but the proportion of serpentine is such that the ore would require concentration. Examination of the section reveals large irregular grains of chromite with rounded contours. The chromite is brown, translucent, and is traversed by fractures which show a distinct tendency to parallel orientation within the individual grains. These fractures and the interstices between the grains are filled with talc and with serpentine of at least two ages.

Sample L

Sterrett mine, lots 7 and 8, range X, Cleveland

This deposit lies within the same serpentine body as the last. The sample was taken in pit No. XI (see Figure 13, page 97). It may be seen from the sketch map referred to that the deposit does not lie within the extension of the main ore-zone.

In each of these samples the ore was crushed in a laboratory jaw-crusher and pulverised in a disc pulveriser. A preliminary concentration was effected by panning, and finally a few grams of the concentrates were carefully purified by means of heavy solution. Methylene iodide, sp. gr. 3.3, was used for this purpose. The chromite thus obtained contained less than one per cent of silica. The analyses were carried out by Mr. Maurice Archambault in the laboratories of the Ecole Polytechnique, Montreal, who determined in each case the following constituents: SiO_2, Al_2O_3, Cr_2O_3, MgO, CaO, Fe_2O_3, and FeO.

The results of these analyses are given in the following table:

Analyses of Quebec Chromite

Sample	A	B	C	D	E	F	G	H	I	J	K	L
SiO_2	0.61	0.35	0.40	0.45	0.62	0.52	0.41	0.52	0.77	0.77	0.55	0.55
TiO_2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	tr.	n.d.	n.d.	n.d.	n.d.	n.d.
Al_2O_3	13.70	10.69	12.60	9.85	14.80	15.22	9.07	13.53	10.80	13.68	14.74	13.14
Cr_2O_3	54.62	56.33	55.61	54.90	51.09	54.03	51.30	50.62	57.81	49.11	50.90	50.68
MgO	15.71	10.01	9.97	8.00	7.09	11.41	12.42	11.68	8.93	10.95	12.79	13.49
CaO	0.44	0.24	0.35	0.37	0.59	0.93	0.19	0.37	0.69	0.98	0.62	0.39
Fe_2O_3	5.79	3.60	6 92	5.45	2.35	3.12	11.50	7.80	4.55	6.11	6.15	4.31
FeO	9.93	19.10	13.91	20.44	23.29	14.31	14.70	14.18	21.91	17.70	13.50	16.80
Total	100.80	100.37	99.76	99.46	99.83	99.54	99.59	98.70	99.56	99.30	99.25	99.36

The percentage 'molecular composition' of the chromite in each of these samples, and also in Poitevin's samples (see analyses, p. 40), was calculated in the following manner:

The analyses were recalculated to total 100, and the resulting corrected percentages of the several constituents were then divided by their respective molecular weights, giving the 'molecular proportions'. The SiO_2 shown in the analyses was assumed to be present in the chromite as admixed olivine of composition $2MgO.SiO_2$. After deducting the requisite number of molecules of MgO to combine with this SiO_2, the molecular proportions were recalculated to total 100, giving the percentage 'molecular composition' of the chromite and also the $R''O: R'''_2O_3$ ratio. The results are given in the table on the page opposite, and are graphically represented in Figure 3.

The figures obtained from these analyses do not lend themselves to conclusive generalization. It may be noted, for instance, that while the chromite from samples *A* and No. 1, both from the Caribou pit, are essentially similar, two specimens (*C* and No. 2) from the Bennett-Martin chrome pit show marked difference in composition, notably in the proportions of MgO and FeO. It may be further remarked that the ratio of the total protoxides divided by the total sesquioxides shows variations ranging from 0.82 to 1.15, and that, moreover, these variations exhibit no tendency to uniformity, *i.e.*, that the ratios obtained are neither consistently above nor consistently below the theoretical value of 1.00. This feature would indicate that the chromite in the samples analysed was not a homogeneous mineral or that the difficulties encountered in the chemical analysis of chromite have not been completely overcome. This must remain a problem for future study.

Molecular Composition of Quebec Chromites

Sample No. *	A	B	C	D	E	F	G	H	I	J	K	L	2	462	432	501	1	518	494	487
Al_2O_3	12.84	10.44	12.79	10.00	14.74	14.84	8.88	13.38	10.90	13.35	14.22	12.30	11.32	13.69	13.45	13.94	14.01	22.09	11.96	18.73
Cr_2O_3	34.16	36.72	37.68	37.23	33.95	35.17	33.54	33.43	35.56	31.87	32.78	31.69	35.19	35.94	34.09	36.26	31.25	28.08	35.96	27.83
MgO	35.60	23.74	24.42	19.16	15.90	26.64	29.66	27.73	18.04	24.70	29.68	30.49	37.85	28.20	29.13	23 84	39.78	25.85	31.37	26.26
CaO	0.76	0.43	0.64	0.68	1.07	1.64	0.34	0.66	1.26	1.73	1.08	0.66	—	1.21	0.87	1.07	—	0.68	0.70	1.19
Fe_2O_3	3 46	2.24	4.48	3.53	1.49	1.94	7.18	4.92	2.93	3.80	3.79	2.57	4.11	0.27	2.51	0.37	3.75	0.67	2.23	2.99
FeO	13.18	26.43	19.99	29.40	32.85	19.77	20.40	19.88	31.31	24.45	18.45	22.29	11.46	20.26	19.42	24.06	11.05	22.10	17.36	22.13
MnO	n.d	n.d.	n.d.	n.d	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	0.17	0 27	0.28	–	0.27	0.22	0 24
NiO	n.d.	n.d	n.d.	n.d	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.80	0.26	0.26	0.18	0.16	0.26	0.20	0.63
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Molecular percentage of Mg_2SiO_4 in original sample	2.85	1.72	2.02	2.26	3.04	2.51	2.00	2.52	3.79	3.66	2.61	2.54	—	2.51	2.51	2.94	0.74	1.57	2.43	1.98
$R''O:R'''_2O_3$	0.98	1.02	0 82	0.97	0.99	0.92	1.02	0.93	1.02	1.03	0.97	1.15	0.97	1.00	1.00	0.98	1.04	0.97	0.99	1.02

* See lists, pages 36 and 43 of this report.

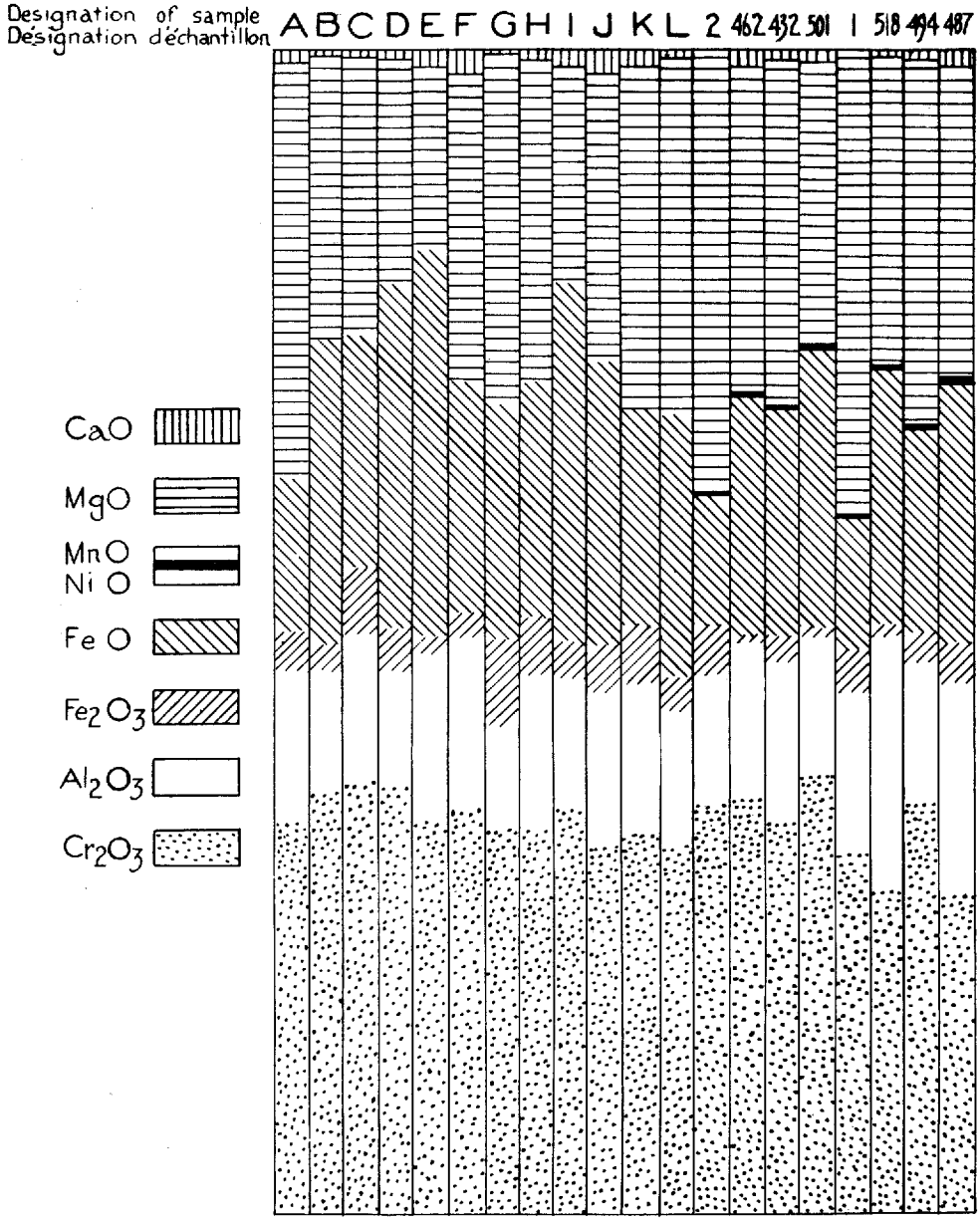


FIGURE 3.—Graphical representation of the molecular composition of chromites from the Province of Quebec.

Summary

Any attempt to explain the genesis of the chromite ore-bodies in the Province of Quebec must take into account:

1.—The widespread occurrence of the mineral throughout the rocks of the Serpentine series.

2.—The fact that it is only within the basic phases of the intrusions that the concentration of the chromite has been sufficient to result in the formation of economic ore-bodies.

3.—The irregularity of the mode of occurrence of the mineral, notably:

(*a*) The 'grape ores', *i.e.*, rounded nodules of practically pure chromite surrounded by relatively barren serpentine; this mode of occurrence suggests the migration of chromite particles through a fluid magma to centres of accumulation.

(*b*) The disseminated ores, which occur both as irregular patches, and as alternate bands of serpentine and of chromite and serpentine; the latter feature suggests concentration by a complex process of crystal-settling within a fluid mass.

(*c*) The brecciated ores, *i.e.*, angular fragments of chromite, or of chromite mixed with serpentine, enclosed in serpentine or in 'granites'; the occurrence of chromite under these conditions, together with the evidence pointing to a primary flow structure in disseminated ores (page 30) suggests movements and slight readjustments within the mass as a whole immediately prior to and during the period of final consolidation of the magma.

4.—The evidence pointing to solution and redistribution of the chromite, and of the chromium in minerals which accompany the chromite. (References to chromium-bearing pennite and vesuvianite are quoted on pages 40 and 80 of this report, while the possibility of solution and redistribution of chromite is mentioned on pages 80 and 91.)

5.—The relation between the composition of the chromite and the composition of the enclosing rocks; the analyses that have been made of the chromite indicate that the evidence so far obtained is not conclusive.

The writer considers that evidence favours the theory that the chromite, a primary constituent of the magma, has been concentrated by segregation following the intrusion of the rocks of the Serpentine belt; that the chromite crystallized, and that, where local conditions within the intrusion were favourable, the chromite accumulated by a complex process of crystal-settling to produce the banded disseminated ores; that, more rarely, during the period of crystallization, the chromite particles were attracted to centres of crystallization, thereby forming the 'grape ores'. During the period of final consolidation of the intrusive mass and the partial serpentinization of the more basic phases, mechanical readjustments were effected, notably by fracturing of the solid portions, and it is possible that some of the chromite was redistributed by solution and redeposition, but the writer believes that any such redistribution by solutions was of no importance in the formation of the ore-bodies.

Special efforts were made by the writer in the attempt to recognize some system of ore-control which would be of value both in the development and exploitation of the deposits, and in prospecting for new ore-bodies. The results achieved in this direction are negative and therefore disappointing.

The granite or aplitic dykes to be seen in many of the chromite pits are later than the ore. Similar dykes are extensively developed in the asbestos workings where chromite does not occur. It is therefore concluded that the chromite is not in any way dependent upon them.

Attempts to localize some ore-bearing 'horizon' of rocks within the intrusions as a whole have met with no success. So little is known of the detailed petrography or geological structure of the intrusions that it is useless to theorize or speculate on the existence of untraceable horizons, ore-bearing or otherwise.

All the economic deposits so far discovered are located within areas of basic rocks—dunites, peridotites, and pyroxenites; the gabbros,

diabases, and 'greenstones' do not contain more than occasional traces of chromium. Large deposits have, however, been found in each of the three types of basic rock mentioned. Dresser ① has suggested that rocks intermediate in composition between peridotite and pyroxenite are the most favourable. It is the writer's opinion that the dunites and peridotites more frequently contain the ore-bodies, but the difficulty encountered in the identification of the altered, serpentinized rocks, both macroscopically and microscopically, is probably sufficient to explain the difference of opinion.

As already stated, Poitevin's mineralogical investigation of the Quebec chromites led him to the conclusion that "the chromites from the dunites are comparatively high in Cr_2O_3 and comparatively low in Al_2O_3, whereas the chromites from the lherzolites... are comparatively low in Cr_2O_3 and high in Al_2O_3".

The distribution of the ore-bodies within the intrusive masses is likewise far too erratic to permit generalized conclusions. The contacts between the intrusions and the sediments, where the former are represented by the basic phases, do not appear to be more favoured than the central portions of the masses, so that it seems that the discovery of new bodies must be purely fortuitous, and equally possible at any point within the ultra-basic phases of the rocks of the Serpentine belt.

Although the bodies themselves are most irregular in form, their tendency to conform to foliation or banding within the intrusive masses, or to the contacts of the enclosing rocks, which in turn usually follow the direction of general Appalachian folding, may prove of assistance in individual cases.

Systematic diamond drilling in the vicinity of ore-bodies, in order to find extensions or new bodies, has usually yielded rather unsatisfactory results in the pockety deposits. The banded deposits, where a lineal arrangement of the chromite is characteristic, are amenable to this system of exploration.

The irregularity of the pockety type of deposits renders estimation of tonnage and value of reserves extremely hazardous. One

① *Op. cit.*, p. 88.

effect of this feature is the encouragement which it offers to perseverance in exploration of the small outcrops of ore, for the possibility, though not the probability, that a large body may be concealed is undeniable. The fact should, however, also be borne in mind that lateral extensions, susceptible of exploration by trenching and stripping, are equally possible and usually less costly to verify.

Electrical prospecting methods have been applied in the search for new ore, but, as far as can be gathered, this work has been rather in the nature of preliminary research on the problem, and hardly sufficient to establish the economic applicability of the method.

List of Chromite Occurrences in the Province of Quebec

Township	Range	Lot	Name of Pit	Owner	Page
COLERAINE.....	Blocks	A & B	More than 40 pits, including Caribou, Greenshields, and Standard.....	Asbestos Corp. Ltd.....	56
"	A	15	.....	.....	
"	A	16	Hall mine.....	Dom. Mines & Quarries, Ltd.	67
"	A	17 N.E.	.....	E. T. Gray.....	70
"	A	17 S.E.	.....	L. A. Carrier.....	
"	A	18 N.E.	.....	J. Lessard et al.....	
"	A	18 S.E.	Stewart mine.....	Prof. A. Boyer et al.....	71
"	B	8	.....	.....	
"	B	6 & 7	American Chrome Co. pit.....	Beebe Realty Corp.....	71
"	B	12	.....	.....	
"	B	13	.....	Beebe Realty Corp.....	
"	B	23	Noel mine.....	Marie Louise Noel.....	74
"	B	26	Ross lot.....	Asbestos Corp. Ltd.....	75
"	B	27 & 28	No 6 pit.....	Black Lake Asbestos & Chrome Co.....	76
"	C	32	.....	.....	
"	I	22	.....	.....	
"	II	22	.....	.....	
"	II	25	.....	Dom. Mines & Quarries, Ltd.	
"	II	25 & 26	Montreal pit.....	Dom. Mines & Quarries, Ltd.	76
"	II	27	.....	.....	
"	III	25	Gagné prospect.....	Napoléon Gagné.....	82
"	III	26	.....	.....	
"	IV	4	.....	David Oppenheim.....	
"	IV	5	.....	Israel Frechette.....	
"	IV	7 to 10	.....	Beebe Realty Corp.....	83
"	IV	25	.....	Mutual Chemical Co.....	
"	X	1	.....	.....	
"	X	2	.....	.....	
"	X	3	.....	.....	
"	X	4	.....	.....	
"	X	5	.....	.....	
"	X	6	.....	.....	
"	X	19 N.W.	Reed-Bélanger deposit.	Mutual Chemical Co.....	83
"	X	19 S.E.	.....	Robutel Théberge.....	83
"	XIII	2	.....	Dom. Mines & Quarries, Ltd.	
"	XIII	4	.....	.....	
"	XIII	5	.....	Rosalie J. Thompson.....	
"	XIII	6	.....	.....	
"	XIII	7	.....	.....	

Township	Range	Lot	Name of Pit	Owner	Page
COLERAINE	XIII	8	Huard mine	L. H. Huard	87
"	XIII	9			
WOLFESTOWN	II	24			
"	II	28			
"	III	23		Can Reduction & Mng Co., Ltd	89
"	III	24		Asbestos Corp. Ltd	
"	III	25			
"	III	34			
"	IV	26			
GARTHBY	I	A		C. L. Campbell	90
"	I	B		C. L. Campbell	90
"	I	C		Prof. A. Boyer	90
"	I	1			
"	II	4			
"	II	5 to 8		Prof. A. Boyer	90
"	V	36			
"	V	37	Brousseau mine	Napoléon Brousseau	92
SOUTH HAM	I	41 N.E.		Reed Estate	93
"	I	48		Reed Estate	
"	I	54		Reed Estate	
"	II	8			
"	II	40			
"	II	42			
"	II	54			
THETFORD	III	8			
"	IV	16	Pennington mine	Banque Can. Nationale	94
"	IV	17			
"	IV	18			
"	V	17			
LEEDS	X	1		Reed Estate	95
"	X	10			
CLEVELAND	X	7 & 8	Sterrett mine	Que. Asbestos & Chrome Co.	95
"	X	9			
IRELAND	I	28		Asbestos Corp. Ltd.	98
"	II	24			
"	II	25			
"	II	26			
"	II	27			
"	II	28			
"	III	26			
MELBOURNE	VI	22			
BOLTON	IV	13			100
"	VI	26			
"	VI	27			
"	VII	9			99
"	VII	13			
"	VII	23			100
"	VII	26½			
BROMPTON	IX	25	McCaw mine	Fletcher Pulp & Lbr. Co. Ltd	100
"	IX	26		Fletcher Pulp & Lbr. Co. Ltd.	
ORFORD	XII	4		Fletcher Pulp & Lbr. Co. Ltd.	100
AWANTJISH	IV	11		Napoléon and Pantaléon Plante	101

DESCRIPTION OF OCCURRENCES

COLERAINE TOWNSHIP

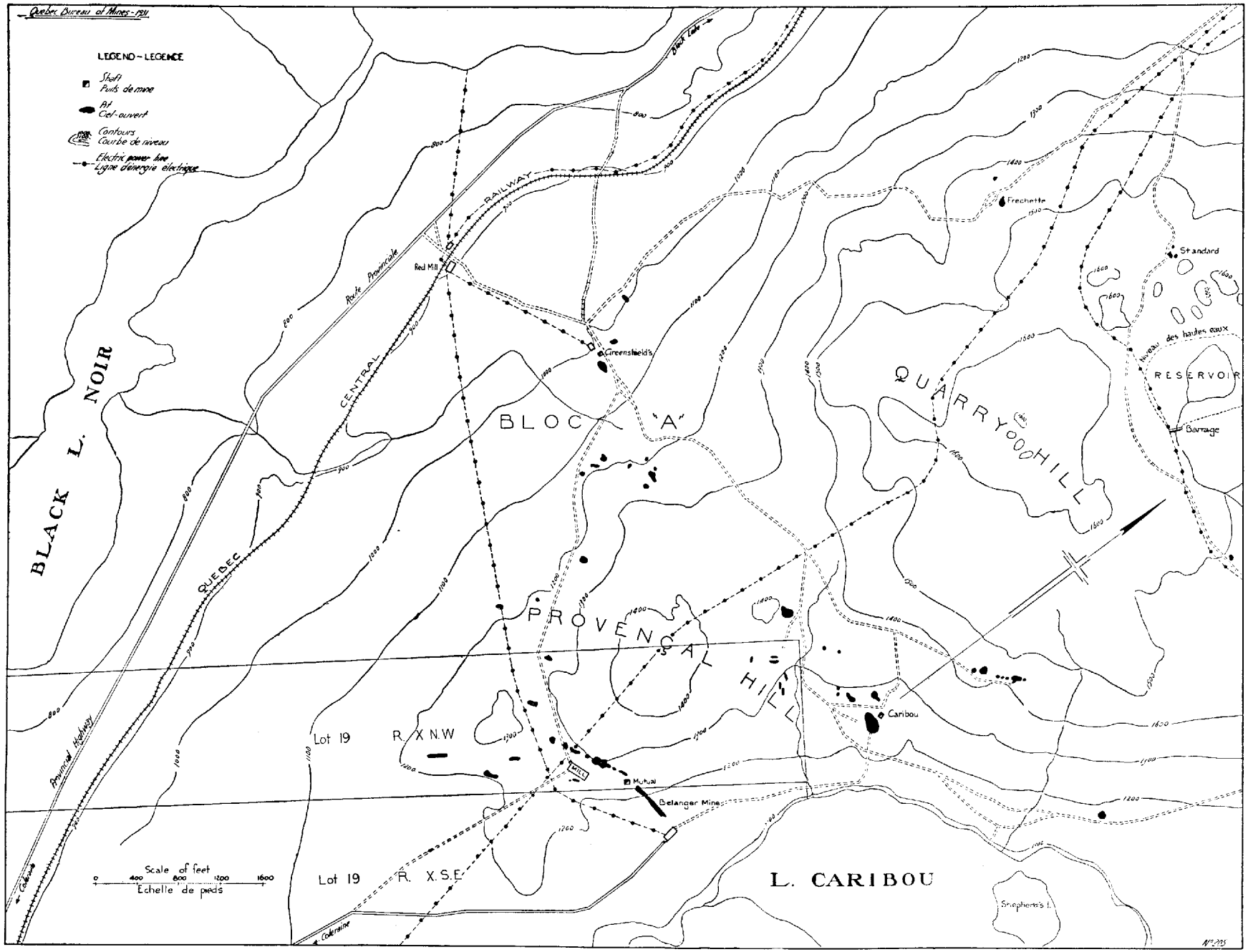
Blocks *A* and *B* (Asbestos Corporation, Limited)

Blocks *A* and *B* of Coleraine township comprise 6,006 acres of land to the south of Black Lake village. The northwest boundary is slightly more than four miles in length. Running at right angles to this, the southwest boundary of the lot is a little more than two miles long. From the southern corner of the area, the southeast boundary parallels the northwest boundary for roughly two miles, when it turns at right angles to the northwest for a distance of slightly more than a mile, and then again runs northeast to Caribou lake. This area includes Provençal hill where chromite was originally discovered in the region, and the fact that within its boundaries there are some 60 chromite pits, including some of the largest in the Province, testifies to its importance in the history of Quebec's chromite industry. The whole area is now the property of the Asbestos Corporation, Limited.

Data on the history and production of individual pits are very difficult to obtain, owing to previous diversity of ownership of different portions of the area, and also because much of the work was by lease or on contract.

Geological maps show the whole of this area as underlain by serpentinized dunite and peridotite, Actually, however, serpentinization is not complete, and in detail it may be seen that petrographic uniformity in the area is lacking; while peridotites are the rocks most frequently encountered, outcrops of pyroxenite are met with, and the distribution of the various rock types seems to follow no definite pattern.

Access to the numerous pits is possible along old trails or waggon roads, which are in varying states of disrepair. None of the roads are suitable for motor traffic in their present state, and many of the trails can only be traced with difficulty. Some of the smaller prospects have lain idle for almost thirty years. Descriptions of the principal workings in this area follow.



Sketch-map of chromite occurrences in eastern part of Block A, Coleraine township.

GREENSHIELDS PIT--BLOCK *A*:

This pit is on the west slope of Provençal hill, about 1,500 feet east of the Quebec Central railway and two miles south of Black Lake station. An old waggon road which branches from the main highway on the edge of Black lake, and crosses the railway tracks, affords easy access to the property. This was formerly the No. 1 pit of Black Lake Asbestos and Chrome Company. The deposit was discovered in 1898 and at the end of the period of activity in 1909 it had established the enviable record of having produced more chromite than all the other mines in the Province of Quebec together. This output, totalling some 30,000 tons, apparently all came from one continuous ore-body, a chimney-like deposit, 60 feet in length, 5 to 50 feet in width, and having a depth of 340 feet. The average dip was 60° to the east. In 1906 the pit was described as having a length of 120 feet and a width of 50 feet ①: "At a depth of 80 feet, the ore-body takes a sudden pitch, and, in following the same towards depth, it was found that the deposits, both in length as in width, increased considerably, the width in some places between enclosing walls being 45 or 50 feet. Two skip-ways with self-dumping skips, operated by a hoisting engine on the surface, and following the general dip of about 60°, serve as a means of getting out the ore. In this way the deposit was developed and worked to a depth of 340 feet; however, the dangerous condition of the overhanging roof in the shaft rendered working in the latter very dangerous, and it was decided to stop operations therein altogether, pending the sinking of a new shaft. This new shaft was started at a point close to the old pit, about 50 feet distant. Its inclination is 60 degrees and its dimensions 6 by 10 feet inside timbers. At present, it has attained a depth of 300 feet, and sinking is to be continued to below the 340-foot level. At the 250-foot level a cross-cut will be driven to a body of ore, which had been left as a safety pillar in the early workings; while at the 340-foot level the lower part of the same ore-body will be reached by a second cross-cut".

Although these workings were pumped out in 1916, it is reported that no new ore was found. The surface area of the pit, which is now filled with water, is about 200 feet by 150 feet. The mill has been demolished, and the shaft is boarded over. To the west of the pit

① Cirkel, F., *Op. cit.*, p. 56.

there are large dumps on which a little disseminated ore is seen. The rock is brown-weathering serpentinized dunite or peridotite.

An analysis of chromite from this pit is given on page 40 (Analysis No. 494).

CROTEAU PIT—BLOCK *A*:

About 75 feet to the south of the end of the Greenshields, or No. 1, pit, a smaller but similar ore-body was discovered during the war period and the deposit was followed downward for a depth of 180 feet. The ore is reported to have been of relatively low grade. A large proportion of it was sold to the Mutual Chemical Company, who were at that time operating the Black Lake Asbestos and Chrome Company mill. The total production from this pit could not be ascertained.

LAMBLY AND NADEAU PITS—BLOCK *A*:

From 800 to 1,200 feet to the east of the Greenshields pit, there is a group of eight pits and prospects. This is the site of the first discovery of chromite in the region, and also of the first mining operation.

The most easterly of these pits are known as the *Lambly pits*. They were exploited from 1894 to 1897, and a little additional ore was taken out in 1914-15. The largest of the Lambly pits has a total length of about 250 feet, and is divided into three sections by granite or aplitic dykes. Its general direction is N.78°W. From west to east, the sections have dimensions as follows: 50 feet diameter by 30 feet deep; 150 feet by 70 feet, and 50 to 60 feet deep; and 35 to 40 feet diameter by 20 feet deep.

The rock is dunite and sheared serpentine, the shearing and shattering being especially manifest in the serpentine in the south wall. The aplite between the western and central sections runs east-west, that is, parallel to the direction of the pit; it ranges up to two feet in width, and is discontinuous. The complete serpentinization of the enclosing rock at its contact with the dyke is in evidence. The dyke between the central and eastern sections is narrower, only a stringer in fact, which apparently pinches out at both ends.

A little low-grade ore is exposed in the massive serpentinized dunite in the north face of the largest (central) section of the pit,

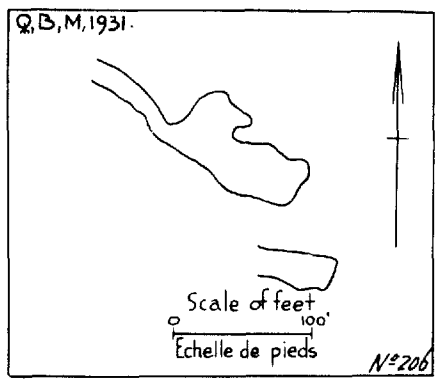


FIGURE 4.—Sketch-map of Nadeau pits, Block A, Coleraine.

and a small pocket, one foot by six inches, of high-grade ore was also noted here. In the south wall, only sheared serpentine and a little dunite were seen.

The other excavations in the vicinity are very small, and either represent pockets of worked-out ore, or exploration pits.

The *Nadeau pits* are 400 feet to the southwest of the Lambly pits and their history closely parallels that of the latter. The accompanying sketch-map, Figure 4, indicates the disposition of the workings. In the larger opening, a few streaks of disseminated ore and a little 'crude' can be seen. In the other, a small aplite stringer, at the east end. In both, the rock is massive brown-weathering dunite, partially serpentinized, which breaks into irregular angular blocks along small slip-planes.

It is estimated that the combined production from the Lambly and Nadeau pits has totalled some 2,300 tons.

At a distance of 1,200 feet slightly east of south from the Nadeau pits, and 100 feet to the west of the road, there is a small pit 30 feet long, 8 to 12 feet wide, and 10 to 12 feet deep. The rock here is similar to that in the Nadeau pits. Exposed in the face of the pit are two parallel bands of disseminated chromite ore, four feet apart and four to six inches in width. They strike N.72°W. with dip 45°S.W., and are abruptly cut off by a small slip-plane along which picrolite is developed. The production from this pit could not have amounted to more than a few tons. This small working is 400 feet

to the northwest of the boundary between Block *A* and lot 19 N.W., range X, which latter is owned by the Mutual Chemical Company and is described on a later page.

About midway between the Lambly pits and the Caribou pit (which is 3,200 feet to the east of them) there is a cut in the hillside to the southwest of the road. This working is very irregular in outline; the main axis has direction N.85°W. (mag.) and is 90 feet long by 20 to 30 feet wide, and 10 to 30 feet deep. A second opening, touching the last at its western end, has a direction of N.65°E., is 40 feet long by 30 feet wide, and 25 feet deep at its western end. The rock in both is typical brown-weathering serpentinized dunite, and shattered serpentine. No aplite dykes were seen. A little chromite, in coarse (one-eighth inch) grains, was seen in the larger of these pits. At 600 feet to the east (N.80°E.) of these workings, on top of a small knoll, there is a pit, 30 feet by 20 feet, now full of water. The rock and ore are quite similar in character to those in the pits just described. About 500 feet to the southeast of the latter, there is a group of six pits. These are in the north corner of the Mutual Chemical Company's property (lot 19 N.W., range X) and are described on a subsequent page. The pit on the top of the knoll is about 30 years old, and no records of production from it are known to exist. The one to the immediate southwest of the road yielded at least two cars of ore.

Caribou Pit and Nearby Workings—Block *A*:

The Caribou workings, a few hundred feet to the northwest of Caribou lake, are among the most important in the district. They may be reached either from Black Lake village or from the Red Mill siding on the Quebec Central railway. The better road, although not suitable for motor traffic, is that from Red Mill siding, a distance of 1½ miles. The road and trail from Black Lake is about 2½ miles.

Operations were commenced at this pit in 1895, and in his report on mining operations in the Province for the year 1904, Obalski notes that up to that time about 800 tons of ore had been produced. There was great activity in this and neighbouring pits until 1909 when, as already noted, the industry waned; but satisfactory estimates of the production are not obtainable. A small mill was erected near the pit, but it was subsequently dismantled. When the second, or war,

period of activity commenced, operations were resumed, and numerous lessees worked at various points in the excavation. Owing to this method of mining in this and in the other pits of this section, it is impossible to ascertain the production from individual workings on these several properties. The Caribou pit is now about 150 feet in diameter and from 60 to 70 feet deep.

In 1918, the Black Lake Asbestos & Chrome Co., then owner of the property, commenced the sinking of a shaft, at a point to the north of the pit. It reached a depth of 200 feet, and levels were driven at 115 feet and 188 feet. All the underground workings are now flooded. According to information supplied by the Asbestos Corporation, Limited, the present owners, about 600 feet of drifting and cross-cutting was done on the first level, the main drift running 150 feet to the west and 225 feet to the east of the shaft, with most of the cross-cutting to the south, or towards the pit. On the 2nd level, drifts were extended 400 feet east and 300 feet west from the shaft, and, in all, about 800 feet of exploratory drifting and cross-cutting was carried out, mostly to the north of the shaft. According to the mine-plans, the ore occurs in innumerable small pockets or lenses, usually having an east-west trend, but occasionally with most irregular outlines. These bodies appear to range in size from tiny pockets up to bodies 30 feet in length by 10 feet in width. Very little ore was disclosed on the second level beyond a point 255 feet to the east of the shaft. The workings would indicate that the ore-zone dips to the north, and from the plans it would seem that the proportion of ore to waste would be of the order of 1 to 10.

The ore was reported as being particularly massive, and indeed that left on the dump bears this out.

Fracturing of both ore and gangue is a well-marked feature, and a variety of ore locally termed 'fish-meat' ore is encountered, in which the lumps of chromite are so completely coated with fibrous serpentine that only their greater weight indicates their true nature.

The ore in the original Caribou pit was, according to reports, mostly obtained from two large granite dykes, 20 to 30 feet in width and 75 feet apart. Although the pit is dry, the caving of the walls, as well as the presence of material fallen in from the dumps, makes a detailed study of the geology impossible. On the mine plans, granite is indicated at numerous points in the underground workings, but it

is not possible to correlate the several exposures of this rock shown on these plans. Two analyses of chromite from the Caribou pit are given on page 40 (Analysis No. 1) and on page 47 (Analysis *A*).

To the west and northwest of the Caribou pit, there is a series of excavations in the hillside. At 200 feet to the northwest, there are two such excavations, almost touching one another, and, respectively, 35 feet and 30 feet long with 40-foot face. Both are in highly sheared serpentine, but in the north face of the 30-foot pit granite is exposed over a length of 30 feet with a thickness of 10 feet. Its attitude suggests that it is a sheet. Both excavations are badly caved.

About 275 feet west of the Caribou shaft there is a pit 35 feet in diameter and 20 feet deep, largely filled-in with blocks of sheared serpentine; and to the immediate west of this excavation a cut, some 60 feet long by 10 feet high, has been made parallel to the face of the hill. Granite is exposed in both these excavations, and though no chromite was observed in the walls, a little disseminated ore was seen on the dumps. Farther to the west, at 250 feet and 300 feet, respectively, there are two small test pits on the dumps from which there is a little chromite.

The abundance and extent of these workings testify eloquently to the activity which reigned in this vicinity during the two 'boom' periods. Ore pockets, apparently, were particularly numerous but small. The rock is locally so badly sheared that great care must be exercised in mining such a deposit. Working over the dump at the main Caribou pit would doubtless yield an appreciable quantity of high-grade ore, and, in fact, it is possible that the whole dump might prove to be ore of milling grade.

Opposite Shepherd's island, in Caribou lake, there is another large pit, 50 to 60 feet in diameter and forty feet deep, in intensely sheared serpentine. The pit is now largely filled-in by overburden and loose waste. The material on the dump is all very fine grained, but the ore seems to have been almost exclusively 'crude'.

VAILLANCOURT AND OTHER PITS—BLOCK *A*:

To the north of the Caribou shaft, at a distance of about 1,000 feet, there is a group of seven pits and prospects, aligned in a northeast-southwest direction, and extending over a length of from 500 to

550 feet. The largest of these pits is 70 feet in diameter and 80 feet deep. It is now partially filled-in by caving. In the south corner there is an opening which leads to some inaccessible underground workings. These workings were apparently reached by an adit which runs towards the pit from a point on the hillside about 40 feet from the south wall of the pit. The rock is sheared serpentine, and the ore was apparently high-grade, for all that could be found on the large dumps were a few small pieces of 'crude', about the size of a walnut.

To the northeast of this pit and about 500 feet distant, there is a second large pit, cut in the hillside. It is about 60 feet in length, and, like the last, is badly caved. Both crude and disseminated ore are found very sparingly on the dump.

At a short distance both to the east and to the west of these two pits there is a small excavation, and between them there are three other small openings. All these pits appear to be very old. The recorded production from them is about 12½ carloads, of which ten came from the large pit first described. The grade of the ore is reported as 38 per cent Cr_2O_3.

FRÉCHETTE PIT—BLOCK *A*:

About 4,500 feet to the north of the Greenshields, or No. 1, pit, and situated on the trail leading from Black Lake village to that pit, there is a large excavation on the west slope of the hill. This pit was worked prior to 1900 by M. L. Fréchette. It is reported to have yielded over 1,000 tons of high-grade ore, and Cirkel ① states that concentrates obtained from some of this ore yielded over 60 per cent oxide of chromium.

The pit now measures 60 feet by 70 feet and is 60 feet deep to water-level in the east face; the west face is 15 feet deep to water-level. The rock is very massive dunite, grading towards peridotite. The chromite occurs in small tabular masses of 'crude', showing, on the whole, quite clean-cut boundaries with the rock. Little disseminated ore was noted. No aplite dykes were seen in this pit.

STANDARD PITS—BLOCK *A*:

The pits known by this name are situated 1½ miles southeast of Black Lake station, on the trail leading to the reservoir which supplies

① *Op. cit.*, p. 59.

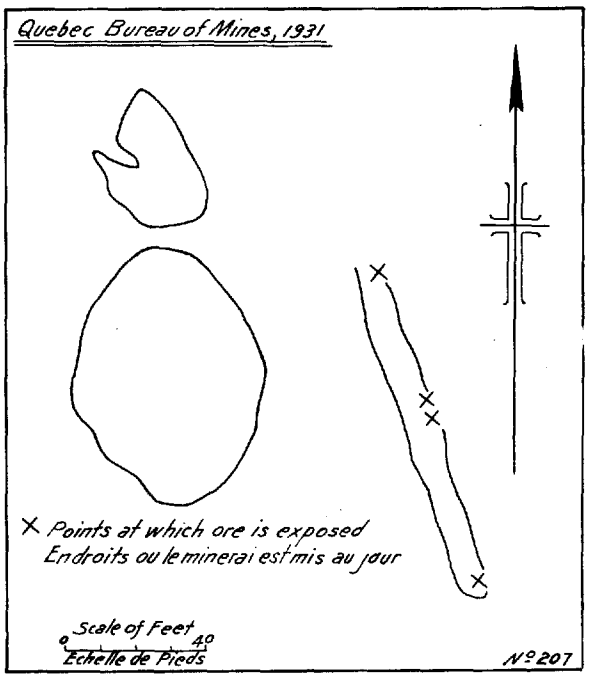


FIGURE 5.—Sketch map of Standard pits, Block A, Coleraine.

the village of Black Lake. They were opened in 1895, and it is reported that 2,000 to 3,000 tons of high-grade ore was extracted. The property was owned first by the Standard Asbestos Company, then by the Anglo-Canadian Asbestos Company, and, after a long series of transfers, it eventually became part of the holding of the Asbestos Corporation, Limited.

There is no recorded production from this property until 1915-16, when W. J. Woolsey mined 668 tons of ore. In 1918 there was a further production of 30 tons.

There are three pits on this property, disposed as shown in the accompanying sketch. The largest is 70 feet by 60 feet, and the smallest 40 feet by 30 feet; these are now both full of water. The third opening is a trench-like excavation, 100 feet long and 10 to 15 feet wide,

with a maximum depth of 15 feet. Some patches of disseminated ore are exposed in the southern end of this working. The rock in all three pits is massive partially serpentinized dunite.

On the dumps, a little 'crude' is visible, and some coarse-grained disseminated ore. Specimens of 'grape ore', already described, were found here.

An analysis of the chromite from this pit is given on page 40 (Analysis No. 501).

PITS TO EAST OF BLACK LAKE RESERVOIR—BLOCK *A*:

To the east (2,000 feet) of the reservoir, and 160 feet to the north of the power line, there is a pit of irregular shape, but trending N.50°W. for a length of 70 feet and having a maximum width of 40 feet. The ore is apparently of the disseminated-banded type, in brown-weathering dunite. Peridotite is also found on the dump, but in relatively small amount. No granite was seen. The pit is now completely filled with water.

To the northwest (N.58°W.) of this pit, and about 600 feet distant, there is a smaller north-south pit, 35 feet long and 2 to 6 feet wide, with its greatest width at the south end. The rock is dunite and the chromite is mostly coarsely crystalline; there is, however, a little finer disseminated ore of the usual type, and a very minor amount of 'crude'. The ore is banded. No granite was seen. No records of production from these two pits are available, but it appears to have been quite small.

QUARRY HILL PROSPECTS—BLOCK *A*:

On the top of Quarry hill, 200 feet to the northeast of the powerline, there are three test pits in which chromite is found in very coarse grains or aggregates, one-eighth to half an inch in diameter. The rock is peridotite cut by a few narrow stringers of pyroxenite. These pits are six to eight feet in diameter and two to four feet deep.

PITS TO WEST OF BLACK LAKE:

About 2,800 feet to the west of the southern half of Black lake, there is an old chrome working known as the Old Greenshields shaft.

It is most readily reached from the Old Megantic mine, 2½ miles west of Coleraine station, by a rather overgrown trail. The pit is 400 feet above the lake level, and is 60 feet long by 10 to 18 feet wide, with trend N.10°E. The rock in the pit is massive serpentinized brown-weathering dunite, but in the nearest surface outcrop, about 50 feet to the west of the pit, the rock is partially serpentinized pyroxenite. The pit is now filled with water, but the size of the dump indicates that it must be quite deep. There is little ore to be seen on the dump, but both disseminated ore and 'crude' were noted.

About 600 feet to the west of the Old Greenshields shaft, there is another working, about 25 feet in diameter, now full of water. Sixty feet to the east of this an adit, trending N.55°E. and 20 feet in length, ends in a small excavation from the middle of which a shaft or raise extends to the surface, 15 feet above. At the point where the shaft breaks into the underground chamber, there is a small pocket, 2½ feet by 6 inches, of massive 'crude' chromite. A little disseminated ore was also seen. To the west of the large pit there is a succession of shallow pits, all full of water. The total distance from the first to the last of these pits is 80 feet, in a direction N.25°E. The chromite seen on the dump is very coarsely crystalline disseminated ore, with also a few small lenses and pockets of crude. The rock appears to be dunite.

NADEAU CHROME PIT—BLOCK *A*:

About 4,800 feet to the north of the Old Megantic pit, near the end of the west branch of the inlet to Black lake, and to the south of that stream, there is a chromite pit on the north slope of Kerr hill, at an elevation of 1,300 feet. This, known as the Nadeau pit, is about 100 feet long, 10 to 20 feet wide, and 50 feet deep to water-level. The outline is irregular, but it would appear that the original ore-body dipped steeply to the east. The rock is brown-weathering massive serpentinized dunite. Ore is scarce on the dump.

An analysis of chromite from this pit is given on page 40 (Analysis 432).

At a point 500 feet to the north of this pit, on the north side of the brook, there are two old excavations, the larger of which is 25 feet in diameter. In its western end there is a zone four feet wide, with strike N.20°E. and dip 70° northwest, in which disseminated

chromite is rather irregularly distributed. The grain of the chromite is very fine, and in some of the specimens on the dump that were examined 50 per cent of the rock consists of grains of chromite up to one-sixteenth of an inch in diameter. The rock in this pit is serpentinized peridotite containing 15 to 20 per cent of pyroxene. The surrounding rock is pyroxenite.

All these pits were worked more than twenty-five years ago, and although production figures are unobtainable, the extent of the workings and the aspect of the dumps indicate that the output was small.

Woolsey Chrome Pit—Block *A*:

Near the boundary of Block *A*, 2,800 feet northwest of the Old Megantic pit, a small chromite mine was worked during the war-period by W. J. Woolsey. The pit is 55 feet long and the main face, 40 feet high, runs at N.20°E. The rock is a peridotite, and a little patch, four feet by two feet, of disseminated ore is visible in the face of the working.

Lot 16, Range *A*, Coleraine Township

Hall Mine:

The Hall mine is situated 4½ miles southwest of Thetford Mines and is reached by a road from that town. The last half-mile of this road is not in sufficiently good repair for motor traffic. The property is owned by the Dominion Mines and Quarries, Limited, who refer to it as the Thetford quarry.

Chromite was discovered on this property in 1899 by Jos. Nadeau and R. Topping, and before 1903 some 1,700 tons of ore were produced. At that date, the mine was taken over by the Canadian Chrome Company. The following description of the property is reproduced from Cirkel's report ①: "The principal pit measures on the surface 100 by 125 feet; its depth is 60 feet. The ore occurs here mostly in the disseminated or low-grade form, very little crude being produced. Several granitic intrusions, running mostly in a northwesterly direction, can be noticed. One of these is four feet wide, and close to it occur a number of rich streaks of ore, delivering a high percentage of

① *Op. cit.*, p. 60.

crude. The serpentine is generally of a soft quality, of dark green colour, with numerous cracks and slickensides. The latter are followed in several places by streaks of disseminated ore, which gives rise to the supposition that these fissures may have had some influence upon the formation of the ore. The slickensides of the serpentines are often coated with a fine film of very dark green rock, highly polished, probably composed of olivine.

"There are several other pits close to the one described, but most of them are filled with water, and no examination can be made. However, the writer was impressed with the great amount of dumps lying on the property close to the various pits, exhibiting, on closer inspection, quite a content of excellent milling ore. Judging from the appearance of these dumps, it seems quite evident that the area over which these pits are distributed is a valuable one. The very irregular distribution of the disseminated ore at this mine seems to point to the open-cast method as the only one whereby the ore can be cheaply mined, and the writer has no doubt that if these pits were systematically worked under capable management in one large open-cut (suspending operations for three or four months in the severe winter season), the result would be quite different from those obtained under the present working conditions.

"The ore is delivered by tramway to the mill and dumped into a chute, which leads into a jaw-crusher; from which it is elevated and placed in the bin. Twenty stamps, with four Wilfley tables, are in operation, an extra Wilfley taking charge of the middlings from all the other tables. The entire mill is run by electric power, supplied by the St. Francis Power Company, and delivered through a 100 h.p. three-phase induction motor. Water is furnished through a 3-inch pipe from a creek a quarter of a mile from the mill; for the dry summer season, enough water is stored by the dams to supply the mill for several months. The concentration in the mill is about six tons of ore to one ton of concentrates.

"The mine is equipped with a sleeping camp, kitchen, office, and accessory buildings for the accommodation of 25 men. At present, 20 men are employed in mine and mill".

At the beginning of the war, the mine was taken over by the present owners who immediately resumed operations and during the years 1916, 1917, and 1918, extracted nearly 1,000 tons of chromite ore.

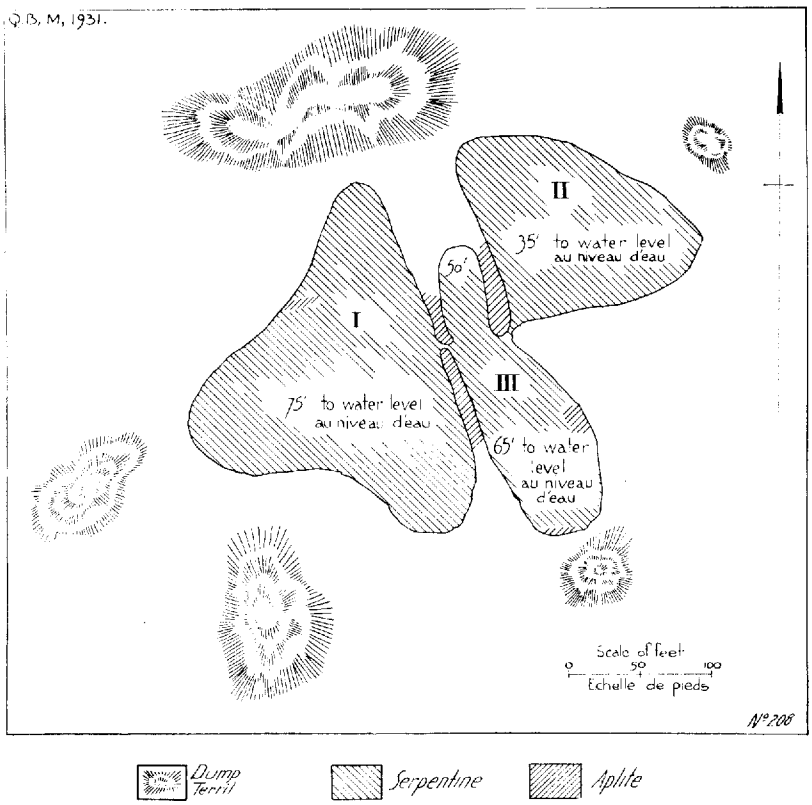


FIGURE 6.—Map showing chromite occurrence on lot 16, range A, Coleraine township.

The outline of the pits is shown in the accompanying sketch-map, Figure 6. The workings, as may be seen, comprise three contiguous excavations, the shape of which is largely controlled by granitic or other acidic dykes. The north part of pit III is quite accessible, although the floor and part of the walls are partially masked by caved material. The other pits are filled with water. Water-level in pit II is 30 feet above the water-level in pit III, which in turn is about 10 feet above the water-level in pit I. It is possible to cross from the north side of the pits to the south side along the granite dyke which forms the east wall of pit I, but in pit III the water reaches to the level to which the dyke has been cut down. The dyke between pit II and the north part of pit III is about six feet in width, but at a

height of 20 feet above the water-level, and 15 feet below the top of the pit, it abruptly terminates, without loss in width. Although, in the zone of serpentinization adjacent to the truncated dyke, the rock is badly shattered, the contact does not appear to be a fault. Close inspection was not possible, however. This dyke does not appear on the south side of the pits. The dyke between pit I and pit III extends across the excavations. It has a width of about five feet. In the south wall of pit III are two separate small lenses or sections of aplitic rock, not connected to one another, while in the east wall there is a narrow aplitic stringer which has an almost horizontal attitude. Unfortunately, owing to the inaccessibility of these exposures, it was not possible to study the relation of the aplite to the enclosing wall-rock.

The country rock is serpentinized dunite, but to the east of the pits are outcrops of peridotite and pyroxenite. The latter rocks appear to cut the former, but they may be bands due to segregation or differentiation.

The ore is rather evenly crystalline, and disseminated ore of this type is abundant on the dump. The relations of the ore to the serpentine present some unusual features, which have been described on an earlier page (page 31). The chromite is usually found in small nests or masses in the serpentine, but parallel bands of ore, separated by barren serpentine or by disseminated ore, may also be seen.

In the north part of pit III, which alone is accessible, a few small lenses and irregular masses of 'crude' were seen in place.

It is said that tongues of chromite penetrate the granite (or aplite) in this mine, but although the writer was informed of a precise locality where this phenomenon could be well observed, a careful examination of the occurrence showed that the evidence was far from conclusive. A very careful search of the dump failed to produce any specimens showing these relations.

The analysis of a sample of ore from this mine is given on page 47 (Analysis *D*). It contained 54.90 per cent Cr_2O_3.

Lot 17, Range *A*, Coleraine Township

Gray Prospect:

At the northeast end of lot 17, range *A*, Coleraine township, Mr. E. T. Gray has been carrying out exploratory work on a newly discovered occurrence of chromite. The site of present activities is

about 2½ miles to the southeast of Thetford Mines, and is readily accessible by a trail, about half a mile in length, which branches to the northeast from the road leading from Thetford Mines to the Hall mine.

The mining rights on the southwest portion of this lot were granted to Jos. Lemelin in 1901, but no extensive operations were carried on by him. During the past summer, a small showing of coarsely crystalline high-grade chromite occurring within a few feet of two of the older excavations on the boundary between lots 17 and 18, was investigated by Mr. Gray. The total exposure of ore measured about two feet by four feet at the time of the writer's visit, but by the end of the season a few tons of ore had been taken out.

Lot 18, Range *A*, Coleraine Township

Stewart Mine:

The mining rights on this property were granted to Robert Stewart in 1903. In 1919 they were acquired by the Victory Chrome Mines, partly owned by Prof. Aurélien Boyer, of Montreal.

On this lot, at a distance of about 500 feet northwest from the prospects on lot 17 last described, there is a pit 60 feet long by 10 to 15 feet wide, with trend N.60°E. The rock is massive, brown-weathering, serpentinized dunite. A little banded disseminated ore and a few lumps of crude can be seen on the dump. A small production was recorded from this pit in 1918.

Lots 6 and 7, Range *B*, Coleraine Township

American Chrome Company Pits:

These pits are situated about 7½ miles east of Chrome siding on the Quebec Central railway. They are most readily reached from the road leading from the siding to the Montreal pit of Dominion Mines and Quarries Limited, by following the road which branches from the Montreal Pit road a short distance beyond the point where the latter crosses a small stream (the second stream). Two roads branch off at this point, and it is the more northerly branch that leads to the American pits, which are two miles from the intersection. The property has been owned by various companies, in all of which Messrs. Beebe Bros., of Boston, Mass., have been the principal shareholders. The present owner is the Beebe Realty Corporation.

Operations were first carried out on this property in 1899-1900, by the American Chrome Company, who in 1901 erected a concentrating mill on lot 9, range XIII, Coleraine township, to treat the ores from this and other properties. This was the first successful mill erected in the Province for the concentration of chromite ores.

Cirkel visited the property in 1908 and reported that ①: "The principal work is carried-on on lots 6 and 7, range *B*. Most of the pits at the time of examination were filled with water and little could be seen on the surface exposures. It appears that the ore occurs mostly in dissemniated form, assuming, when exposed to atmospheric agencies, a decidedly brownish colour. There are all together about six pits, the largest of them, No. 1, measuring on the surface 30 by 80 feet; the depth is reported to be 65 feet. The milling rock from this pit gave as an average 25 per cent of concentrates. Pits 2 and 3 are separated by a granitic dyke, eight inches wide, and, on both sides of this dyke, rich streaks of disseminated ore can be seen. Pit No. 2 measures about 50 by 60 feet on the surface, while its depth is reported to be 30 feet. No. 4 is a long cut, 125 feet long by 40 feet wide, following the trend of a disseminated ore-body of considerable dimensions. Granitic dykes of small dimensions are frequent, but accumulations of ore near these dykes could not be observed. The serpentine is, as a general rule, interwoven with fine, minute fissures and cracks, and the fissure planes are covered frequently with a coating of dark green serpentine, showing disseminated ore. It breaks up easily, and very large pieces are seldom obtained. Frequently it takes a brownish tarnish, due to oxidation of the iron.

"At the time of the visit of the writer, operations were carried on in a small pit some distance from No. 4, where there appeared to be quite a body of disseminated ore, some of it accompanying cracks and fissures in the rock. The mill is about one mile distant from the mine, on lot 9, range XIII... The mill was built under the direction of Mr. Whitney, then manager of the Company—1901. It contained a Blake crusher, two pair of rolls, a battery of five stamps, and a Wilfley table with the usual accessories. The output was about 20 tons of concentrates per week, and in the first year of operation about 100 tons were obtained. Later on, a number of improvements were introduced and at present the mill contains ten stamps, and three Wilfley tables.

① *Op. cit.*, p. 61.

In 1905, about 500 tons of concentrates were obtained, which were all shipped to the Company's works at Boston. Water for the mill is pumped from a creek in the vicinity".

With the resumption of activity in the industry in 1915, the pits were reopened, and Mr. D. Wilson, operating under a lease, extracted about 500 tons of ore. In 1916, the Mutual Chemical Company took over the mines and installed a large modern concentrator ①: "The building is 62 feet by 100, and contains Blake crusher (10 in. by 20 in.); chain elevator; Hardinge mill (6 ft. by 22 in.) with chrome-steel balls; a standard duplex Dorr classifier; a Dorr thickener; Callow screen; and seven Wilfley tables. The concentrates are dried by steam heat. The electric motors, of 60 h.p. for the Hardinge mill, 30 h.p. for crusher and the elevator machinery, and 15 h.p. for the rest of the machinery, respectively, run the mill. The installation is intended to concentrate 80 tons a day of 12 to 15 per cent ore to 15 or 16 tons of 50 per cent ore...

"A trial run in December gave satisfactory results. The principal mine workings are on lot 6. All the mining is done in open pits. On lot 7, a great deal of trenching has uncovered a wide band of serpentine containing irregularly disseminated chromite. The Company has another mill at Black Lake, near the track of the Quebec Central railway. This is the old mill of the Black Lake Chrome and Asbestos Company, which has been repaired and is now used as a custom mill. The machinery consists of jaw crusher, six batteries of five stamps each, and seven Wilfley tables. The concentrates, which are 50 per cent Cr_2O_3 or more, are all shipped to the Mutual Chemical Company of America. The feed capacity of the mill is 70 tons of 15 per cent ore".

In 1917, active development and prospecting work was carried out ② but little production (251 tons) was made, and at the end of the year both mine and mill were idle.

In 1918, the mill was sold to the Quebec Asbestos and Chrome Company at St. Cyr and was transported to that site.

There are nine pits on the property (see sketch-map, Fig. 7). The first group of five pits are now filled with water, as also is pit IX.

① Que. Bur. Mines, Ann. Rept., 1916, p. 35.

② Davis, J. W., Can. Min. Jour., 1919, pp. 36-38; 1,426 feet of shot-drilling were carried out, but no new ore was found, and the erratic nature of the deposits was confirmed.

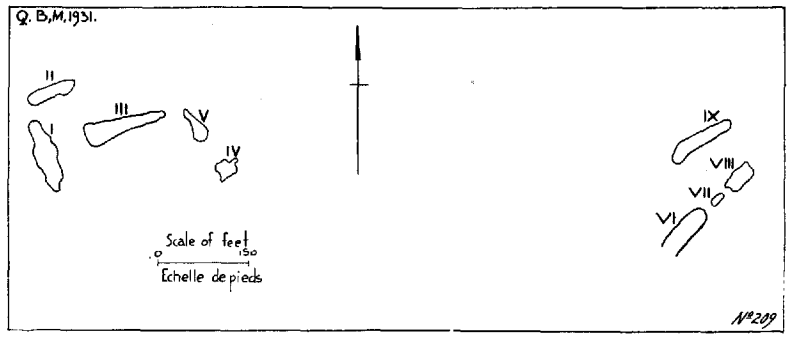


FIGURE 7.—Map showing chromite occurrences on lots 6 and 7, range B, Coleraine township.

The remaining three are not completely filled and are thus partially accessible. No chromite in place was observed in any of them, and the state of the workings makes any satisfactory examination quite impossible. The country rock is serpentine, which in pit IX is cut by an aplitic dyke. Disseminated ore is to be found on the dumps, but is not abundant. An analysis of the chromite from this property is given on page 40 (Analysis 487).

LOT 23, RANGE *B*, COLERAINE TOWNSHIP

NOEL MINE:

This property is situated on the southeast slope of Murphy hill, about half a mile north of Caribou lake. The trail leading to the mine has been practically obliterated, and the workings are not easy to find.

The property was worked intermittently before 1908, but no large shipments were made. The only officially recorded production was in 1918, when 129 tons of ore were shipped.

The workings consist in a pit, 100 feet long by 10 to 20 feet wide, whose general direction is N.55°W. The outline of the pit is, however, convex toward the southwest, and the dip of the face, which presumably indicates that of the original ore-body, is 70°N.E. The pit is now full of water and caving of the hanging-wall is imminent. The country rock is typical brown-weathering serpentinized dunite. The disseminated ore on the dump is rather coarsely crystalline (2.4 mm. grain).

Lot 26, Range *B*, Coleraine Township

Ross Lot:

This property, known as the Ross lot, is about 1½ miles east of Black Lake station, and is readily accessible by a good road which leads out of the village in that direction. The mine is on the south slope of Murphy hill, a few yards to the north of the road.

R. P. Hall did a limited amount of work on the property in 1898, but apparently did not ship any ore. Two years later, in 1900-1901, J. M. Johnston, working under contract, took out some 450 to 500 tons. From that date the mine was idle until the war period. Cirkel ① mentions that: "The main pit is 125 feet in length, 12 to 15 feet wide, and with a face 15 feet high, the direction of the pit being N.35°W. Little crude ore could be noticed, but the disseminated variety is abundant judging from the appearance of the walls and of the dump. Water for milling purposes can be obtained from lake Caribou, which is about one mile distant".

During the war, Mr. Johnston resumed operations on the property and produced about 4,500 tons of ore during 1915 and 1916. The pit is now 125 feet long by 35 feet wide, with depth ranging from 18 to 40 feet. In its centre is a two-compartment timbered shaft, with headframe, shaft house, and hoist house. The shaft is now full of water and inaccessible. It was said that operations were suspended because further production would have entailed considerable expense in development work.

Disseminated chromite was seen in place on the north wall of the pit, near the shaft house, the ore exposed covering about 10 feet by 6 feet. On the dump, similar ore is abundant, and a little crude can also be found. The rock is largely serpentinized brown-weathering peridotite, with the chromite occurring in the more basic, dunite type. No granitic or aplitic rock was seen. The ore is, on the whole, rather coarsely crystalline and streaky.

The present owners of the property are the Asbestos Corporation, Limited.

An analysis of the chromite from this property is given on page 40 (Analysis 518).

① *Op. cit.*, p. 62.

Lots 27 and 28, Range *B*, Coleraine Township

No. 6 Pit:

One mile east of Black Lake station, on lots 27 and 28, range *B*, there is a large asbestos pit, locally known as No. 6 pit, the property of the Black Lake Asbestos and Chrome Company.

During the war some comparatively large lenses of chromite were mined in this pit, and in 1916 a production of 14,500 tons is recorded, In the following year there was a much smaller output. Then, as no further ore was found, the pit became once more solely a producer of asbestos.

The rock is a partially serpentinized peridotite, and on the floor of the pit a small patch of chromite, measuring only a few square inches, may be seen.

Lots 25 & 26. Range II, Coleraine Township

Montreal Pit:

This property, situated 7½ miles east of Chrome siding on the Quebec Central railway, is owned by the Dominion Mines and Quarries Company, Limited. Although referred to by the Company as the Black Lake quarry, it is locally known as the Montreal pit, or Paré pit. It may be reached from either Black Lake or Coleraine, on the Quebec Central railway. About midway between the two villages, a road leading eastward crosses the railway track at Chrome siding. This road may be travelled by motor car for at least two miles from the railway, but owing to the destruction of two small bridges, and also to the general state of disrepair of the road, the remaining five miles are best covered on foot, although it is possible to drive by horse and buggy.

Regarding this mine, Cirkel says ①: "The property, which comprises lots 25, 26 range II, and lot 26, in range III, was purchased from the government in 1894 by Messrs. H. and T. Leonard, D. Morin, and A. Labrecque.

"The surface showings on these properties, it is reported, were some of the largest ever found in the district, but the ore was not

① *Op. cit.*, p. 58.

high-grade, yielding not more than 45 per cent of chromic oxide. The mines were, according to Mr. Obalski's report, worked up to 1900 in a most primitive manner, no machinery of any kind being used. Up to January 1, 1900, some 3,200 tons had been extracted, of which 2,200 tons were sold; and a far larger quantity could have been shipped if the demand for this low-grade ore had not been so limited. In 1901, the Montreal Chrome Iron Company was formed, and in 1902 a mill was built for the treatment of the low-grade ores. This mill has a jaw crusher, and 15 stamps of 1,000 lb each; three concentration tables all driven by an 80 h.p. high-speed engine; and a boiler plant consisting of two boilers of 50 h.p. Concentrates to the amount of 4½ tons per ten hours were produced, and the ore shipped over a good road, 7½ miles long, to Chrome siding. In 1903, during five months' operations from April to August, about 500 tons of concentrates were shipped.

"In the year 1906, the Black Lake Chrome and Asbestos Company acquired all the properties belonging to the Montreal Company. The great amount of exploratory work done by the new Company for the purpose of determining the approximate tonnage of ore available in the deposits has placed this undertaking on a safe footing.

"The mine proper is located on the gentle slope of a mountainous range some distance from a little lake. It consists of a number of pits, cuts, and excavations, extending over a length of 425 feet, the main trend of all these openings being N.W.35 degrees. The principal pit is the most southerly one, and measures, on the surface, 75 by 125 feet, the depth being about 30 feet. The occurrences of chrome iron ore can be studied to great advantage in the pit, which exposes not only the disseminated variety, but also pockets of crude ore, granitic dykes cutting the serpentine, as well as the disturbances therein caused by the shifting of the whole formation. Slickensides and faults as a result of these movements are very frequent, and in some places have cut off entire ore-bodies. In this case, the cutting plane has a more or less polished surface, and is covered to some extent by soft, slippery serpentine. The writer has taken from this pit ore with such highly polished surfaces that any one not acquainted with the outward features of the rock in the pit would suggest artificial cutting and subsequent polishing of the rock faces. . .

"All the other pits, located in a northwesterly direction from the main pit, consist of open-cuts, exhibiting the same features as those observed in the big pit. Through these operations, it has been shown that the available ore-body consists of quite a number of disconnected large pockets, with disseminated ore between. The exact dimensions of this ore-bearing formation cannot be given yet, but judging from the mining work and diamond drilling so far done, it appears that it has a length of at least 350 feet, with an average width of 60 feet, while the depth must be at least 75 feet. The ore located by diamond borings is at present taken out by a drift run in from the main pit, and the results so far obtained compare very favourably with those of the drill holes.

"The mill at this mine is located about 400 feet from the main pit, and the system adopted is the same as that in operation at the mill of No. 1 shaft. The ore, after passing a jaw crusher, is fed to 15 stamps. The pulp then passes over three Wilfley tables, the middlings again being treated on a fourth table. The mill engine is a single-cylinder Corliss engine, the steam being supplied by two 45 h.p. flue boilers.....

"The camp..... consists of office building, sleeping house and kitchen, and several accessory buildings".

Dresser states ①: "The work has been done chiefly by an open-cut of 100 by 40 feet, with a maximum depth of 60 feet. The original ore-body, which dips toward the northwest at a low angle, has been followed all the way. It was 15 feet thick at the surface, and maintained that thickness at different places. Where this has been removed, several bore-holes have been sunk to test the underlying rock. The logs of two of these holes are given below. The hole *A* is a vertical one, that at *B* dips northwest at 60°. This is the direction of the dip of the ore-body, but at a considerably higher angle. The holes begin at practically the same place.

① *Op. cit.*, p. 86.

A			*B*		
0-43	feet	serpentine	0-47	feet	serpentine
43-46	"	ore	47-50	"	ore
46-55	"	serpentine	50-51	"	serpentine
55-58	"	ore	51-59	"	ore
58-74	"	serpentine	59-62	"	serpentine
74-80	"	ore	62-63	"	ore
80-82	"	serpentine	63-65	"	serpentine
82-83	"	ore	65-73	"	ore
		serpentine	73-83	"	serpentine
			83-84	"	ore
			84-88	"	serpentine
			88-98	"	ore
					serpentine
Total ore, 13 feet.			Total ore, 31 feet.		

"Some portions of the rock, classed as serpentine in the above logs, are granite; but their measurements are not distinguished. Boring *B*, being nearly parallel to the dip of the lenses, shows the dimensions along the axes nearest to the vertical, which appear to be approximately two and a half times the thickness of the ore-bodies".

After having been idle for five years, the property was reopened in 1915 by Mr. Aurèle Paré, who was given a lease. Shortly afterwards, however, the Dominion Mines and Quarries, Ltd., acquired the rights, and Mr. Paré continued work on contract under their supervision until December, 1918. During this period, nearly 20,000 tons of ore were shipped from this mine, almost the whole of it, apparently, being low-grade crude.

The main pit now measures about 450 feet in length by 100 feet in width, and it is said to be 150 feet in depth at the deeper end (see sketch-map, Fig. 8).

In this pit, numerous aplite-like dykes cut the serpentine and these have proved to be of great interest to mineralogists, on account of the unusual minerals which compose or occur in them. Much of the material described by Poitevin and Graham in their memoir on

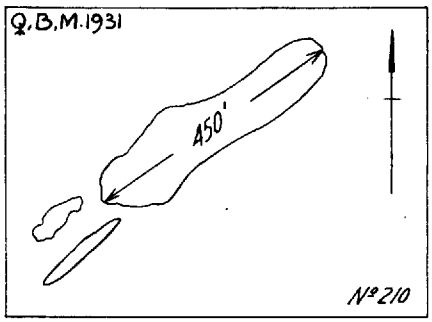


FIGURE 8.—Sketch-map of Montreal pit, lots 25 and 26, range II, Coleraine.

the mineralogy of Black Lake ① was collected from this locality. Some of these dykes have a pink colour, a feature which was commented on by Cirkel ②. These are composed of lilac vesuvianite, "but had it not been for their exceptional colour there would be nothing in the description (Cirkel's) to warrant one in regarding them as anything but granite. Many vesuvianite 'dykes', however, as well as all those composed of diopside and grossularite, are white or pale in colour, and so closely resemble aplite that, unless examined individually, they might easily be mistaken for such in the field" ③.

While claiming that the chromite is in the main primary, Dresser ④ qualifies this statement by adding:

"Subsequent solution and redeposition may have taken place to some small extent; but of this there seems, as yet, to be no certain proof, since the small vein-like bodies of chromite, which are occasionally found, show no internal structure to distinguish them from ultrabasic offshoots of chromite-bearing portions of the intrusive rock".

On this subject, Poitevin and Graham express the following views: "The view that there may have been, locally, a partial resolution of the chromite would seem to be confirmed by the occurrence of deep emerald-green chrome vesuvianite (and also of a crystal of ouvarovite) at the Montreal Chrome pit. The vesuvianite is

① Poitevin, E., and Graham, R. P. D., *Contributions to the Mineralogy of Black Lake Area, Quebec*; Geol. Surv. Can., Museum Bull. No. 27, 1918.

② *Op. cit.*, p. 27.

③ Poitevin and Graham, *op. cit.*, p. 19.

④ *Op. cit.*, p. 90.

found either deposited directly upon the compact chromite along narrow seams and partings, or else lining druses within the massive white diopside which cements the brecciated ore. It would thus seem that the magmatic waters, or 'extract', which in an earlier section have been credited with exerting a powerful solvent action on the peridotite and other rocks they bathed, have also been capable of dissolving the chromite with which they came into contact. It is also possible that some of the chromite thus taken into solution was later redeposited as a secondary mineral, since small veinlets of chromite are found, not only within the country rock, but also penetrating the 'dykes' of diopside and vesuvianite" ①.

The walls of the pit are now quite inaccessible, but specimens of dyke-rock containing chromite are numerous on the dump. It is interesting to note that this chromite has an unusually fine texture, quite unlike the normal ore, in which the crystalline nature of the mineral is apparent. The specimens collected from the dump all suggest that the chromite is included in the 'dyke' material, a view which is supported by microscopic study, which shows that the chromite is not homogeneous, and is cut by stringers of the vesuvianite rock. The contact between the chromite and dyke rock is marked by a zone of earthy cryptocrystalline emerald-green mineral, whose optical properties could not be determined.

In the normal ore, the chromite occurs as disseminated anhedral grains in a green-weathering serpentine. The grains show fractures which are traversed by veinlets of serpentine. The rock is so completely serpentinized that its original character is entirely masked. On the map accompanying this report, the country rock is indicated as serpentinized pyroxenite, and the deposit lies within a few hundred feet of the margin of the intrusive mass. Shattering and brecciation of the ore have been accompanied by faulting and slickensiding, and in some cases ore-bodies have been entirely cut off along the planes of such movement. The pure selected chromite is reported to be low in chromium; a sample taken by the writer contained only 49.11 per cent Cr_2O_3 (See page 47, analysis *J*).

① Poitevin and Graham, *op. cit.*, p. 19.

LOT 25 (N.W.½), RANGE III, COLERAINE TOWNSHIP

GAGNÉ PROSPECT:

This prospect lies within a few hundred feet of the road leading from Chrome siding to the Montreal pit. A trail which leaves this road a short distance beyond the point where it crosses the fourth brook from Chrome siding, leads directly to the mine, which is on the west slope of a large hill.

Chromite was discovered on this property shortly before the end of the war, and it is claimed that three or four car-loads of crude ore were shipped. The present owner is Napoléon Gagné, of Thetford Mines.

The excavation consists of a cut in the hill-side, about 45 feet wide by 25 feet high, from the bottom of which a steeply sloping shaft or pit, 20 feet by 15 feet, has been sunk to a depth of 30 feet. The pit is normally full of water but this can, if necessary, be siphoned out. An ore-zone about two feet in width is visible in both walls of the shaft. It is claimed that the best ore came from the bottom of the excavation, but the water, and also the presence of material which has fallen in by caving, made it impossible to verify this.

The country rock is a green-weathering serpentine, in which occasional crystals of pyroxene may be distinguished by their cleavage faces. The serpentine is very much sheared and the chromite is rather evenly disseminated through the rock in small (1 mm.) grains. This ore is quite similar in appearance to that of the Montreal pit. To the southeast of the prospect, the summit of the hill is underlain by coarse-grained pyroxenite. In the excavation, a small aplite dyke is exposed. It pinches out rather abruptly before it reaches the surface, and its downward extension is hidden beneath caved material (Pl.III-B).

On the dump, about 15 tons of chromite ore has been set aside, all of milling grade. It is claimed that the ore concentrates readily to 40 to 44 per cent Cr_2O_3. This low figure possibly indicates that the chromite in this ore, like that of the Montreal pit, is a variety low in chromium. A sample of the mineral from this prospect was analyzed and found to contain 50.62 per cent Cr_2O_3 (analysis *H*, page 47.)

Lots 7, 8, 9, and 10, Range IV, Coleraine Township

On the northeast slope of Nadeau hill, 2½ miles due east of Coleraine village, there are a number of chromite pits and prospects, which were worked by the American Chrome Company. The present owners are the Beebe Realty Corporation, of Boston, Mass.

The main workings are on lot 10, range IV, and are most readily reached by a somewhat obscure trail which starts from the end of the road which follows the southwest boundary of range X, Coleraine. Two pits about 30 feet in diameter, and a few smaller excavations, mark the site of operations. All the ore seen on the dumps is of the disseminated variety, rather coarse-grained, in green-weathering serpentine. If any ore was produced from these pits, the quantity must have been small. Analysis of a sample of the chromite from this locality gave 54.03 per cent Cr_2O_3 (analysis *F*, page 47).

There is another chromite prospect, on lot 7, range IV, situated near the top of a hill on the northeast side of the power-line. Nearby is an asbestos mine, known as the Harris mine. The workings here consist of a trench 80 feet in length and a few feet deep, in which a band of 'banded ore', two feet in width, is exposed for a length of six feet, where it is abruptly cut off by a fault. The chromite in this trench is highly magnetic. A sample taken by the writer was found to contain 51.30 per cent Cr_2O_3 (analysis *G*, page 47).

The complexity of the mutual relations of the several phases of the rocks of the Serpentine Belt series are well shown on the large, bare outcrops of Nadeau hill.

Lot 19, Range X, Coleraine Township

Reed-Bélanger Deposit:

This is by far the most extensive deposit of chromite ore discovered to date in the Province of Quebec. Although essentially a single deposit, and all lying within lot 19, range X, of Coleraine township, there is divided ownership. The northwest half of lot 19 was purchased from the Reed estate in 1918 by the Mutual Chemical Company, who still retain their title to this portion of the lot. The southeast half was acquired by Mr. J. V. Bélanger, also in 1918, but in 1921 the ownership passed to the United States Ferro Alloys Cor-

poration. This Company, in turn, sold the property to the Colonial Chrome Company, Limited, which is controlled by the Vanadium Corporation, Limited. Finally, in 1926, this southeast section was sold for taxes to Robutel Théberge, of Coleraine village, but the legality of this sale is contested by the previous owners. Although the ownership of the deposit is thus divided, it constitutes a unit and will be described as such.

The mine workings are to the southwest of Caribou lake, 2½ miles south of Black Lake village. and they may readily be reached from Chrome siding on the Quebec Central railway by a gravelled road about one mile in length.

Chromite was discovered on this lot in 1894, and Cirkel (writing in 1909) states that, on the northwest half of the lot ①: "The principal pit was the most westerly of all the workings... Some 524 tons of crude were taken out of a cut 200 feet long, and from 20 to 30 feet deep, the main trend of this pit being N.E.42 degrees. The walls still exhibit at some places good milling material, and some crude ore can be noticed at the face of the cut. All operations on this property were suspended in 1896, and no work has been done since". In 1915, production was resumed from these pits, but it was not until the year following that the main ore-bodies were discovered and work commenced on the site of the extensive series of open pits which are now visible. During 1916 and 1917, Mr. J. V. Bélanger carried on mining by open-pit methods on that part of the deposit in the northwest half of the lot, and in 1917 extracted 13,367 tons of ore. In the following year, the Mutual Chemical Company acquired the property and plans were immediately made for underground mining. In the meantime, Mr. Bélanger, whose mill was located on the southeastern half of the lot, proved the extension on the deposit across the boundary line, and, having purchased the remaining half of the lot, continued mining there by the open-pit method. Both Mr. Bélanger and the Mutual Chemical Company were important producers of chromite during that year, In 1919-1920, despite the slump in the demand for chromite, the Mutual Chemical Company continued underground development work, and erected a concentrating mill near their mine to treat the ore which, since they had become owners of the mine, had been concentrated at the Lakeside or Red mill of the Black Lake Asbestos

① *Op. cit.*, p. 62.

and Chrome Company, Limited. The J. V. Bélanger Mining Company, who had acquired Mr. Bélanger's new mine on the southeastern half of the lot, also carried on underground development and erected a new and larger concentrator, with a capacity of 170 tons per 24 hours. Production was maintained by both Companies until the end of 1920, when the Mutual Chemical Company closed their mine, and by the end of 1921 the Bélanger mine had also suspended operations.

The total production from the northwest half of the deposit was about 30,000 tons, of which the greater portion was extracted by underground methods. The southeast portion of the deposit yielded 25,000 tons, mined by the open-cut system.

The report of the Bureau of Mines for the year 1920 gives the following particulars of the workings and operations of the Mutual Chemical Company ①:

"First level (100 feet), length of drifts and cross-cuts	1,323 ft.
Second level (200 feet) " " " " " "	2,693 ft.
Third level (300 feet) " " " " " "	316 ft.
Depth of shaft	316 ft.
Raises	122 ft.

"or in all 5,488 ② feet of underground workings.

"The lens of chromite appears to be about 500 feet long, and varies in width from 8 to 60 feet. Most of the ore hoisted during the year comes from the second level. The ground is very blocky and fissured, and dangerous. The haulage-ways have had to be timbered in many places and there are two gangs of scalers at work all the time. In open places, the ore and rock slough down, or drop, continually."

The Bélanger mine, which starts at a point 90 feet to the southeast of the Mutual Chemical Company's shaft, was a large open pit, 500 feet in length and 100 to 150 feet wide.

No undue difficulty was encountered in supplying the mills with sufficient ore, and the ore reserves, proved by development work and diamond drilling, were adequate to warrant continuation of operations had the price of chromite justified this.

The ore zone, as indicated by the open-cut workings, is some 1,400 feet in length by 100 feet in width, and the workable ore-bodies consist of a series of lenses, of variable dimensions, separated by sections so

① Que. Bur. Mines, Ann. Rept., 1920, p. 44.

② According to the figures quoted, this total should be 4,770 feet.

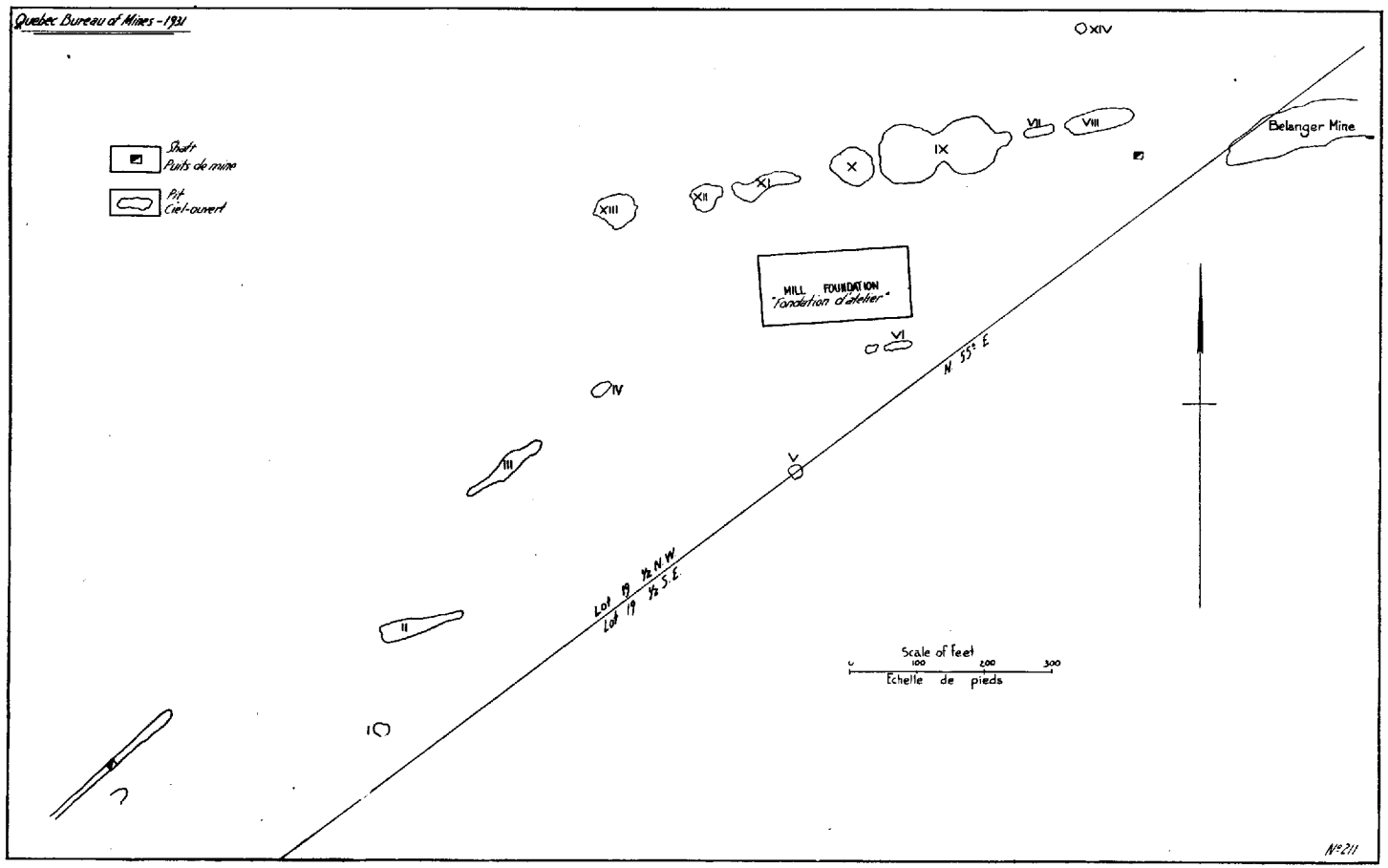


FIGURE 9.—Map showing excavations in Reed-Bélanger chromite ore-body, lot 19, range X, Coleraine township.

lean as to be unworkable. The general direction of the zone is east-west, with dip steep to the north. While pockets of high-grade ore are encountered, the ore is usually of the banded disseminated type, containing 12 to 15 per cent Cr_2O_3. This was concentrated to 50 per cent Cr_2O_3 in the mills. The country rock is brown-weathering serpentinized dunite, and it is recorded that in the Bélanger mine the ore on the surface was so badly weathered and disintegrated that, during the first year of operations, it was mined by pick and shovel.

There are a number of other pits on lot 19N.W., range X, from which chromite has been extracted, both before and during the war period. The disposition of these pits, shown on the accompanying sketch-maps, Figures 9 and 10, tends to emphasize the irregularity of occurrence of chromite deposits. The group of eight excavations to the south and southwest of the main ore-zone indicate a zone roughly parallel to the main horizon, but in their present state, and from surface indications only, their correlation is impossible. The largest of these pits is the "most westerly of all the workings" mentioned by Cirkel in the passage quoted above. In the middle of this pit there is a shaft, now full of water. Very little chromite can be seen in the walls of the pit. In the west end of pit No. 2, some good milling ore is exposed; the rock is sheared, shattered serpentine.

In the north corner of lot 19N.W., there is a group of six pits (mentioned on page 60). No estimate could be made of the production from these pits, and they are now full of water, but the extent of the dumps indicates that they must have been from 25 to 40 feet deep. Both disseminated and high-grade ore can be seen on the dumps. The rocks are partially serpentinized dunite and shattered serpentine, and granite or aplite is a prominent feature on the north walls of pits I and IV. The disposition of the pits, and of the nearest pits on Block *A*, shows the irregular, pockety nature of the ore lenses.

Lot 8, Range XIII, Coleraine Township

Huard Mine:

This property lies to the north of the road leading from Chrome siding to the Montreal pit. The mine dump may be seen from the road, at a point four miles from the siding

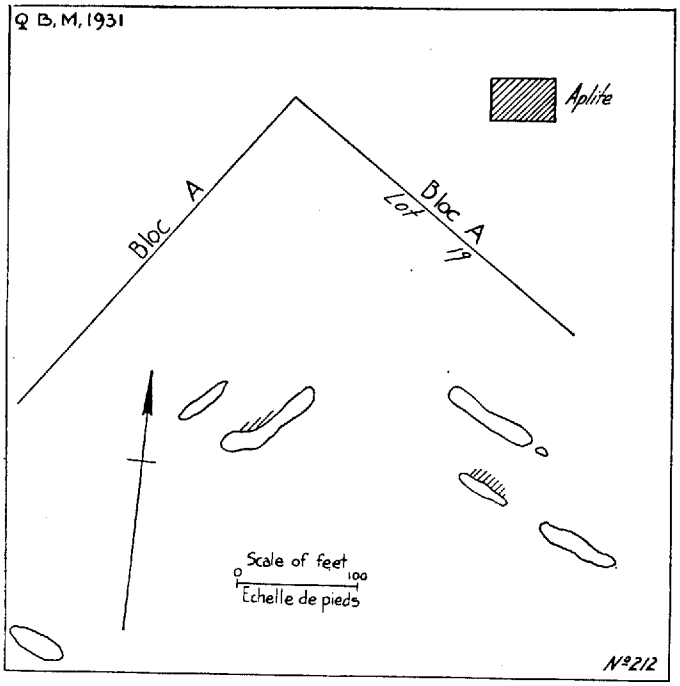


FIGURE 10.—Map showing location of pits in north end of lot 19, range X, Coleraine.

Chromite was first mined here in 1894-5, and about 50 tons of ore were taken from a cut 75 feet long and 8 to 10 feet wide. Cirkel ① noted "a fissure in serpentine accompanied on one side by a solid vein of chrome iron ore from 4 in. to 6 in. in width, with graduations of disseminated ore over a width of two feet down to pure serpentine", and that the cut as a whole exhibited quantities of good milling material.

During the war, the property was acquired by Mr. L. H. Huard, and exploration work was carried on by several parties, some of whom extracted a few tons of chromite. The total production appears to have been less than 100 tons. The sketch-map (Fig. 11) indicates the disposition of the workings; they are now filled with water.

Six hundred feet to the northwest of pit 2, there is a cut, 30 feet in diameter, in the hillside, but chromite is very scarce at this point.

① *Op. cit.*, p. 64.

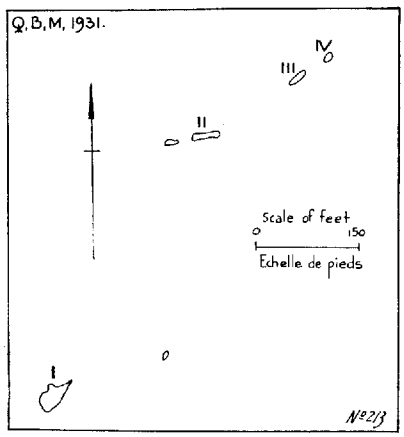


FIGURE 11.—Sketch map of Huard mine, lot 8, range XIII, Coleraine.

The rock is serpentinized peridotite and dark green serpentine of uncertain origin. What ore was seen on the dumps was of the disseminated variety.

OTHER OCCURRENCES IN COLERAINE TOWNSHIP

In addition to the deposits described in the foregoing pages, there are, in Coleraine township, a number of properties from which little or no ore has been shipped. The ranges and lots in which these are situated are indicated in the list of occurrences on page 54.

WOLFESTOWN TOWNSHIP

LOT 23, RANGE III

There are a number of chromite prospects in Wolfestown township, but, until the war, no development work nor mining had been done on any of these. During the war, however, a certain amount of development work was done on lot 23, range III, by the Canadian Reduction and Mining Company, Limited, and about 60 tons of ore were shipped from here. There are several asbestos mines and prospects in the vicinity, and it is impossible to distinguish between these and the chromite pits.

GARTHBY TOWNSHIP

LOTS *A*, *B*, AND *C* OF RANGE I AND LOTS 5, 6, 7, AND 8 OF RANGE II

(VICINITY OF BREECHES LAKE)

There are a number of chromite properties between the south-eastern end of Breeches lake and Sunday lake. They are nine miles from Disraeli on the Quebec Central railway, and are rather difficultly accessible. From Disraeli, there is a road 6½ miles in length, parts of which are 'improved', and the remainder under construction. The remaining 2½ miles may be traversed either by boat across Breeches lake or through bush along the lake shore. From the end of Breeches lake to Sunday lake there is an excellent trail which follows the watercourse connecting the lakes, and about half-way to Sunday lake an old bunk house, situated at the foot of a ridge and about 500 feet from the main workings, constitutes a readily recognizable landmark.

The mining rights on lots 5, 6, 7, and 8, of range II, and lot *C*, range I, belong to Professor A. Boyer, of Montreal; Mr. Colin L. Campbell is owner of the mining rights on lots *A* and *B*, range I.

The mining rights on lot *C*, of range I, together with lots 5, 6, 7, and 8 of range IIN. were acquired from the government by the late H. Leonard and others, following the discovery of chromite in the serpentine which underlies these lots. Lot *B*, range I, was patented about 1898 by Messrs. Gosselin, of Disraeli, who later sold their rights to Mr. C. L. Campbell. The deposit on lot *A* was discovered by Mr. Gosselin during the war, and he later disposed of it to Mr. Campbell.

Obalski ① states that from 1894-1896 there were shipped from lot *C* "400 tons of very high-grade ore; some shipments having yielded as high as 55 per cent Cr_2O_3. The work was done by hand, and the ore, which was very friable, had to be shipped in bags." In 1917, prospecting and exploration work was resumed, and in the next year a little ore was shipped; it had to be taken up Breeches lake in scows and then transported to Disraeli station. In 1896, some 30 tons were taken from lots 6 and 7, range II, by Mr. R. Gagné.

① Obalski, J., *Chromic Iron in the Province of Quebec*; Dept. of Colonization and Mines, Quebec, 1908, p. 13.

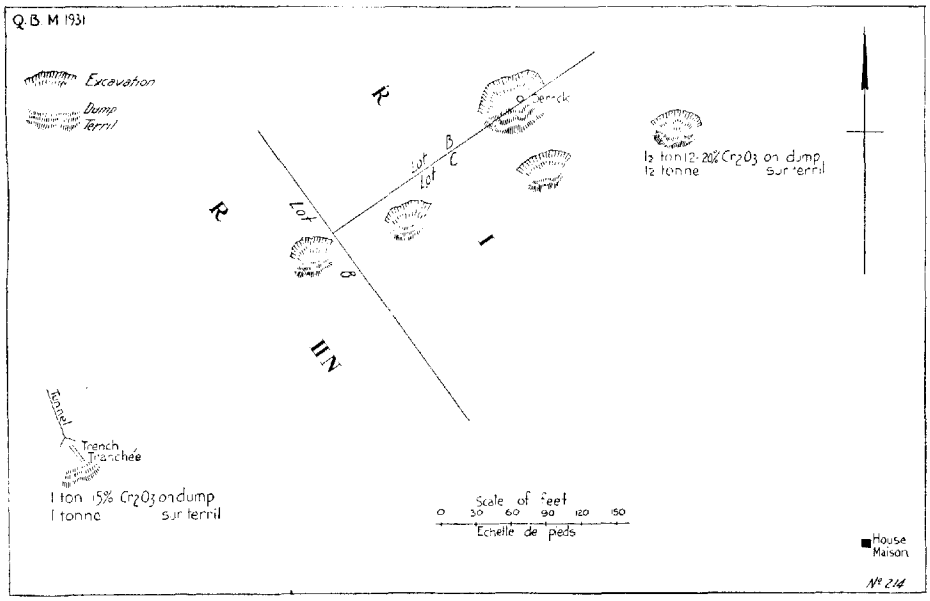


FIGURE 12.—Map showing chromite occurrences near the southwest end of Breeches lake, Garthby township.

The chromite occurs in small segregations, and as disseminated ore, in a highly serpentinized brown-weathering peridotite. Burton ① mentions that "veinlets of chromite apparently cut serpentine veinlets", and also that "the chromite is closely associated with veinlets wholly of serpentine, and in places appears to be contemporaneous with the latter". He concludes that the chromite, for the most part, is a primary constituent of the rock, but that some, at least, may be secondary and the result of deposition from thermal solutions.

On lot *A*, the workings consist of a small pit about 20 feet in diameter on the steep northeastern slope of the hill. It is now filled with water and largely caved. Very little chromite was observed in the walls. On the dumps, a little low-grade ore was seen.

On lots *B* and *C*, range I, and lot 8 of range II, there are a succession of workings, indicated on the accompanying sketch-map (Fig. 12), which extend over a length of about 600 feet along the southeast slope of a very steep ridge. To the extreme southeast, there is a trench-like

① *Op. cit.*, p. 130.

excavation, some 30 feet in length, leading to an adit, 60 feet in length, which runs about N.30°W. into the hillside. The only ore seen at this place was a small pile, containing perhaps one ton of low-grade ore. About 275 feet to the northeast, near the corner-post between lots *B* and *C*, range I, on the range-line between range I and range II, a sloping excavation about 15 feet wide has been made into the hillside for a depth of about 25 feet. Very little chromite was seen in the walls.

On lot *C*, range I, about 50 feet to the northeast of the corner-post, a small pit, now badly caved, has been sunk into the hillside at an angle of about 40°, and there is another, slightly larger, pit 120 feet to the northeast of this. The ground between them has been partially stripped and excavated. Patches of chromite are visible in both of these pits, but the state of the excavations is such that it is not possible to make a satisfactory, or indeed a safe, examination. About 100 feet to the northeast of the larger of these pits, there is another small excavation running into the hillside; no chromite was seen in the walls, but on the dump there has been accumulated about 1½ tons of ore of fair grade.

On lot *B*, to the northeast of the middle pit on lot *C* and about 50 feet higher in elevation, there is a larger pit, semi-circular in form and about 60 feet in diameter. A derrick, still in place, was used in making this excavation. The pit is now full of water and in its present state reveals no features of particular interest.

All the country rock in the vicinity of these pits is serpentinized peridotite, through which are disseminated occasional grains of chromite.

Lot 37, Range V, Garthby Township

Brousseau Mine:

This mine lies two miles to the north of Disraeli, on the highest point of Brousseau hill. It may be reached by an old waggon road which branches from the road that leads northeast from Disraeli. The property is also readily accessible from the main highway. Brousseau hill forms a prominent landmark about half a mile from the highway at the end of Disraeli bay. The mine is owned by Mr. Brousseau, of Disraeli, and was opened in 1896. In 1908, when Cirkel visited

the property, the principal pit was 30 feet by 20 feet, and it was then filled with water; but it was reported that some 100 tons of good crude ore had been shipped from it.

In 1916, the property was reopened and a production of 116 tons is recorded in that year. Although exploration work was carried on for the next two years, no further ore seems to have been shipped.

When the writer visited the property, he found two excavations, one 50 feet by 35 feet, and the other smaller, 70 feet to the northwest. Both appear to be quite deep, but they are now completely filled with water.

The country rock is massive green-weathering serpentine. Chromite is abundant on the dumps, forming bands in the rock, but the ore all appears to be of low grade. A remarkable feature is the brecciated appearance of some of the ore bands in the apparently massive rock. Calcite veins are abundant, occasionally containing a few grains of chromite and small inclusions of serpentine. The top of the hill is relatively bare and the rock well exposed, but no chromite was seen in place in any of the outcrops.

On the northeast slope of the hill there are two cuts into the hillside, in each of which grains of disseminated chromite are visible in the serpentine. These excavations are about 700 feet from the Brousseau mine.

SOUTH HAM TOWNSHIP

Lot 41, Range 1, North of Nicolet Lake

On this lot, formerly numbered lot 21½W, range I, there is a deposit of chromiferous magnetite. The only working is a small pit, which is difficult to locate, situated on the north side of Nicolet lake, about 90 yards from the shore and two miles from the northeast end of the lake. The property is owned by the Reed Estate.

The ore is solid magnetite, and although insufficient work has been done to permit estimation of the extent of the deposit, it seems probable that the body of ore is large. A magnetometric survey of the immediate area suggests itself as the most obvious method to be adopted for further investigation, should a use be found for this particular type of ore.

The deposit occurs just within the northern margin of a large intrusion of rocks of the Serpentine series, in a band of serpentine which at this point constitutes the intrusive rock in contact with the sediments. The relation of the ore to the enclosing serpentine is nowhere exposed. From the small pit, which is about 12 feet in diameter and apparently 15 feet deep, about 100 tons of ore, reported to contain 4 per cent of chromium, have been extracted. The analysis of a sample taken by the writer gave the following result:

SiO_2	0.96
TiO_2	19.85
Al_2O_3	8.42
Cr_2O_3	10.81
Fe_2O_3	24.83
FeO	28.22
MgO	2.31
CaO	1.20
	96.60

Other Occurrences in South Ham Township

On lot 41, range I, to the south of Nicolet lake and within a few feet of the road which skirts the lake, there is a small pit in which a little disseminated chromite, in dark-green-weathering serpentine, is exposed. It is said that the first chromite mined in Canada came from here.

Chrome iron ore is reported to have been found on lots 48 and 54 of range I, and on lots 40, 42, and 54 of range II, but the writer was unable to find any evidence of mining operations on these lots.

THETFORD TOWNSHIP

A small body of high-grade chromite was encountered in the Beaver pit of the Asbestos Corporation. A few tons of this ore are to be seen at the mine dump, but the working face of the pit is at present inaccessible and in danger of caving.

Chromite occurs in serpentine on lot 16, range IV, but no production has been reported from here. The serpentine body in which this

chromite occurs is a relatively small outlier of the Serpentine series. This lot became the property of the Banque Canadienne Nationale following liquidation of the former owners, the Pennington Asbestos Company, Limited.

LEEDS TOWNSHIP

Lot I, Range X

It is reported that, in 1887, Dr. Reed shipped 54 tons of chromite from this lot, which is 12 miles distant from Robertson station, Quebec Central railway. This ore contained between 51 and 52 per cent Cr_2O_3. The small pit from which it was taken is on the southwest slope of a steep ridge and is very difficult to locate. The country rock is dark-green-weathering serpentine, which occurs here as a small outlier of the Serpentine series.

CLEVELAND TOWNSHIP

Lots 7 and 8, Range X

Sterrett Mine:

This mine is about three and a half miles to the southeast of St. Cyr station on the Canadian National railway. At the time it was operating, it was accessible by road from St. Cyr station. It is still possible to motor to within a mile of the property, but at that point a bridge, which formerly crossed a small stream, has been destroyed. Beyond the stream, however, the continuation of the road is suitable for a car.

The property was opened-up in 1916 by Mr. D. B. Sterrett, and the Quebec Asbestos and Chrome Company was formed to operate it. During the year 1917, 9,370 tons of ore, with an average Cr_2O_3 content of 32.5 per cent, were extracted by open-pit mining methods. In 1918, the Company purchased a mill from the Mutual Chemical Company, and both building and machinery were transported from Black Lake to St. Cyr, where the mill was placed in operation in the early part of November. During that year, 5,136 tons of crude ore and 823 tons of concentrates were shipped. Early in 1919, the Company, antici-

pating the impending curtailment of activity in the chromite industry, disposed of the concentrating mill, and the machinery was returned to Black Lake, where it was re-installed by the Mutual Chemical Company.

During the year 1918, a system of underground mining was developed. A shaft, 4 ft. 8 in. by 8 ft., with timbering reinforced with steel rods, was sunk to a depth of 196 feet. Levels were opened at 109 feet and 184 feet, and on each of these cross-cuts were driven to intersect the ore. That on the first level was driven 191 feet, and cut one good vein 67 feet from the shaft. On this vein a drift was opened, following the ore for 100 feet towards the south and for 75 feet towards the north. Southward, the lens practically pinches out, but at the end of the year the north drift was still in ore. On the second level, a cross-cut was driven 74 feet and revealed a little ore.

In addition to the underground workings, there are seven large, narrow pits, distributed over a length of 1,400 feet. All of these, as well as the shaft, are now filled with water and therefore inaccessible.

The deposits occur in the long, narrow serpentine band which extends from range XV Cleveland township to range VII Shipton—a length of eight miles. The band has a width varying from 300 yards to one mile, and the deposits are located within the region where the band is widest. The ore-bodies consist of a series of lenses, the width of which varies from a few inches to 18 feet. Their general direction, N.35°E. (magnetic), and their dip, which is steep to the northwest, corresponds roughly to the direction of elongation and dip of foliation of the enclosing serpentine body.

To the west of the main pits, Nos. VII and VIII on the sketch-map (Fig. 13), a zone of chromite parallel to the long axes of the pits has been traced for a length of about 300 feet. This zone varies in width from a few inches up to 16 inches.

The altitude of the walls of the pits is difficult to determine due to the level of the water in them.

There is abundant evidence of faulting, later in age than the ore. Thus, specimens of ore with highly slickensided surfaces are to be found on the dumps Also, the continuity of the chromite lenses between pits VII and VIII is interrupted, presumably by a small fault.

The serpentine in pit I is cut by small dykes of aplitic nature. Exposed on the surface immediately to the northwest of pits VIII, IX,

Photo R. Harvie

Courtesy Geological Survey of Can., Ottawa.

General view of Caribou Lake chrome district

A.—Bélanger chromite mine, worked by open-pit, S.E. ½ lot 19, range IX, coleraine township

B.—Surface work along the strike of chromite deposit at Sterrett mine, lots 7 and 8, range X, Cleveland township.

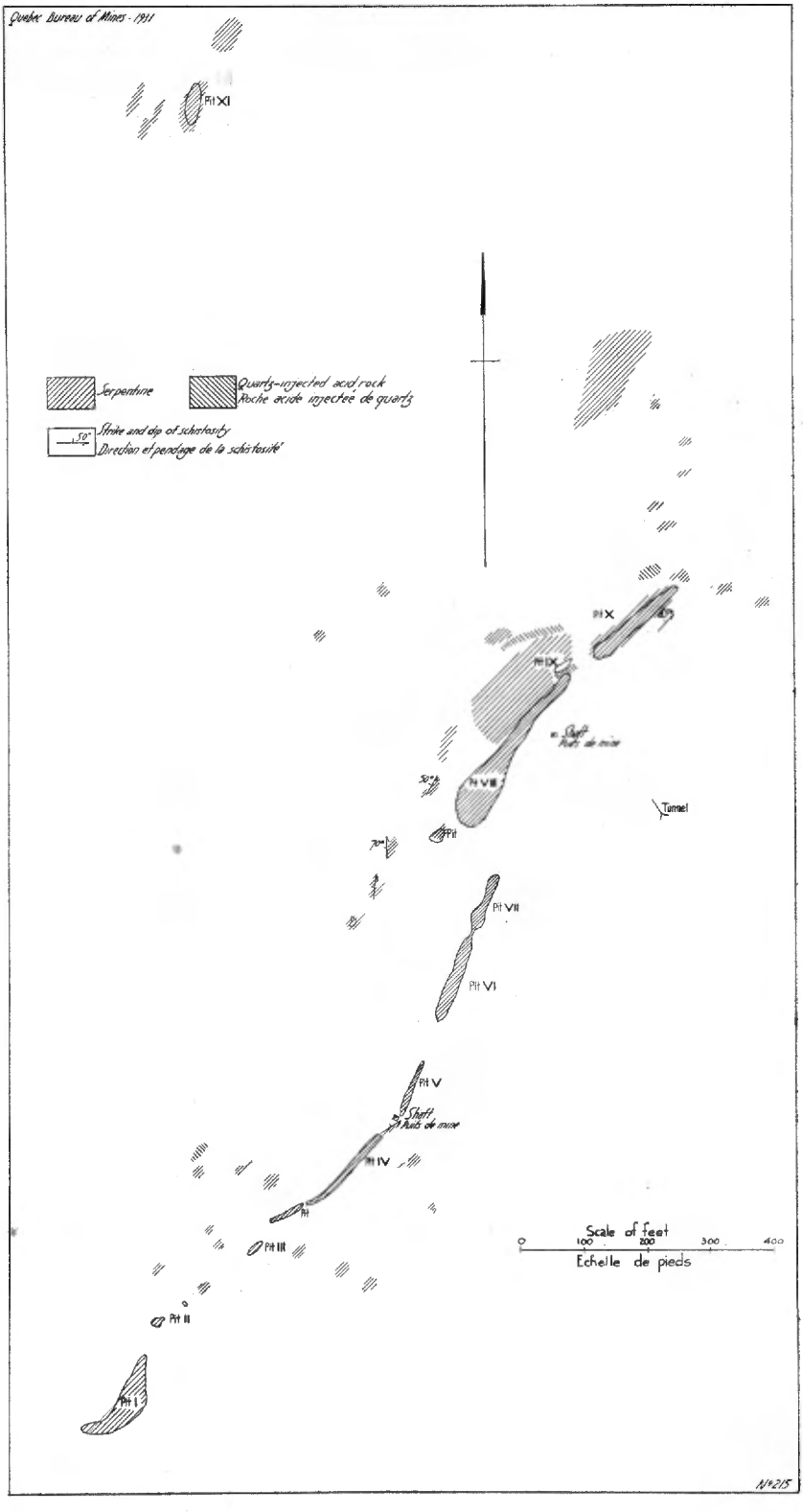


FIGURE 13.—Map showing chromite occurrence at the Sterrett mine, Saint-Cyr, Cleveland township.

and X is a narrow band of acid rock which is cut by innumerable quartz stringers (See map accompanying this report). The appearance of this rock is strongly suggestive of a metamorphosed arenaceous sediment, but its relations to the enclosing serpentine are not clear.

The relation of the last pit—which is offset far to the northwest of the prolongation of the ore-bearing zone—could not be established. There is a little chromite exposed at the south end of this pit.

All the rock outcrops seen in the vicinity of these deposits consisted of serpentine. It is therefore established that, across the strike of the formation, the serpentine extends for at least 1,000 feet on each side of the ore-bearing zone.

The ore is the typical banded variety. Where the serpentine does enclose chromite, the latter is rather evenly disseminated through the rock. The serpentine is of the green-weathering type, and occasionally the chromite is found in a talcose friable rock. Seen under the microscope, the grains of chromite are reddish-brown and translucent. They are much fractured, the fractures being filled with serpentine of at least two ages.

On the various dumps of this property there remain about 400 tons of ore containing 20 per cent Cr_2O_3, and it is reported that, at the time operations were suspended, development work underground had blocked out about 5,000 tons of ore.

Analysis of two samples of chromite from this locality gave 50.90 per cent Cr_2O_3 (analysis *K*), and 50.68 per cent Cr_2O_3 (analysis *L*).

IRELAND TOWNSHIP

Lot 28, Range I

This property is situated 2½ miles to the northwest of Coleraine village. It is on the south slope of a steep ridge (Caribou mountain) and can be easily seen from the road leading to the Vimy Ridge asbestos mine, being about 250 yards from this road. The present owners of the property are the Asbestos Corporation, Limited.

In 1909, at which time the property belonged to the King Brothers Company, the workings consisted in an open-cut in a band of disseminated ore, "8 inches wide, 25 feet long, and apparently terminating in what appears to be a considerable deposit of disseminated chrome iron

ore" ①. Production up to that year was stated to have been about 50 tons, and Cirkel expressed the opinion that the deposit might contain a large tonnage of good milling ore. He gives the Cr_2O_3 content of the 'crude' as 45.85 per cent.

During the war period, this property, then under the ownership of the Bennett-Martin Asbestos and Chrome Company, produced nearly 2,500 tons of ore, the most active year being 1918, when 1,557 tons were shipped. Several ore lenses were encountered in the workings. The pit is still relatively accessible. It has a length, in a N.40°E. direction, of 300 feet, and is 12 to 25 feet wide and 15 to 30 feet deep. The country rock is brown-weathering serpentinized dunite in which a very few pyroxene crystals can be seen. In the pit, the serpentinization is complete. Disseminated ore is visible in the floor of the pit, at about the middle point. The serpentine at the north end of the pit is much shattered and jointed.

The ore mined on this property was apparently all sold as 'crude', and a few pieces of very pure crude were observed on the dump. At this property, also, remarkable specimens of 'grape ore' may be seen. The 'grapes' range from a quarter of an inch to an inch and a half in diameter. However, most of the ore to be seen today is of the disseminated variety, and not sufficiently rich to permit marketing without concentration.

The Asbestos Corporation, Limited, acquired this property, together with the other assets of the Bennett-Martin Asbestos and Chrome Company, when the asbestos industry was reorganized in 1926.

Two analyses of chromite from this property are given on page 40 (analysis 2) and on page 47 (analysis *C*).

BOLTON TOWNSHIP

According to J. Obalski, 27 tons of ore containing 49 per cent Cr_2O_3 were shipped from a deposit on lot 9, range VII, of Bolton township, in 1896-97.

From the historical point of view, it is of interest to note that the first discovery in Canada of what appeared to be a commercial body of chromite was made, about 1845, in Bolton township, on lot

① Cirkel, F., *Op. cit.*, p. 65.

23, range VII. Chromite also occurs on lots 13 and 26½ of range VII, on lot 13 of range IV, and on lot 26 of range VI; but prospecting that was carried on during the war period failed to reveal any large bodies of chromite in this township.

BROMPTON TOWNSHIP

Lots 25 and 26, Range IX

There is a chromite deposit on lots 25 and 26, range IX of Brompton township, about 1,200 feet to the west of the south end of Little Brompton lake. This property is owned by the Fletcher Pulp and Lumber Company, who, from 1916 to 1918, carried on exploration work and shipped about 200 tons of ore. This mine was not visited by the writer, but it is reported that there was still ore in sight when mining operations were suspended at the end of the war.

ORFORD TOWNSHIP

Lot 4, Range XII

During the war, a few hundred tons of ore were shipped from a deposit on lot 4, range XII, of Orford township, owned by the Fletcher Pulp and Lumber Company. The property is situated about one mile to the west of Webster lake, and ten miles to the north of the town of Magog. A good motor road leads to the south end of Webster lake, but from this point it is necessary to employ a boat. On the west shore of the lake, near its north end, an old wharf marks the point at which the trail from the mine reaches the lake.

The workings consist of two large pits, 60 feet to 70 feet in diameter. They are now partially filled with water, but their depth to water-level is 35 to 40 feet. The rock is green-weathering serpentine of uncertain origin. To the north and west of the pits, the rocks outcropping show the complexity of the intrusive mass. On the dump may be seen both crude and disseminated ore. The total production was about 600 tons. It is reported that the Cr_2O_3 content ranged from 32 to 60 per cent, and that no further ore was in sight when operations were suspended.

AWANTJISH TOWNSHIP

Lot 11, Range IV

On this lot, Messrs. Napoléon and Pantaléon Plante have been prospecting extensively for asbestos during the past three years.

In the course of this exploration work a small pocket of massive chromite was discovered. A trench made to trace the extension of the chrome-bearing zone revealed, according to information given, that disseminated chromite occurs irregularly in the rock at intervals over a length of 20 feet. At the time of the writer's visit, the trench was filled with water and vegetable matter so that no satisfactory examination of the exposure could be made. A little of the massive chromite was, however, visible in the serpentine at the point of the original discovery, and the ground in the immediate vicinity was strewn with lumps of that material. A sample was sent to the Provincial Assay Laboratory, for partial analysis, the result of which was:

Cr_2O_3	36.75	per cent
SiO_2	9.90	" "
Al_2O_3	12.30	" "
MgO	15.57	" "
Fe	13.20	" "
Corresponding to Fe_2O_3	18.86	" "

This chromite discovery is of interest, for it is a most favourable indication of the possibility of the discovery of economic bodies in this portion of the Serpentine belt. While the occurrence of the mineral has been previously noted as far to the northeast as the centre of the Gaspé peninsula, no prospect worthy of the name has been yet mentioned in the extension of the Serpentine series in this direction.

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