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Department of Mines

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CONTRIBUTIONS TO THE MINERALOGY OF BLACK LAKE AREA, QUEBEC

by

Eugene Poitevin
and
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Erratum

Page 59, first line of table, for 182° 7′ read 18° 27′

View of Black lake and surrounding country showing topography.

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Illustrations.

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Contributions to the Mineralogy of Black Lake Area, Quebec.

By EUGENE POITEVIN and R. P. D. GRAHAM.

INTRODUCTION.

The minerals described in the following pages were collected by the writers at different times during the summers of 1913-14-15, from some of the asbestos and chromite mines and pits in the neighbourhood of Black lake (Plates I and II). The region is situated in the southeastern and northwestern portions, respectively, of Ireland and Coleraine townships, Megantic county, province of Quebec (Figure 1). The area is one of the most productive sections of the so-called "serpentine belt" of the Eastern Townships, and includes many of the most important asbestos properties; in addition, there are a number of deposits of chromite which have been profitably, though intermittently, worked for the past thirty years.

Although mining operations have been carried on in the district for many years, and the geology of the area has been investigated in some detail, very little attention has been paid hitherto to the mineralogy of these deposits. J. A. Dresser, in 1910, was the first to call attention to the peculiar dykes of lilac vesuvianite at the Montreal chrome pit, and the specimens he collected were at that time examined and described by one of the writers. In this connexion it is interesting to note that several very poorly crystallized specimens of this material were subsequently found, unlabelled, in McGill University mineral collections, having been apparently collected, or received, several years ago and set aside for examination; the locality given for these is the St. Francis mine, Coleraine district, Megantic county, which at the present time is known as the Black Lake quarry of the Dominion Mines and Quarries, previously known also as the Montreal chrome pit.

Special attention was first called by Robert Harvie to the wealth of mineralogical material which the district affords. He pointed out that a study of the minerals might throw some light on the genesis of the serpentine and chrysotile-asbestos, and it is largely as a result of his suggestion that the present work was undertaken. Mr. Harvie also very kindly assisted the writers on one or two occasions in the collection of material, and has from time to time supplied them with specimens which he had himself collected.

When the International Geological Congress held its twelfth session in Canada in 1913, an excursion (A5)[1] was made to the asbestos and chromite deposits under the direction of T. C. Denis and J. A. Dresser, with R. Harvie as guide. This excursion proved of exceptional interest to mineralogists, who were able to collect specimens of many of the minerals now described in this bulletin.

The writers wish to acknowledge the courteous treatment they have in all cases received from the management of the various asbestos and chromite pits visited, where every facility was freely accorded them, both for the examination of the deposits and also for the collection of material. They are indebted to John Stansfield of McGill university, who has made most of the microphotographs, and to G. G. Clarke of the Geological Survey, who made the remainder of the series. It is with great pleasure that the writers take this opportunity to record their indebtedness to R. A. A. Johnston, mineralogist and curator, for much helpful criticism and many useful suggestions while the work was in progress, as well as for his kindness in reading and correcting the final manuscript.

Both the collection of the material and its investigation were made independently by the writers until the present summer, when, at the suggestion of Mr. Johnston, it was decided that the results of the work might most conveniently be combined and published as a joint bulletin Accordingly E. Poitevin spent one month at McGill university collaborating with R. P. D. Graham, with this end in view. The results of this collaboration are set forth in the following pages, which are believed to present a fairly complete account of the mineralogy of Black Lake area.

The crystallographic work was done at Harvard university under the direction of Professor C. Palache, at Cornell university and in the mineralogical laboratory of the Geological Survey, by Poitevin; and in Professor Beck's laboratory in Vienna and at McGill university, by Graham. Some of the chemical analyses have been made in the chemical laboratory of the Department of Mines by M. F. Connor, and the remainder at McGill university.

Several of the minerals are exceptionally well crystallized and in many cases they further exhibit features, such as unusual habits, forms, or

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[1] Congrès géologique international, compte-rendu de la XII session, Canada, 1913, pages 968 and 969.

colours, which render them additionally interesting. The area has yielded one new species, which occurs in well defined, though minute, crystals; this has been named colerainite and is described on page 66. In addition to this several amorphous or very compact substances were noted, which present a somewhat unusual appearance, but these have been found on examination to be not sufficiently definite in chemical composition and other characters to admit of their being listed as new mineral species.

For the sake of completeness a brief outline of the essential features of the geology of the area and a description of the principal rocks is given at the outset, for which, as well as for the map and much of the information relating to serpentine and chromite, the writers are indebted to J. A. Dresser's "Preliminary Report on the Serpentine and Associated Rocks of Southern Quebec."[1] Following this, a section is devoted to a discussion of the mode of origin of the several minerals and finally, each mineral is described in detail.

GEOLOGY.

An extensive study of the geology of the serpentine belt in southern Quebec was made by J. A. Dresser during the seasons of 1907 and 1909, and the conclusions he reached regarding the structure of the area, and the mode of origin of the asbestos and chromite, are set forth in a preliminary report published in 1913.[2] Since that time a considerable amount of field work has been carried out in the area by Robert Harvie, but his investigations being still in progress, no final report has yet appeared. The following summary of the general geology of Black Lake area is based on Dresser's report.

The serpentine belt consists of a series of igneous rocks, for the most part of basic composition; areally these appear in a discontinuous zone striking from the state of Vermont across the province of Quebec with a northeasterly, or east-northeasterly trend. The exact age of their intrusion is unknown, and it seems possible that it may not have been synchronous everywhere throughout the belt. Over a large part of the province these igneous rocks are found intruding Palæozoic sediments of Upper Cambrian and lower Ordovician age; in adjacent areas to the south, Silurian and early Devonian strata are not intruded,[3] and northeast of Black Lake and Thetford, in the township of Broughton, the time of intrusion seems to have been slightly earlier than in the greater part of the belt, though even there it is at least post-L'Islet in age and possibly late Cambrian. In general it may be said, therefore,

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[1] Geol. Surv., Can., Mem. 22, 1913.

[2] Ibid.

[3] Geol. Surv., Can., Sum. Rept. 1915, p. 214.

that the igneous rocks of the belt are principally post-Ordovician in age, and were probably intruded in pre-Devonian time. While the rocks comprising this igneous complex are, for the most part basic, they actually range in composition from the most basic to the most acid types; the series may be said to include dunite, peridotite, pyroxenite, gabbro, porphyrite, hornblende granite, and aplite; although in the field there is as a rule no sharp line of demarcation between any two of these owing to the occurrence of intermediate types. Dresser believes that the whole complex presents a gradual transition from the composition of a dunite to that of a granite. These and other considerations have led to the view that the various rock types have all been produced by differentiation from a single magmatic intrusion.

The rocks of the serpentine belt do not form a continuous unbroken band along their strike to the northeast, but appear as a series of isolated stock-like masses, which vary considerably, both in length and width. In the Black Lake-Thetford area, they outcrop in a northeasterly direction for a distance of about 10 miles and roughly form two parallel bands about 2 miles apart, each of which is from 2 to 3 miles wide. Black lake is situated at about the centre of the northern band, on its northwestern margin.

The two bands may be regarded as a batholith, or possibly a thick laccolith,[1] although actually they present the appearance of many isolated stocks, which may be connected with one another at depth. It is found that the different rock varieties are arranged in the order of decreasing density, or basicity, from the centre outwards. Thus in the ideal case and where there has been sufficient erosion, peridotite of the dunite type is exposed at the central part of such a stock, and as this is traced outward the rock is found to become progressively more and more acid, passing by gradual transitions through pyroxenite, gabbro, diabase, and porphyrite until at the margins of the mass it may be a normal hornblende granite. These different rock types are rarely sharply distinguished from one another, even the granite in some places having been observed as a differentiation product. More frequently, however, the granite, together with aplite, has been injected a little later than the main intrusion, and it then appears in the form of dykes, sills, and intrusive sheets cutting the other more basic types (Plate III).

It should be stated that in Black Lake area erosion has truncated the stocks or the foliated laccolith, to such an extent that the more basic central or lower phases, especially peridotite, are now exposed almost to the exclusion of the marginal differentiates of more acid composition,

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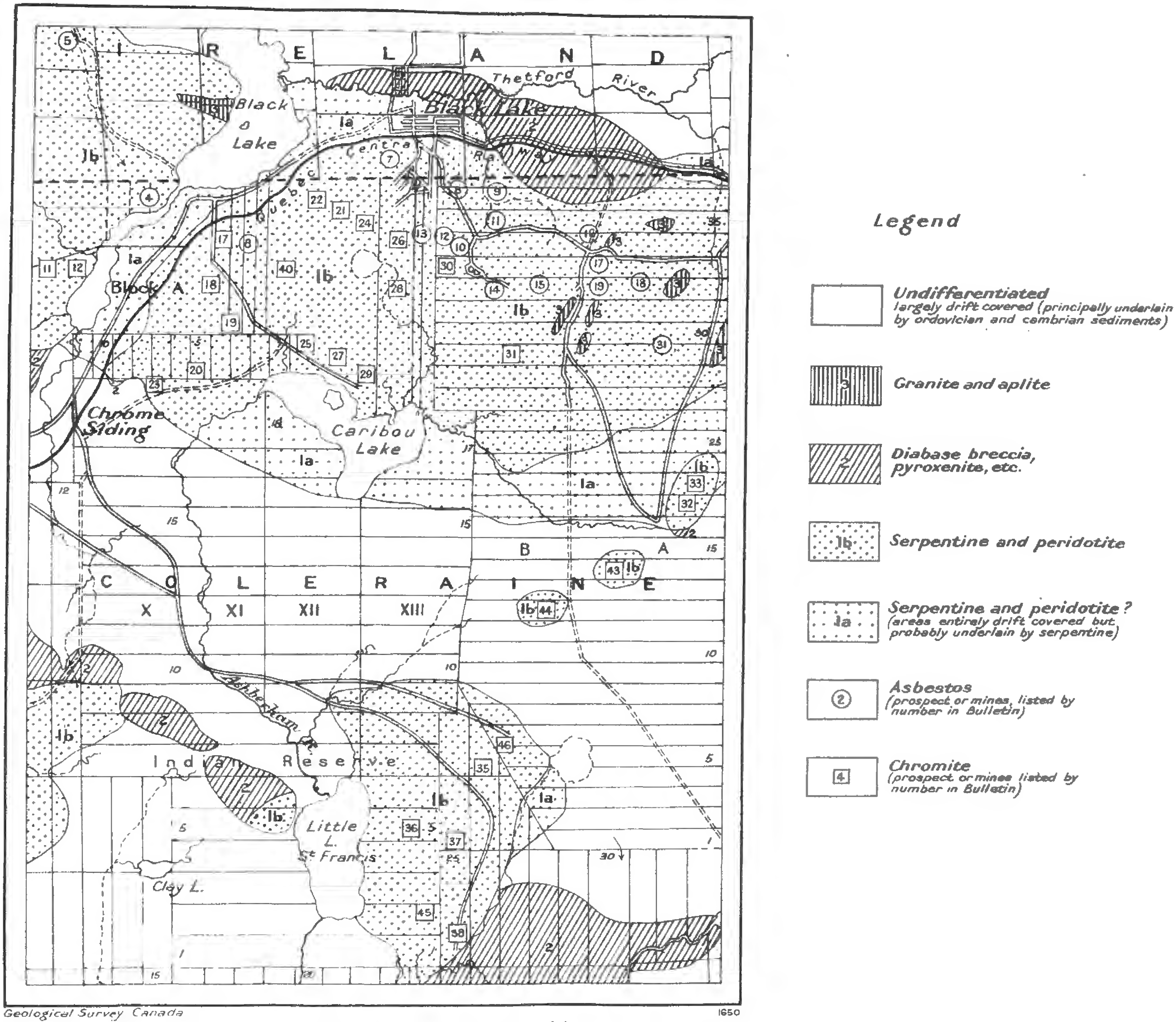
[1] Harvie, in a private communication, has informed the writers that in Garthby township, the serpentine has the form of a folded laccolithic sheet lying between quartzites beneath and slates above. See Sum. Rept., 1916.



Geological Survey Canada

Figure 1.

Diagram of part of **Coleraine Township, Megantic County, Quebec.**

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Miles

To accompany Museum Bulletin by E. Poitevin and R. P. D. Graham.

and granite appears only in the form of dykes. Further, although these igneous rocks are usually referred to collectively as the "serpentine belt," this is owing to the economic importance of the serpentine and not to its prominence; serpentine itself is the least abundant rock present, and is, of course, of secondary origin, having been derived from the alteration of peridotite and pyroxenite.

As a general rule in this area, foliation of the igneous rocks due to regional compression, although observable, is not so pronounced as it is in the Broughton region farther to the northeast. Faults of small displacement are numerous in the serpentine, but are less frequent in the other igneous rocks; many of these are due to small movements and have produced much slickensiding. Displacements of several feet are also frequently found. The rocks have a well-defined system of joints, which, in the peridotite, have determined the positions of many of the larger serpentine bands; in the serpentine itself the joint system is obscured by the shattered condition of the rock.

The general distribution of the rocks is shown in Figure 1, on which also are marked the locations of the principal asbestos and chromite pits. In each case these are indicated by a numeral, which for asbestos is inscribed within a circle, and for chromite within a square. These numerals are taken from Dresser's report, where they are shown on Map 23A. The more important occurrences of each of the two minerals are given below; in these lists, the principal localities at which specimens were collected are printed in italics.

Occurrences of Asbestos.

(4)	Coleraine	block A, Black Lake Chrome and Asbestos Company.
(5)	Ireland	range III, lot 26, King Bros.
(6)	Coleraine	block A, Black Lake Chrome and Asbestos Company.
(7)	"	" " *Standard Asbestos Company.*
(8)	"	" " *American Asbestos Company.*
(9)	"	range B, lots 30 and 31, *American Asbestos Company.*
(10)	"	block A, *American Asbestos Company.*
(11)	"	range B, lots 29 and 30, *Johnson's Asbestos Company.*
(12)	"	block A, *American Asbestos Company.*
(13)	"	" " *American Asbestos Company.*
(14)	"	range B, lots 27 and 28, west half, *Union pit.*
(15)	"	" " lot 28, east half, *Southwark pit.*
(16)	"	range A, lot 29, *Dr. James Reed.*
(17)	"	range A, lot 28, *Dr. James Reed.*
(18)	"	range B, lot 27, east half, *Bell's Asbestos Company.*
(19)	"	range A, lot 27, *Dr. James Reed.*

Occurrences of Chrome Iron Ore.

[11]	Coleraine	block A, Black Lake Chrome and Asbestos Company.
[12]	"	" " " " "
[17]	"	" " " " " *(Black Lake chrome pit).*
[18]	"	" " " " " *(Black Lake chrome pit).*
[19]	"	" " Black Lake Chrome and Asbestos Company.
[20]	"	range X, lot 19 northwest.
[21]	"	block A, *Black Lake Chrome and Asbestos Company.*
[22]	"	" " *Black Lake Chrome and Asbestos Company.*

[23] Coleraine range X, lot 9.
[24] " block A, *Black Lake Chrome and Asbestos Company.*
[25] " " " " " " *Caribou chrome pit.*
[26] " " " *Standard Asbestos Company.*
[27] " " " *Black Lake Chrome and Asbestos Company, Caribou chrome pit.*
[28] " " " Standard Asbestos Company.
[29] " " " *Black Lake Chrome and Asbestos Company, Caribou chrome pit.*
[30] " block B, lot 28, Union mine.
[31] " range B, lot 26, Ward and Ross.
[32] " " A, lot 16, *Hall chrome pit* (*Thetford quarry*), *Dominion Mines and Quarries.*
[33] " *range A, lot 17.*
[35] " range IV, lot 25, *American chrome pit.*
[36] " " XIII, lot 5, Indian Reserve.
[37] " " III, lot 25.
[38] " " II, lot 25, *Montreal chrome pit* (now Black Lake quarry), Dominion Mines and Quarries.
[45] " " XIII, lot 2, R. H. Gardiner.
[46] " " IV, lot 25, *American chrome pit.*

ROCKS OF THE SERPENTINE BELT.

As stated above, the serpentine belt consists of a series of igneous rocks which are, in very large measure, basic in composition. In Black Lake area, the series includes peridotite (partially altered to serpentine), pyroxenite, gabbro, diabase, porphyrite, granite, and aplite; all these various types are believed to have originated by progressive differentiation from a single parent magma, although the granite and aplite occur most frequently as dykes, etc., cutting the more basic rocks of the complex.

The following chemical analyses (made by M. F. Connor and reproduced from Dresser's report) show the composition of typical specimens of the more important varieties:

Rock Analyses.

	1 Peridotite	2 Serpentine	3 Pyroxenite	4 Diabase
SiO_2	38·16	40·08	46·30	42·96
TiO_2	none	none	trace	0·66
Al_2O_3	0·63	2·11	2·58	17·45
Fe_2O_3	3·32	1·13	3·45	2·29
FeO	4·76	1·70	3·57	11·04
MgO	41·84	*37·90	23·18	9·77
CaO	0·68	0·20	15·20	6·80
$\left\{\begin{matrix}K_2O\\Na_2O\end{matrix}\right\}$	0·20	0·10	0·15	1·51 1·93
$H_2O-110°$	0·47	1·35	0·66	0·47
$H_2O+110°$	9·63	13·89	4·77	4·75
Total	99·69	98·76	99·86	99·63

*MgO probably low.
1 Near Black Lake station.
2 Near Black Lake station.
3 Garthby, range II, lot 40.
4 Garthby, range II, lot 40.

PERIDOTITE.

The peridotite is massive, with a dark green colour, weathering to a somewhat rusty brown. Locally it is so rich in olivine as to become a dunite; the average type in this area, however, contains 80 to 90 per cent of olivine, together with a little pyroxene (usually orthorhombic) and a few feldspar individuals; magnetite and chromite are also commonly present as disseminated grains. The relative amount of pyroxene present in the rock can usually be roughly estimated by mere inspection of hand specimens, owing to the cleavage and somewhat bronzy lustre exhibited by this mineral; with increase in the amount of pyroxene the rock passes into a pyroxenite.

In thin sections, it is seen that the iron ore crystallized first, followed by the olivine. The crystals of olivine all have about the same size, and they are sometimes enclosed within the pyroxene, which forms rather large individuals, and was the last mineral to crystallize. The olivine is seldom entirely fresh; alteration has commenced as usual around the margins of the crystals, and along cracks traversing them, and as the metamorphism becomes more and more complete the rock passes over into serpentine.

SERPENTINE.

The serpentine, like the peridotite, is uniformly dark olive-green when fresh, weathering to a creamy colour. Since the alteration of the olivine of the peridotite commences on the surface of the crystals, and all stages of the process are to be met with, from the fresh original rock to the completely serpentinized variety, it is not surprising that it is often a matter of difficulty to distinguish between peridotite and serpentine in exposures, or even in hand specimens. For this reason, the two, as well as all partially altered peridotites, are generally referred to collectively at the mines as "serpentine," and, using the term in this sense, it may be said that many of the larger hills in the mining district, such as those near Black lake, are composed of serpentine (Plate IV). Serpentine proper, however, does not form large bodies; it occupies only small areas or zones within the peridotite (or related rock) where the metamorphism has been practically complete, and in this way it forms the country rock of all the asbestos and chromite mines.

The rock has a massive compact texture, but contains occasional crystals of unaltered or slightly altered pyroxene; on freshly broken surfaces these are easily visible, owing to their cleavage and lustre, while on weathered surfaces they stand out in relief, as may be well seen near the summit of the hill adjacent to Black Lake village.

When thin sections of the rock are examined, it is usually found that the whole of the olivine has been completely altered to serpentine, although the outlines of the original crystals may be frequently traced; minute veinlets of parallel fibres of chrysotile may traverse these, marking, no doubt, the positions of cracks in the crystals, along which the serpentinization commenced. Otherwise, the serpentine fibres have no regular orientation, and the material exhibits the usual aggregate polarization. The pyroxene, always present in small amount, is seldom completely altered, and frequently is only very little changed. Grains of iron ore are disseminated throughout the rock in much the same manner as that in which they occur in the original peridotite.

PYROXENITE.

When the rock contains more pyroxene than olivine, it is named pyroxenite, and it is with a rock intermediate in composition between pyroxenite and peridotite that the chromite ore-bodies are associated. The pyroxenite is a dark green rock, and it is often very coarsely crystallized, as for example near the Danville asbestos mines, where the constituent pyroxene crystals commonly show cleavage faces 2 inches across, and occasionally as large as 5 inches by 8 inches. The pyroxene, which is by far the most abundant mineral, is largely diallage, although numerous crystals have the optical character of enstatite, and others of augite. There are subordinate amounts of olivine and of plagioclase feldspar, the rock passing with increase of the plagioclase into gabbro.

GABBRO.

The coarse-grained types which are composed essentially of pyroxene and plagioclase are classed as gabbro. This type of rock is commonly met with between the pyroxenite and diabase; it may be seen exposed along the roadside near the southeast shore of Black lake, and in many other places near the foot of the serpentine hills. The rock consists of grey plagioclase and green diallage; but in place of the latter it may contain colourless hornblende, which is apparently secondary, and the rock may then more properly be called a gabbro-diorite.

DIABASE.

The diabase has the same mineral composition as the gabbro, but is greyish-green in colour and fine-grained, sometimes so much so that no individual minerals can be distinguished by the unaided eye. Its recognition in the field is usually facilitated by the occurrence throughout the rock of yellowish-green streaks and spots, very conspicuous on weathered surfaces, of epidote, which has been derived from the alteration of plagioclase, and, in part also, of pyroxene. Examination of thin sections shows the diabase to be always rather highly altered, the original primary constituents of the rock, plagioclase and pyroxene, having in very large measure been replaced by secondary products, including chlorite, epidote, quartz, calcite, leucoxene, and occasionally tufted aggregates of actinolite needles. Pyrite and magnetite are common accessory minerals.

It is believed that there was no essential difference in the original chemical composition of the gabbro and diabase, but that the same magma has given rise to one or other of these rocks, according to the conditions of cooling.

Diabase is well exposed along the Quebec Central railway between Black Lake and Thetford Mines, and also near the Roman Catholic church at Black Lake. In places, the rock, through loss of pyroxene, becomes more acid in composition and passes into porphyrite near the outer edges of the masses.

PORPHYRITE.

Marginal phases of the diabase frequently exhibit a porphyritic structure, in which phenocrysts of plagioclase are distributed through a groundmass which consists chiefly of fine granular chlorite and epidote. Although unimportant as regards the area it occupies, the porphyrite is noteworthy as marking the acid extreme of differentiation in many places.

GRANITE.

The granite is light-coloured, usually grey, but occasionally it has a pinkish tint. As compared with the basic rocks of the serpentine belt, it occurs only in small amount, but it is important owing to the favourable influence it seems to have had in the formation of the asbestos. Hills of granite are found in the northeastern part of Coleraine, and in other places the rock appears, probably as a direct differentiate, forming isolated masses which grade into diabase or porphyrite. More frequently, however, the granite occurs as dykes intersecting the more basic rocks, and such dykes may be seen in most of the asbestos pits.

The rock is composed usually of quartz, feldspar (both orthoclase and plagioclase), and hornblende; in general, biotite is absent, although in certain localities it appears as an important essential constituent, more especially in the central parts of the larger bosses of granite, and there also the structure is often porphyritic. A little iron oxide is usually present.

APLITE.

Ferromagnesian minerals are absent from some of the dykes. In such cases the dykes are composed of quartz and feldspar only, and often they are so fine-grained that the constituent minerals cannot be distinguished in hand specimens. Such aplite dykes, while comparatively rare, are of interest as representing the acid extreme reached in the differentiation of the magma, from which all the various rock types described above are believed to have separated in turn.

ORIGIN OF THE MINERALS.

The mode of origin of the serpentine (including chrysotile), chromite, brucite, hydromagnesite, etc., is well established or obvious and need not be discussed here.

Many of the other minerals, however, occur in a somewhat unusual manner, which calls for an explanation. These are for the most part alumino-silicates rich in lime, such as diopside, vesuvianite, and grossularite. They are commonly found filling dyke-like fissures within the peridotite, or its altered equivalent, serpentine; these dykes sometimes consist entirely of compact granular aggregates of diopside, vesuvianite, or garnet crystals.

The minerals just enumerated include some of the species most commonly formed in the contact metamorphism of impure limestones. In the present case, however, both the attitude of these deposits and the absence of limestone beds, preclude the possibility of their having originated in this way. The minerals do not occur as a contact phase, but as dykes or veins well within the basic igneous masses; and, moreover, the intruded sediments around the margins of the igneous masses do not include any limestone beds, but consist of Cambrian slates, sandstones, and quartzites.

It becomes necessary, therefore, to seek for some other source for the lime and, at first sight, the igneous rocks with which the minerals are associated do not appear to be the source. The following figures taken from analyses by M. F. Connor, and quoted in Dresser's report, give the percentage of lime in the principal rocks which make up the mass of the serpentine belt:

Lime Content of Rocks.

CaO percentage	Rock	Locality
0·68	Peridotite	Near Black Lake station
0·20	Serpentine	" " "
15·20	Pyroxenite	Lot 40, range II, Garthby, Wolfe county
6·80	Diabase	" " " "

Thus the peridotite, which constitutes by far the major portion of the igneous masses as exposed in this area to-day, contains less than one per cent CaO.

While the writers cannot claim to have made an exhaustive study in the field of the mode of occurrence of these minerals, they have had an opportunity of examining them at many of the pits; as a result of these observations, they are of the opinion that the minerals were deposited in their present positions as a direct result of the last phases of the intrusion, and that the lime they contain was probably extracted by magmatic waters from the already consolidated portions of the igneous mass. The processes involved are outlined below.

It may be assumed that the large bodies of molten magma, which gave rise to the rocks of the serpentine belt, contained certain amounts of aqueous vapour and other volatile constituents which remained in the fluid state until after the main mass of the magma had crystallized. In the present case, the magma, during crystallization, underwent progressive differentiation, until the portion last remaining in the molten condition had approximately the composition of a granite; this then invaded the already cooling, solid mass, giving rise to dykes and other intrusive forms. All the aqueous vapour and other volatile constituents of the original magma (the so-called magmatic "extract") must have been concentrated in this last acidic differentiate and expelled when it consolidated. Although this was the last phase of the intrusion, and represents a period of relatively low temperature, these residual magmas were sufficiently fluid from the presence of hydrous and other volatile constituents, to permit their circulation through the enclosing rocks.

It is not believed that this fluid, as it originally separated from the magma, was sufficiently rich in lime to afford such minerals as diopside, vesuvianite, etc.; its chemical nature, however, suggests that it would have a very considerable solvent action on the walls of the fissures through which it passed, and it is believed that it has been responsible for the serpentinization of the rock in the neighbourhood of these fissures. The peridotite, however, always contains some monoclinic lime-bearing pyroxene, and the amount of this mineral is considerable in the rock associated with the chromite deposits, which is about intermediate in composition between a peridotite and pyroxenite. It is significant, therefore, that the dykes bearing the above-mentioned silicates are more frequently met with, so far as is at present known, in the chromite pits than in the asbestos quarries. As there is an almost complete absence of calcite, in veins or otherwise, traversing these rocks, the writers are of the opinion that the lime (and also alumina) present in the original rock and not required for the formation of serpentine, has been carried away in solution as silicate. Then, as these residual magmatic fluids rose in the fissures, there arrived a time when, either owing to their cooling or to the fact that they were under diminished pressure, they became unstable and commenced to crystallize out, forming "dykes" or veins of such highly calcareous minerals as vesuvianite, grossularite, and diopside, the particular mineral formed depending, no doubt, on such factors as the composition of the fluids and on the temperature and pressure. It will be noted that these are all high temperature minerals, that do not readily crystallize except in the presence of a mineralizer such as would be afforded by the volatile constituents of the residual magma.

Although granite and aplite dykes are quite common, traversing the peridotite and serpentine in all the asbestos and chromite pits, no reference is made in Dresser's report to their displaying pegmatitic structure. True pegmatite dykes do, however, occur, although as a rule they are much altered, some of the feldspar being almost entirely converted into kaolin. Molybdenite, zircon, and tourmaline have been found in small quantities in such dykes at one or two localities, as noted below. Some of the coarse diopside "dykes" also have a structure comparable with that of pegmatite.

According to the view here outlined, the "dykes" of lime-alumina silicates are closely related to the granite and aplite dykes, the fluids bearing these minerals in solution, or in aqueo-igneous fusion, having passed along the same series of fissures in the already solid portions of the magma, and crystallized out as soon as the necessary conditions of temperature and pressure were reached.

Some aplite dykes, examined in thin section, were found to be highly garnetiferous, though others were more or less free from this mineral. Many were found to be traversed by cracks and veinlets cemented by fine granular to compact grossular garnet (Plate IX). This last feature might be taken as supporting the view that the granitic residue of the magma first assumed the solid state, and was later injected by the residual magmatic waters which had, in the meantime, become enriched in such constituents as lime as a result of their solvent action on the walls of the fissures.

The dykes composed entirely of granular or massive garnet, such as those occurring at the Southwark pit and elsewhere, may then be regarded as the limiting phase of the above process, where, the granitic differentiate of the magma having all consolidated, the still fluid magmatic waters have continued to flow along fissures and ultimately gave rise to dykes of garnet. At other localities, where different conditions obtained, vesuvianite or diopside appear instead of grossularite.

MINERALS.

Altogether, some thirty-four mineral species have been observed in the various asbestos and chromite pits in the area. These are described in the following pages, the sequence adopted being that of Dana's System of Mineralogy.

Native Element.

DIAMOND.

Microscopic crystals of diamond were obtained from chromite of the Montreal pit by R. A. A. Johnston, mineralogist of the Geological Survey. The following is his description of the diamonds and the method of extraction.[1]

"No. 1. This specimen consisted of a massive, shiny black, somewhat granular chromite, more or less intimately mixed with some greyish serpentinous material.

"A fragment was broken from this specimen and crushed to a powder passing a sieve of sixty meshes to the linear inch; this powder was, when treated in a separatory tube with Thoulet solution, of a specific gravity of about 3·0; the heavier separate which settled at the bottom of the tube weighed after washing and drying approximately 11 grammes; this was mixed with 50 grammes of chemically pure dry carbonate of soda and the mixture fused in a large platinum crucible at a cherry red heat for four hours; after cooling the melt was digested in distilled water to complete disintegration, the supernatant liquid filtered off, and the residue treated with hydrochloric acid to remove oxides of iron, magnesium, etc. About half of the chromite was removed in these operations. This course of procedure was repeated several times. It soon became evident that this method was of little effect upon the coarser particles of chromite that were being left after each set of operations. Fusion with bisulphate of potassium was then resorted to, and the residue from this treatment, which showed a number of minute diamonds along with some undecomposed chromite, was freed from the latter by a final fusion with sodium carbonate.

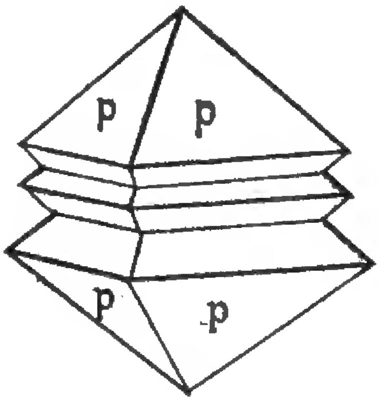

Figure 2. Diamond extracted from chromite collected at the Montreal chrome pit; the crystals are microscopic in size, the one shown in the figure being enlarged nearly 1,000 diameters; it exhibits a parallel growth of octahedra, a feature which has been frequently noted in these minute crystals.

"The residue of diamonds obtained in the manner indicated above was found to weigh nearly 7 milligrammes or 0·06 per cent of the heavy separate operated upon, which constituted nearly the whole of the specimen.

"These diamonds appear to the naked eye as nothing more than dust particles; under the microscope, however, with a moderate power they

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[1] Ibid., pp. 83-84.

are seen to be perfectly transparent and beautifully crystallized; the most common form is that of the simple octahedron; many of them, though, are apparently combinations of the cube and octahedron. The hardness could not be determined with accuracy owing to the very small amount of material available for experiment, but in the course of their removal from a beaker with the aid of a camel's hair brush, it was noted that even such light pressure as was occasioned in this way was sufficient to cause abundant fine scratches upon the glass. When exposed to radium emanations they can be seen to fluoresce distinctly, a test which is regarded as conclusive evidence of the character of the mineral.

"No. 2. From the same locality as the preceding specimen. A dull greenish grey serpentine. Treated in the same manner as No. 1, it gave negative results.

"No. 3. From the same locality as No. 1. A bright pink vesuvianite. It likewise gave negative results.

"No. 4. From near Black Lake station. A dull grey peridotite. It also gave negative results."

When examined with a high power under the binocular microscope, the crystals are found to have, in most cases, an octahedral habit, and they frequently exhibit a parallel growth in the direction of one of the crystal axes, as shown in Figure 2, which represents a typical crystal enlarged nearly one thousand diameters.

Sulphides.

MOLYBDENITE.

Dresser[1] mentions the occurrence of molybdenite in very small amount at the Caribou pit; he states that the mineral was found in veinlets, enclosed in vesuvianite.

The writers have collected a few specimens carrying molybdenite both from the Caribou pit and also from the American chrome pit. In each case the mineral is disseminated through a garnetiferous aplite in the form of minute flakes. These are seen especially near the contact between the aplite and the serpentine, and occasionally also encrusting the serpentine as a film at the immediate contact. The molybdenite, however, is by no means abundant, and was observed in a few specimens only.

A microphotograph of a thin section of the aplite from the Caribou pit is shown in Plate IX and the rock is described under garnet on page 50. One flake of molybdenite in this rock had a diameter of one centimetre, but otherwise, both at this locality and also at the

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[1] Ibid, p. 84.

American chrome pit, the crystals observed were in general very much smaller.

CHALCOPYRITE.

Chalcopyrite is found at many places along the serpentine belt, as a primary segregation, and associated especially with the diabase. In general, the mineral occurs only in small amount, and this is particularly true as far as the Black Lake area is concerned. On many of the specimens collected, minute specks of a brass-yellow mineral, almost microscopic in size, have been observed; these are soft and react for copper and are no doubt chalcopyrite.

PYRITE.

Like the chalcopyrite, this mineral has been observed only as a primary constituent of the diabase and gabbro, through which it is disseminated as occasional microscopic grains.

Oxides.

ANHYDROUS OXIDES.

QUARTZ.

Apart from its occurrence as a constituent of the granite and aplite dykes, quartz is entirely absent from the area. A few crystals were obtained from a boulder found about 5 miles northwest of Black lake; these are associated with apatite, and the occurrence is fully described under that mineral on page 81.

The quartz crystals are perfectly colourless and transparent, and they vary in size up to 5 mm. in width and 1½ cm. in length. The very small crystals are simple combinations of the prism with the rhombohedra $r(10\bar{1}1)$ and $\rho\,(\bar{1}011)$, but many of the larger individuals exhibit in addition faces of the right trigonal pyramid $s(11\bar{2}1)$. A trapezohedron is also present on several of the crystals, and in all cases where this face was observed the crystals were found to be right handed.

The prism faces are striated horizontally on all the crystals; the rhombohedron is quite smooth and bright on the small crystals, but dull and lustreless on the larger ones. The trigonal pyramid is bright and free from striæ.

Some doubtful new forms were observed on one of the crystals measured. The principal forms present were $b(10\bar{1}0)$, $r(10\bar{1}1)$, $\rho(\bar{1}011)$, $s(11\bar{2}1)$, $N\cdot(21\bar{3}2)$, $R\cdot(\bar{2}\bar{1}33)$. The edge rs is replaced by four very narrow oscillation faces, which, in their order from r to s, have the indices $13\cdot6\cdot\overline{19}\cdot6$ $(+\frac{13}{6}\ 1)$, $9\cdot5\cdot\overline{14}\cdot5$ $(+\frac{9}{5}\ 1)$, $13\cdot9\cdot\overline{22}\cdot9$ $(+\frac{13}{9}\ 1)$, $6\cdot5\cdot\overline{11}\cdot5$ $(+\frac{6}{5}\ 1)$. Of these, the last is a fairly well-defined face, but the others are little more than striations or lines. The measured and calculated angles for these forms are as follows:

Form G^1	φ		ρ	
	Measured	Calculated	Measured	Calculated
$+\frac{6}{5}1$	27° 03′	26° 59′	67° 38′	67° 35′
$+\frac{13}{9}I$	24 09	24 00	69 48	69 42
$+\frac{9}{5}I$	20 31	20 38	72 15	72 14
$+\frac{13}{8}I$	17 56	17 59	74 59	74 26

As these indices are calculated from single measurements only, the forms are not to be regarded as firmly established.

MAGNETITE.

Magnetite occurs as a primary constituent of the basic igneous rocks, and also in the form of small irregular masses and veinlets within the massive serpentine, or associated with the chrysotile; it is also found intergrown with the chromite.

In one interesting occurrence, nodules of magnetite up to 1·5 cm. in diameter are completely enclosed within chrysotile, in such a way that the specimens have the appearance of a knotted string. However, when the chrysotile is stripped from the magnetite, the surface of the latter is found to bear the impressions of the asbestos fibres, indicating that in this instance the magnetite may have been formed later than the chrysotile.

CHROMITE.

Deposits of chromite of workable size have been found at many points in the neighbourhood of Black lake, most of the productive mines being situated along the great serpentine ridge, which attains a height of 900 feet above the track of the Quebec Central railway; the locations of the more important pits are shown in Figure 1, page 5.

Occurrence.

The chromite does not occur in well-defined crystal individuals, but forms fine granular aggregates or apparently compact masses, having a black or slightly brownish-black colour, pitchy sub-metallic lustre, and brown streak. The compact ore often has a platy structure, breaking along ill-defined planes of parting, which, in some cases, are coated with a thin film of a white flaky biaxial mineral, which is probably clinochlore. The surface of the ore along such partings may also be highly polished or slickensided, due to differential movement or faulting subsequent to its solidification.

The principal deposits of chromite have been found in a rock intermediate in composition between peridotite and pyroxenite, which represent the two most basic, and earliest consolidated, phases of the differentiation of the magma which has given rise to the igneous complex known as the serpentine belt. In shape, the ore-bodies are roughly lenticular, and they vary in size from small pockets up to masses containing thousands of tons. As a general rule there is no sharply defined wall bounding these lenses, but the ore passes by rather gradual transitions into the country rock, through which chromite is then dispersed as scattered nodules and grains the size of a pea or smaller. When examined in thin section under the microscope, the chromite in these rocks is seen to occur in isolated grains, and it displays the relations of a primary mineral.

A very interesting occurrence of chromite is that at the Martin Bennett property (lot 28, range I, Ireland township). Besides occurring in massive form the mineral is also found as disseminated nodules enclosed in the serpentine adjacent to the massive chromite ore-bodies. These nodules are of all sizes, from mere grains up to masses several centimetres in diameter; one of the largest collected had dimensions 3½ x 2½ x 1½ cm. At first sight they appear to be made up entirely of massive chromite, but, when broken open, it is found that there is, in addition, a fair amount of interstitial serpentine, in part altered to brucite.

At the Hall chrome pit (Plate V) a granular chromite was observed, which is so friable that it can be readily crumbled in the hand.

Analyses show that all the rocks of the serpentine belt contain traces or small percentages of chromium; this is probably present mainly in the form of chromite, disseminated through their mass in an extremely fine state of division, though it is possible that a little chromium may also enter into the composition of some of the ferromagnesian minerals which these rocks contain.

Origin.

Considerations such as those just enumerated, regarding the manner and attitude in which the ore occurs, have led to the view that the chromite was an original constituent of the magma, from which it separated by differentiation. This hypothesis was first advanced by F. D. Adams[1] in 1894, and investigators who have since examined the deposits in the field have been practically unanimous in confirming this view. The evidence for this mode of origin is thus summarized by Dresser:[2] "The microscopic evidence that chromite occurs in isolated grains as a primary mineral, its general occurrence, in traces at least,

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[1] Trans. Province of Quebec Mining Association, 1894.

[2] Op. cit., p. 90.

in all the rocks of the series, the shape of the deposits, their relation to the wall rock, and the fact that they occur principally in a particular phase of the intrusive complex, viz., in transition rock between peridotite and pyroxenite, all go to support the opinion that the deposits were segregated from the magma of the original rock before it was completely solidified."

Further evidence supporting the view that the chromite is primary is afforded by the discovery, made by R. A. A. Johnston, of microscopic crystals of diamond enclosed within the mineral. The theory that the ore was an original constituent and an early differentiate or segregation product of the magma receives additional support from the fact that the granitic dykes, which represent the last phase of differentiation of the same magma, and which may be seen accompanying the chromite in most of the pits, have certainly been injected at some time subsequent to the formation of the ore-bodies.

The frequent occurrence of granitic dykes within, or close to, the ore-bodies has been noted by many observers. F. Cirkel, although expressing the belief elsewhere in his report that the chromite was formed during the cooling of the magma, goes so far as to state that these intrusive dykes exert "quite a favourable influence upon the deposition of the mineral."[1] The field evidence, however, all points to the ore as having been solid before the dykes were injected, and the present writers cannot subscribe to the opinion that the latter could have had any influence, favourable or otherwise, on its deposition.

If the dykes are actually more numerous in the vicinity of the rich ore lenses than elsewhere within the peridotite and other associated rocks, a point which has not hitherto been clearly demonstrated, it might be explained on the assumption that, as compared with the normal igneous rocks, the ore would constitute a brittle mass much more susceptible to fracturing than the relatively plastic peridotite. Further, the contact between the ore and the country rock, although nowhere sharply defined, should form a zone of weakness peculiarly prone to the development of fractures to be later filled by intrusives. This might explain the fact which has been repeatedly noted, that the ore-bodies are at times completely cut off by dykes.

Where such magmatic injections have passed along fissures within the ore, they have frequently ripped off and trapped fragments from the walls, and these are now seen embedded within the dykes. The general shattering of the rocks which preceded or accompanied this last phase of igneous activity, and whose effects are seen especially in the peridotite, extended into the ore-bodies; as a consequence, the ore in many places

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[1] Mines Branch, Can., "Chrome iron ore deposits in the Eastern Townships, Quebec," Report No. 29 1909, p. 25.

has a brecciated character, and subangular blocks and fragments are connected by stringers, veins, or wider bands of dyke material. The cementing material in many such cases is not granite at all, but either compact diopside or vesuvianite, which has resulted from the pneumatolytic action following or accompanying the granite intrusions, as discussed in an earlier section (p. 11).

It may be noted here that the observations of the writers lead them to believe that many of the dykes associated with the chromite, as well, perhaps, as some of those cutting the peridotite and other rocks in the Black Lake area, which have generally been referred to as "granite" or "granitic," will be found on closer inspection to be composed of compact diopside, grossular garnet, or vesuvianite; Cirkel,[1] for instance, in describing the dykes of the Montreal chrome pit (Plates VI and VII) says:

> "Another feature of the granitic dykes in the Montreal pit worthy of attention is the peculiar colour which some of them exhibit. Small dykes have a distinct pink colour, and samples of the dyke granite analysed showed traces of chromium and manganese. However, as chromium with alkali (of the feldspar) gives a distinct purple colour, it is fair to assume that the purple colour of the kaolinized granite is simply due to the presence of chromium."

It is quite certain that the dykes to which reference is here made are those composed of lilac vesuvianite, and described elsewhere (p. 51), but had it not been for their exceptional colour there would be nothing in the description 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.

The shattering and brecciation of the ore have been accompanied by faulting and slickensiding, and in some cases entire ore-bodies have been cut off along the planes of such movement.

While claiming that the chromite is in the main primary, Dresser[2] 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 ultra basic offshoots of chromite-bearing portions of the intrusive rock."

The view that there may have been locally a partial re-solution 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

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[1] Op. cit., p. 27.

[2] Op. cit., p. 90.

Montreal chrome pit. The vesuvianite is 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.

Microscopic Character.

Microscopic examination of thin sections of the ore by Dresser revealed the interesting fact that it is not homogeneous but is made up of two distinct varieties of chromite, viz., a reddish-brown translucent substance and a black opaque material. The relative amounts of these present in the ore are variable, and Dresser was able to establish the fact that the high-grade ores contain as much as 90 per cent of the translucent variety, while in poor ores the black variety is greatly in excess. With regard to the microscopic character of the ore, he says:

"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."[1]

The microphotograph of a thin section reproduced in his report shows the translucent variety with fairly sharply defined crystal outline, while the black material fills irregular spaces and sends off arms into the other. Judging from the photograph it would seem that these arms follow planes of cleavage or partings, since they show an obvious tendency to parallelism, both among themselves and also to the crystal outlines. In this connexion Dresser remarks: "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."[2]

Chemical Composition.

Dresser treated a quantity of the crushed ore on a Wetherell magnetic separator, in an attempt to isolate the two varieties, the translucent

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[1] Op. cit., p. 77.

[2] Op. cit., p. 79.

reddish-brown material being less magnetic (as well as lighter and more friable) than the black opaque portion. The two portions were then analysed and yielded the following results:[1]

Analyses of Chromite.

	Reddish-brown fraction	Black opaque fraction
SiO_2	6·54	4·10
Al_2O_3	10·34	11·34
Cr_2O_3	45·30	48·20
FeO	13·94	15·66
MnO	0·32	0·36
CaO	2·50	1·50
MgO	16·70	15·66
CO_2	2·46	1·45
TiO_2	0·12	0·12
H_2O	0·12 2·03	0·08 1·97
	100·37	100·44

Although it is not so stated in Dresser's report, the writers are informed by M. F. Connor, by whom the analyses were made, that there was no special determination of the ferrous iron in the samples, but that in each case the total iron was estimated as Fe_2O_3, and the results so obtained then reduced to the form FeO. It is not probable, however, that the whole of the iron is actually present in the mineral in the ferrous condition, and for this reason it is impossible, from the above analyses, to calculate formulæ to represent the compositions of the two varieties. All that can be said is that the black fraction is the richer in oxide of chromium and also of iron and aluminum, while the reddish-brown material contains relatively more of the alkaline earth metals, calcium and magnesium. In each case the presence of about 2 per cent of water, which is only expelled on ignition, indicates an admixture of some mineral containing water of constitution, and this is possibly a hydrous magnesium silicate, such as serpentine or clinochlore.

HYDROUS OXIDES.

LIMONITE.

Yellow hydrous oxide of iron forms a thin film on weathered surfaces of the basic rocks, such as diabase. Earthy limonite was also found, as an alteration product of siderite, on the apatite specimens described on page 81.

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[1] Op. cit. p. 78.

In Dresser's report the molecular ratio for MgO in the black opaque port on is given as 0·341; this should be 0·391.

BRUCITE.

Brucite occurs as an alteration product of the serpentine, and is probably widespread in the area, though specimens were collected from only two or three localities.

At the American asbestos pits this mineral occurs lining fissures in the massive green serpentine, which is also traversed by veins of chrysotile asbestos. The brucite crystals, having a diameter of about 1 mm., are colourless and transparent, with a pearly lustre on the basal plane, which is usually triangular in outline. The crystals are not sufficiently good for goniometric measurement, but examination under the binocular microscope shows them to be combinations of the rhombohedra $r(10\bar{1}0)$ and $p(20\bar{2}1)$ with the basal pinacoid. Associated with the crystals there is frequently a white pulverulent product, and generally also hydromagnesite in white acicular needles forming radiated groups.

Other specimens were collected by Mr. Jos. Johnston from the Consolidated Asbestos and Chrome property, where they occur in a new pit operated by Mr. Chretien. There the brucite occurs as veinlets, both in the serpentine and in massive chromite, forming foliated masses having a somewhat feathery appearance due to a radial arrangement of the cleavage plates. Normal to the cleavage, these flakes are colourless and have a pearly lustre, but when viewed transversely the mineral has a greenish colour and dull lustre. When the fissures are irregular, especially in the chromite, minute crystals of similar habit to those described above are found. Associated with the brucite are small octahedra of magnetite, rosettes of aragonite, and the alteration products already referred to. A similar occurrence to the last, in which brucite is associated with serpentine and chromite, is that at the Martin Bennett property. Reference has already been made to this under chromite.

A very interesting specimen of brucite, pseudomorphous after chrysotile, was received by the writers from Professor C. Palache, who had collected it in 1913 when he visited the asbestos district with one of the Geological Congress excursions. The exact locality for this is not known. The specimen, of a bluish-green colour, is composed of fine fibres, packed closely together in parallel position, and having a length of about 3 cm. Examination shows the fibres to be largely brucite (nemalite) but, in part also, and especially toward the extremities of the fibres, they are chrysotile. There is sufficient hydromagnesite present to cause the material to effervesce when treated with hydrochloric acid; on warming, the brucite also dissolves, and fine threads of chrysotile are left insoluble. It is clear that the material was originally a vein of chrysotile, which subsequently underwent alteration, fibre by fibre, each from its surface inward, to brucite, although in the specimen examined the change is not quite complete. Further changes have converted part of the brucite to hydromagnesite.

Carbonates.

ANHYDROUS CARBONATES.

CALCITE.

Calcite occurs in small amounts throughout the area, forming veinlets and filling fissures in the various rocks; and, where it is found in vugs and druses, it is sometimes well crystallized. Transparent crystals with bright faces are, however, the exception. As a general rule they are white and drusy, with rounded edges. In some cases the drusy coating is obviously the result of a later deposition of microscopic calcite crystals on the plane surfaces of the original transparent crystals, since the coating can occasionally be removed, leaving the faces of the underlying crystal sufficiently bright to admit of measurement on the goniometer. At other times the rounded drusy surfaces appear to have been produced by a partial re-solution of the crystal.

An exhaustive study of the crystallography of the calcite was not attempted; none of the crystals appeared to be very complex in forms and those present could, as a rule, be easily identified by inspection. Some of the best crystals were measured on the two-circle goniometer, and in doubtful cases the forms present on the drusy ones were confirmed by measurement with the contact goniometer. The forms observed are given in the following table:

Crystal Forms of Calcite.

Dana		Goldschmidt (G_2)		Michel-Levy
m	$10\bar{1}0$	b	$11\bar{2}0$	e^2
r	$10\bar{1}1$	p·	$11\bar{2}1$	p
M	$40\bar{4}1$	m·	$44\bar{8}1$	e^2
Γ	$35\bar{8}4$	b⁝	$\bar{1}\bar{1}\cdot\bar{2}\cdot13\cdot4$	$d^{\frac{1}{5}}$ $d^{\frac{1}{2}}$ $b^{\frac{1}{4}}$
f	$02\bar{2}1$	ϕ·	$\bar{2}\bar{2}41$	e^1
ϕ	$05\bar{5}4$	ν·	$\bar{5}\cdot\bar{5}\cdot10\cdot4$	$e^{\frac{2}{3}}$

The measured and calculated angles for the form *Γ* ($35\bar{8}4$) are as follows:

	Measured	Calculated
φ	.... 8° 05'............	.... 8° 13'
ρ	............60 00............	.................59 55

Occurrences.

Montreal Chrome Pit. The best crystals were found at the Montreal chrome pit, especially in vugs in the massive lilac vesuvianite rock, or coating the slickensided surfaces of certain fissures in the serpentine. Three different habits were noted: one of these shows the simple acute negative rhombohedron $f(02\bar{2}1)$, like the common form of "*Fontainebleau sandstone*"; a second habit is also a simple negative rhombohedron, the so-called "cuboid" $\phi(05\bar{5}4)$, and crystals of this type might easily be mistaken for chabazite. In each case these usually occur as interpenetration twins, with twin plane $c(0001)$. The third habit is prismatic, the forms exhibited being $m(10\bar{1}0)$, the positive rhombohedra $r(10\bar{1}1)$ and $M(40\bar{4}1)$ and the scalenohedron $\Gamma(35\bar{8}4)$; M is larger than r while $\Gamma(35\bar{8}4)$, although appearing as very bright facets on all the crystals measured, is almost microscopic in size.

The rhombohedral crystals are seldom more than 1 mm. in diameter; the prisms are similarly thin needles with a length up to 2 cm.

The massive calcite occurring at this pit is occasionally manganiferous, forming transparent or translucent cleavable masses of lilac colour.

Caribou Pit. Crystals of calcite are found within the druses of a miarolitic granite of aplitic character at this pit; the calcite, in simple negative rhombohedra $f(02\bar{2}1)$, rests upon crystals of white albite which forms the walls of the druses.

American Chrome Pit. The grossular garnet described below (p. 48) as exhibiting the very rare cube faces, is associated with massive white calcite.

DOLOMITE.

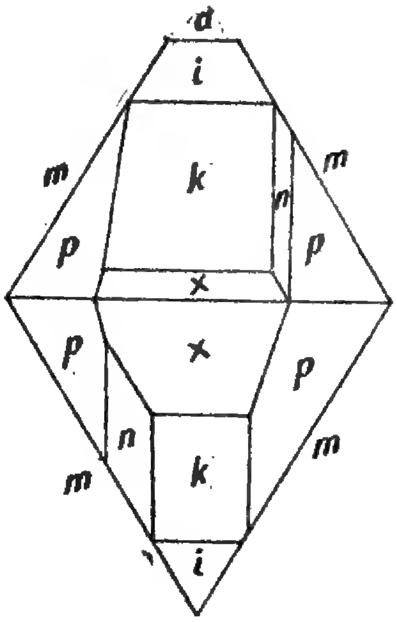
Although carbonates of lime and magnesia are abundantly associated with serpentine in many regions where the latter rock is found, in the serpentine belt of Quebec they are seldom met with, and then only in small amount. Dolomite may occasionally be seen as very narrow veinlets following joint planes which traverse the massive serpentine. Poorly crystallized specimens were collected from the Black Lake Consolidated Company's chrome prospect on the east side of Kings mountain. The crystals are very flat rhombohedra, with a somewhat lenticular form and a rough drusy surface.

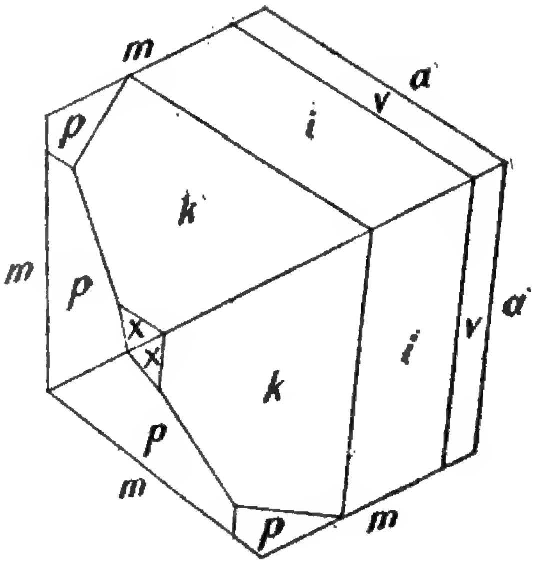
SIDERITE.

Only one occurrence of siderite was observed. Brown rhombohedra, with a diameter of about half a centimetre, are associated with the apatite crystals described on page 81.

ARAGONITE.

As with calcite, the best examples of aragonite were collected from the Montreal chrome pit, where it occurs in druses associated with vesuvianite in its various colours, colourless diopside, yellowish-green garnet, and clinochlore. With the exception of calcite, it has been the last mineral to be formed here. The crystals are colourless and transparent or occasionally milky, and, for the most part, they are simple





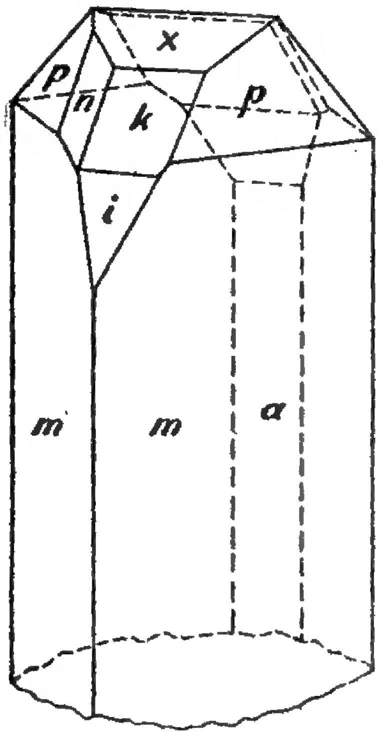


Figure 3. Aragonite from Montreal chrome pit, simple crystal with prominent development of the prism *m* (110).

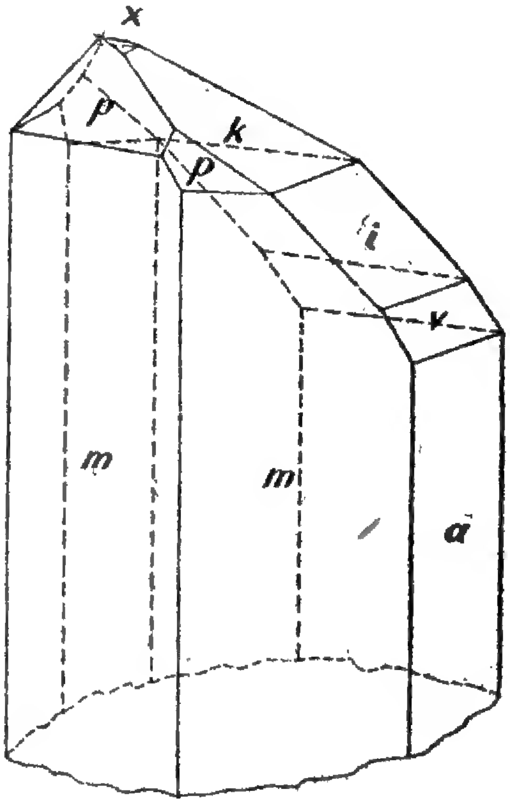


Figure 4. Aragonite from Montreal chrome pit, crystal twinned on *m* (110).

individuals having an extremely thin bladed habit, tabular parallel to the brachy-pinacoid, a(010); less frequently they are twinned on m(110), and sometimes stout six-sided prisms are met with as the result of the repetition of this mode of twinning.

The bladed crystals occur either as isolated individuals or in radiated or tufted groups, implanted upon the vesuvianite or other matrix; they measure less than 1 mm. across the blades, with a length up to about 3 cm., and they are seldom doubly terminated. The forms most frequently present are: a(010), m(110), v(031), i(021), k(011), x(012), p(111) and n(122); of these, the domes (v,i,k,x) and the unit pyramid (p) are usually developed to about the same size, but n was only observed as a narrow line face truncating the edge between k and p. In the prism zone, the brachy-pinacoid a is present almost to the exclusion of the prism m in the bladed crystals, but at times the mineral presents a different habit, with the prism (m) as dominant form, as shown in Figure 3. It may also be noted that in several of the crystals examined the forms m and a do not form a true prismatic zone, being in reality an extremely steep pyramid and brachy dome, respectively, inclined to the vertical axis at angles of from 3 to 8 degrees.

The twin crystals show two or more individuals in juxtaposition without re-entrant angles; a common type is illustrated in Figure 4. They exhibit the same forms as the simple crystals, except that n (122) was not noted; the dome x(012) also is usually not so large as the other forms.

Aragonite in acicular crystals was also observed filling small cavities in crystalline masses of amber grossularite from the Hall chrome pit.

HYDROUS CARBONATES.

HYDROMAGNESITE.

Hydromagnesite is most frequently associated with brucite, of which it is the common alteration product. It forms stellate groups of radiated acicular crystals, having a white colour and somewhat silky lustre. Under the microscope the crystals show parallel extinction, and in convergent light an optic axis is usually seen to emerge obliquely, the plane of the optic axes lying at right angles to the length of the blades. The mineral also occurs as a white chalky incrustation. The best specimens collected came from the American asbestos pits, but good specimens were also obtained at the Consolidated Asbestos and Chrome property from a new pit operated by Mr. Chretien; at the latter locality the radiated groups of needles, associated with the chromite, have an azure-blue colour which was found, on microchemical analysis, to be due to nickel.

In most of the open pits, joint planes in the massive serpentine are seen to be coated in places with a thin deposit of hydromagnesite, in the form of stellate groups of acicular crystals.

STICHTITE.

The precious serpentine collected at the old Megantic mine, and described on page 77, sometimes includes small patches, or is traversed by narrow veinlets, of a lilac coloured mineral which has been identified as stichtite. Robert Harvie collected the first specimens of stichtite that were identified by the authors.

Occurrence in Tasmania.

This rare mineral was first found, associated with serpentine, near the Adelaide mine at Dundas on the west coast of Tasmania, and up to the present time it has not been recorded from any other locality. The literature dealing with the mineral has been collected and reprinted in a report[1] of the Tasmanian Department of Mines, published in 1914. In view of its interest in connexion with the occurrence at the old Megantic mine, a brief review of the history of the original stichtite is given below.

Petterd describes the mineral as occurring in irregular masses, veins, and blebs in a pale yellowish-green serpentine, within which, also, it more rarely forms ill-defined bands. At times the serpentine is speckled with patches of stichtite, which vary in size from mere spots up to a diameter of 10 or 12 mm. The colour is lilac, weathering to brown, and the mineral frequently encloses nuclei of chromite. Hardness $1\frac{1}{2}$; specific gravity 2·20, and also of a purer fragment, 2·12. The structure is foliated to compact, or granular. Owing to the common foliated character, the mineral has a chloritic appearance, and was at first referred to kammererite, under which name it appeared in the "Catalogue of the minerals of Tasmania" in 1896. Later investigations having proved that the mineral was a definite new species it was named *stichtite*, after Mr. R. Sticht, the general manager of the Mount Lyell Mining and Railway Company, and it is listed under this name in the 1910 catalogue. Petterd gives an analysis, made by A. S. Wesley, which is reproduced in column (1) (p. 28); the analysis leads approximately to the formula $(CrFe)_2O_3.6MgO.CO_2.13H_2O$. He further states that the mineral is soluble with effervescence in hydrochloric acid, yielding a bright

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[1] Stichtite, a new Tasmanian mineral, Geological Survey Record No. 2, Dept. of Mines, Tasmania, 1914. This report contains the following papers: "Description of the mineral," by W. F. Petterd (Catalogue of the minerals of Tasmania, pp. 167-169, 1910); "Note on the optical characters," by L. K. Ward (Ibid, pp. 169-170); "Chemical composition," by Laura Hezner (Centralblatt f. Min., etc., No. 18, 1912, p. 569); "Physical and optical characters," by A. Himmelbauer (Tscherm. Min. u. Petr. Mitth., Bd. XXXII, Heft 1 u. 2, 1913, p. 135).

green solution, but leaving a limited amount of flocculent residue; and that on heating it turns a bronze colour and becomes perceptibly magnetic.

More recently, the mineral has been analysed by Dr. Laura Hezner. She refers to the stichtite as forming a rock mass composed almost entirely of a scaly mica-like mineral, recalling lepidolite, but with poorer cleavage and a rather oily lustre; she states that the mineral appears to have been derived from the serpentine, while grains of chromite in the latter have been converted entirely into stichtite. Dr. Hezner's analysis is reproduced in column (2) below. The author considers the SiO_2 and FeO, shown in the analysis, to be due to admixed serpentine and chromite respectively, and after removing these, the figures agree very closely with the formula $Cr_2O_3.7MgO.2CO_2.12H_2O$ or $2Cr(OH)_3.5Mg(OH)_2.2MgCO_3.4H_2O$. This is taken as the formula for stichtite, and column (3) gives the calculated percentage composition of the mineral.

Analyses of Stichtite.

	1	2	3
SiO_2	—	3·87	—
CO_2	7·2	10·45	11·95
Cr_2O_3	11·5	20·44	20·65
Fe_2O_3	9·0	—	—
FeO	—	1·10	—
MgO	36·0	37·12	38·06
$H_2O-120°$	36·1	0·95	—
$H_2O+120°$		26·31	29·34
	99·8	100·24	100·00

1. Analysis by A. S. Wesley.
2. Analysis by Dr. Laura Hezner.
3. Calculated percentage composition.

Ward examined the mineral optically. Under the microscope he found that it has the form of fibres and tufts, sometimes curved, radially disposed about nuclei of chromite. The radiating aggregates are wrapped round with a mosaic of small scales and fibres. He states that the mineral is not perceptibly pleochroic, that the fibres have parallel extinction, and are optically positive (measured with respect to their elongation), and that the birefringence is strong.

The physical and optical characters were later determined by Himmelbauer. He describes the mineral as occurring in scales with a good basal cleavage. Hardness 1¾; specific gravity 2·161. Optically uniaxial, or occasionally feebly biaxial, negative. Refractive index of flakes, determined by immersion in a mixture of benzol and nitro-benzol, 1·542; birefringence, $\omega-\epsilon=0{\cdot}026$; pleochroism weak, $\omega > \epsilon$. He further states that the radial arrangement of the flakes around the chromite grains, as seen under the microscope, indicates that the latter mineral provided the chromium, while the magnesium was derived from the serpentine.

Occurrence at Megantic Mine.

In general appearance and mode of occurrence, the stichtite at the old Megantic mine is remarkably similar to that from Tasmania. Moreover, the mineral so closely resembles, in its colour, the lilac vesuvianite occurring at the Montreal chrome pit, that it was not at first distinguished from the latter. The material has not been analysed, but an examination of the general chemical behaviour, as well as of the physical and optical characters, proves it to be stichtite. In making the indentification, the several characters examined have been checked by direct comparison with those exhibited by a specimen received by the Museum of the Geological Survey from Mr. W. H. Twelvetrees, government geologist of Tasmania.

The stichtite apparently occurs very sparingly, and only a few specimens were collected. In these the mineral appears as small patches, and also in the form of narrow veinlets, within the precious serpentine. The colour, on freshly broken surfaces, is deep lilac, but it weathers to a much paler shade. When examined with a lens, or, in some specimens, even by the unaided eye, the mineral is seen to be minutely crystalline, light being reflected from numerous very small faces, which are perfectly flat and have a vitreous to oily lustre. These facets no doubt represent the basal cleavage referred to in the description of stichtite, and no fragment has been isolated showing cleavage in more than one direction. The mineral is easily scratched by a pin, and the hardness is probably below 2. The specific gravity, by immersion in methylene iodide, was determined as 2·166 and 2·185 on two fragments; it is very possible that the true value is somewhat lower than 2·166, since it is difficult to obtain fragments of the mineral entirely free from serpentine.

When fragments are crushed in oil and examined under the microscope, they are found to be made up of minute thin blades or fibres, some forming a network, and others arranged nearly parallel. The colour is very pale lilac, and there is no perceptible pleochroism. The fibres invariably have parallel extinction, and the birefringence is fairly strong. Compensation takes place when the quartz wedge is inserted normal to the length of the fibres, and the Tasmanian stichtite was found to behave similarly. Thus, as stated by Ward, the fibres are optically positive, measured with respect to their elongation. If, therefore, the mineral is uniaxial, and the fibres are elongated in the direction of the principal axis, stichtite is optically positive, and not negative as would appear from Himmelbauer's observations. Notwithstanding the basal cleavage, the writers have in no instance observed a fragment to give an interference figure, as might perhaps have been expected, although a very large number were examined. Determinations of the refractive index, by the immersion method, were not altogether satisfactory, but indicated a value between 1·545 and 1·554.

The powdered material effervesces when treated with dilute hydrochloric acid, and the stichtite appears to be easily and completely soluble, yielding a bright green solution; an insoluble residue, however, always remains, which is white and no doubt consists of the pale coloured serpentine with which the stichtite is intimately associated. The filtered solution reacts for chromium and magnesium. Heated before the blowpipe, the mineral loses its colour and turns brownish or greenish-white, but it does not fuse nor become magnetic. The feebly magnetic character after heating referred to by Petterd is doubtless to be ascribed to admixed chromite in the Tasmanian specimens. At the old Megantic mine also, the adjacent serpentine includes a few small scattered grains of chromite, and it is no doubt from such grains as these that the chromium of the stichtite has been derived.

On most of the specimens collected there is a little magnesite or dolomite, in very minute white crystals, associated with the stichtite, especially where the latter occurs as narrow veinlets. In view of this it may be pointed out that the subtraction of one molecule of $MgCO_3$ from Hezner's formula would bring it into almost exact correspondence with that earlier assigned to the mineral by Petterd; but the descriptions do not refer to the presence of magnesite on the Tasmanian stichtite specimens.

Silicates.

ANHYDROUS SILICATES.

FELDSPAR.

The various feldspars have already been referred to in the section dealing with the rocks of the serpentine belt.

The crystals of albite, mentioned above as occurring with calcite at the Caribou pit, are small prismatic individuals 2 mm. in length exhibiting twinning on b(010). They are not terminated and are of no special interest.

ENSTATITE AND HYPERSTHENE.

These minerals occur as essential constituents of peridotite and pyroxenite, and have been referred to under the descriptions of these rocks.

DIOPSIDE.

While diopside occurs at several localities in the area only that from the Montreal chrome pit has been studied in detail.

White, compact diopside rock occurs here as dyke-like bodies cutting the serpentine, and also in the form of narrow stringers and veinlets in the massive chromite; its mode of origin has already been discussed in an earlier section. Upon the walls of fissures and drusy cavities within this massive diopside rock, where free crystallization has been possible, the mineral appears as small, but well formed, colourless, transparent crystals.

A thin section of the massive rock photographed in ordinary light is shown in Plate VIII A. The rock has a granitic texture, and examination shows it to be composed entirely of diopside, with the exception of a very little calcite or dolomite. The diopside is colourless, and very fresh and clear; it forms fairly large interlocking idiomorphic individuals, and also granular aggregates of smaller crystals, which fill the interstices between these. Small druses are seen here and there, and it is in some of these that the carbonates have been deposited.

A second variety of diopside is found in which the mineral forms large tabular crystals and platy masses with a white, or often pale lilac, colour (the latter due to the presence of manganese). This coarsely crystallized material appears to be closely related to the other, and it often occurs in the same way quite close to the serpentine, from which it is separated only by a narrow zone of the compact white diopside.

It seems reasonable to suppose that, under certain conditions, the solutions from which the diopside crystallized were cooled so rapidly in making their way along the fissures in the serpentine, that they were continually supersaturated, and the diopside crystallized out as a shower of minute crystals; this might be expected in the narrow fissures especially and it would give rise to a "dyke" of compact diopside rock. Residual solutions, filling cavities and druses in such rock, would then cool more slowly, with the formation of the colourless transparent crystals.

Where the fissures in the serpentine were wider, however, different conditions would obtain; in such cases, the solutions would become highly supersaturated only where they were chilled by the serpentine walls. Elsewhere any crystals which formed might continue to grow until they ultimately formed a network stretching across the fissure. It is believed that the large tabular crystals and platy masses have originated in this way.

Colourless Crystals.

The colourless crystals are remarkable for two features: in the first place the occurrence of diopside in absolutely colourless and transparent crystals is in itself somewhat of a rarity; in addition to this, the majority of the crystals present a habit, due to the large relative size of the faces

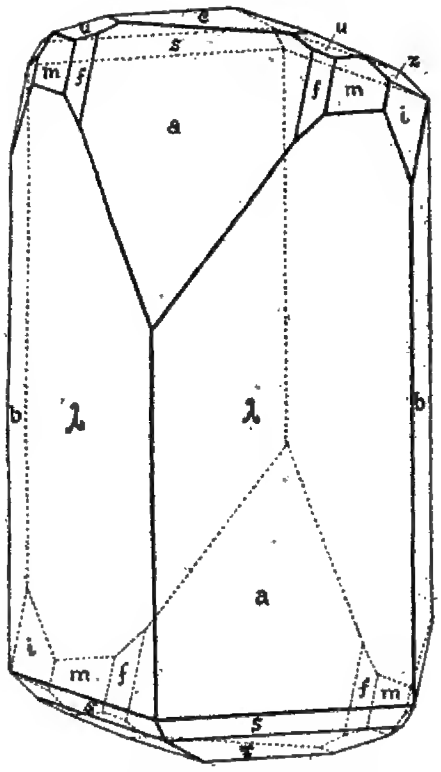


Figure 5. Diopside, colourless crystal from Montreal chrome pit; crystal drawn with the edge (33$\bar{1}$: 33$\bar{1}$) vertical to emphasize the prismatic appearance.

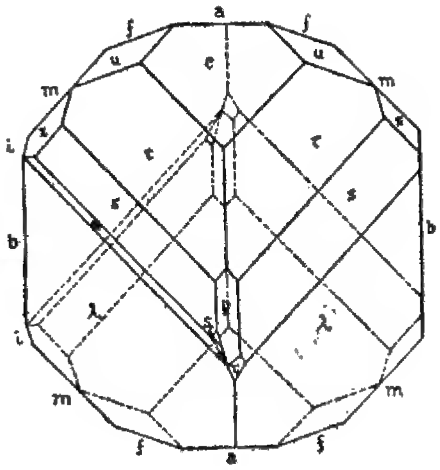


Figure 6. Diopside, colourless crystal from Montreal chrome pit; orthographic projection of one of the measured crystals, showing two of the new forms, *s.* $(\bar{5}34)$ and *r.* $(\overline{15}\cdot4\cdot10)$.

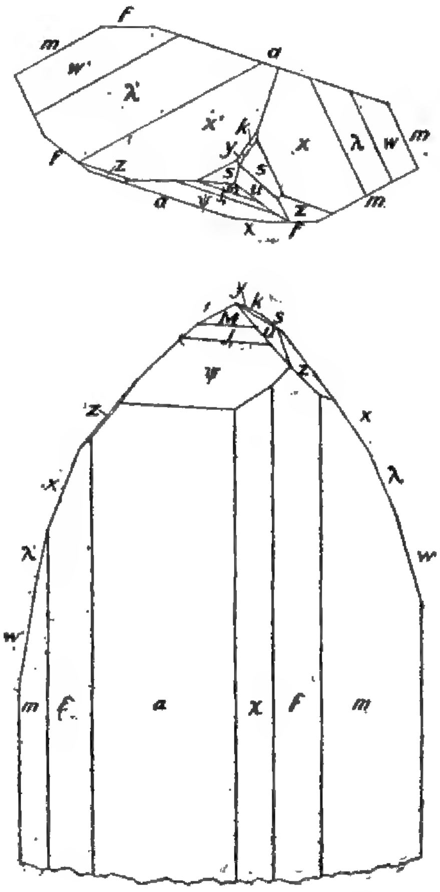


Figure 7. Diopside, colourless crystal from the Montreal chrome pit; illustrates the prominent development of the acute hemi-pyramid, λ($\bar{3}$31); the crystal also exhibits the new forms Y and J.

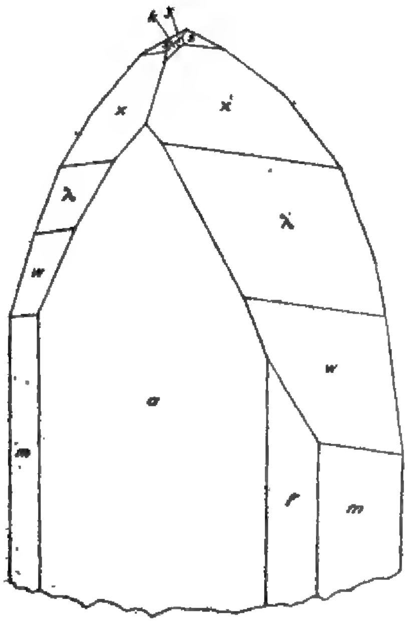


Figure 8. Back view of Figure 7.

of the form $\lambda(\bar{3}31)$, which appears to be unique, so far as the writers can judge from a perusal of the literature to which they have had access.

The crystals under consideration have the form of square prisms, terminated, in some cases at both ends, by various dome-like and other forms, and they are obviously monoclinic, with a vertical plane of sym-

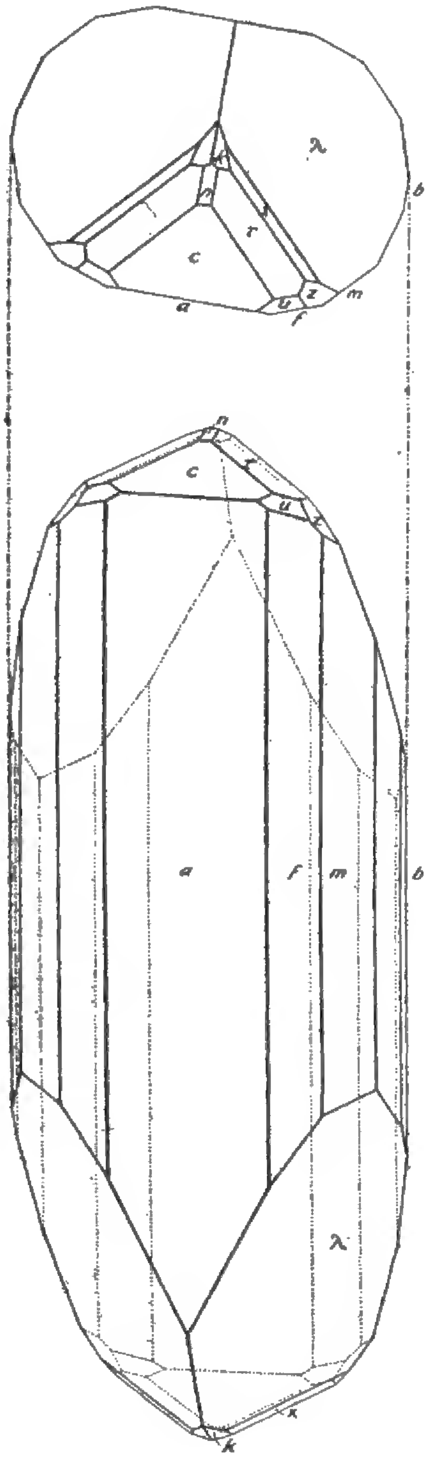


Figure 9. Diopside, colourless crystal from the Montreal chrome pit; idealized intermediate habit representing the average of a number of crystals, but with the length of the prism somewhat exaggerated.

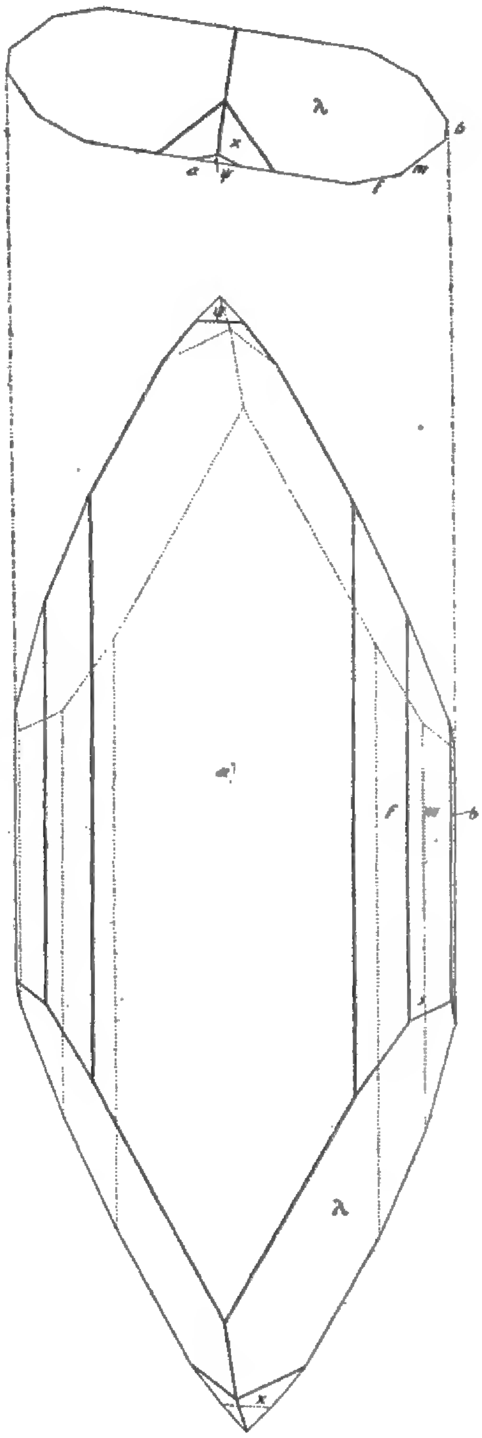
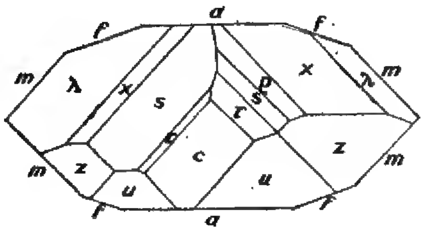


Figure 10. Diopside, colourless crystal from the Montreal chrome pit; tabular habit with acute termination, the prism and the hemi-pyramid λ $(\bar{3}31)$ being the only forms prominently displayed; this illustrates the average type.

metry passing through the prism diagonally. Without close inspection the crystals might easily be mistaken for diopside of normal prismatic habit, presenting the unit prism *m*(110); when measured and correctly oriented, however, it is seen that the apparent prism consists in reality of the four faces of the acute hemi-pyramid λ($\bar{3}31$), the angle $33\bar{1} \wedge 3\bar{3}\bar{1}$ being 91°35′. The true prism zone has the forms a(100), f(310), i(130), b(010), and occasionally certain others, as cited in the list below;



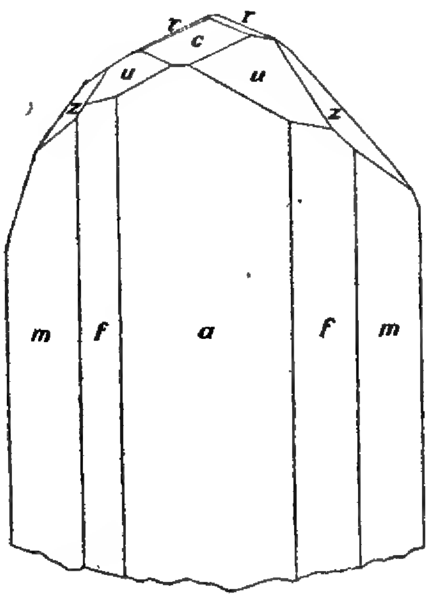


Figure 11. Diopside, colourless crystal from the Montreal chrome pit; crystal with somewhat flat termination, due to the equal development of the pyramidal forms τ ($\bar{1}12$) *s*($\bar{1}11$), *x*($\bar{2}21$), and λ($\bar{3}31$).

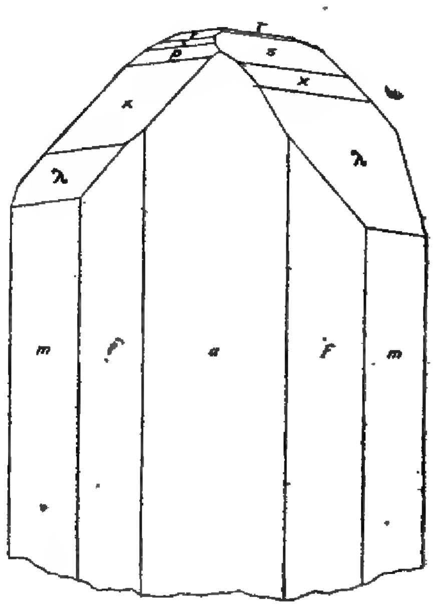


Figure 12. Back view of Figure 11.

but these are all very small as compared with λ($\bar{3}31$), the only one of any prominence being a(100), while b(010) appears only as a very narrow line-face truncating the edge $(33\bar{1}:3\bar{3}\bar{1})$. Other forms almost invariably present are z(021), u(111), x($\bar{2}21$), s($\bar{1}11$), τ($\bar{1}12$), and the basal pinacoid. Figure 5 illustrates the habit and the relative development of the forms commonly exhibited by these crystals; it has been drawn with the edge $(33\bar{1}:3\bar{3}\bar{1})$ vertical in order to emphasize the prismatic appearance. One of the measured crystals having this habit is shown in orthographic projection in Figure 6.

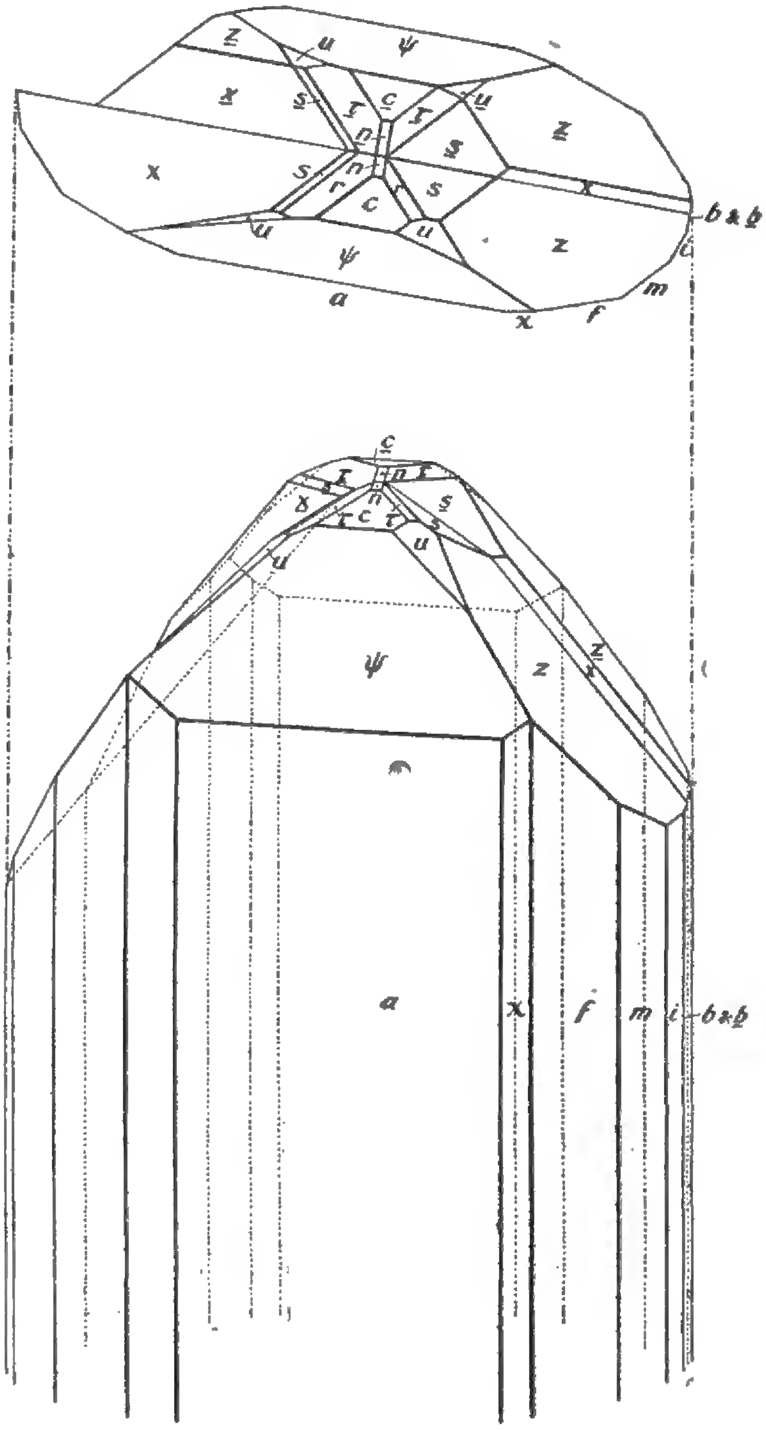


Figure 13. Diopside, colourless crystal from the Montreal chrome pit; contact twin, with *a*(100) as twin-plane, parallel to which the crystal is flattened.

These crystals measure up to 3 mm. in length and about 1 mm. across the prism. They occur in fissures and druses in the white massive diopside, notably in the immediate neighbourhood of the contact between the latter and serpentine. The commonly associated minerals are vesuvianite and andradite, both of pale yellow colour, and generally some thin blades of aragonite; the andradite in particular was noted as invariably occurring with the diopside of this habit.

Less frequently, colourless crystals were observed, somewhat similar in habit to that just described, but with the faces in the prism zone developed to about the same extent as those of the acute hemipyramid; Figures 7 and 8 illustrate this type. Like the last, these crystals are associated with the white massive diopside; but, it was noted that the druses in which they occur are almost always adjacent to veinlets or grains of chromite and that, in addition to the diopside, they usually contain crystals of emerald-green vesuvianite; other minerals which may be present are pale green andradite, calcite, and occasionally clinochlore. The diopside crystals measure up to 4 mm. in length and 1 mm. across the prism, but as a general rule they are rather smaller than this.

Figure 9 shows an intermediate habit, idealized to represent the average of a number of measured crystals, but with the length of the prism somewhat exaggerated.

Another habit is illustrated by Figures 11 and 12. In this type the crystals, elongated in the direction of the vertical axis, are tabular parallel to a(100), the usual dimensions being about 2 mm. by ½ mm. Their terminations are flatter than in the crystals described above, owing to the larger development of the forms τ($\bar{1}$12), s($\bar{1}$11), and x($\bar{2}$21) as compared with λ($\bar{3}$31). The basal plane is small but usually present. These crystals are, so far as noted, less common than the stouter types, and they frequently have a yellowish tint; they appear to favour the narrow fissures rather than the irregular cavernous druses in the massive diopside, and are also found implanted on the walls of fissures in the chromite where they are accompanied by later crystals of emerald-green vesuvianite.

Tabular crystals with acute terminations are also found; the prisms and hemi-pyramid λ($\bar{3}$31) are the only forms prominently displayed, and the basal plane is commonly absent. Figure 10 illustrates this type.

Though twin crystals are not very abundant, a few were observed on the specimens collected. These are contact twins of the usual type and they are flattened parallel to the twin plane a(100); one of these, which was measured, is shown in Figure 13.

White to Pale Lilac Diopside.

This material is not well crystallized. Usually it forms platy masses which may have a surface measuring several square centimetres, with a thickness varying from that of paper up to 2 cm.; the plates or blades are intergrown in the form of an irregular network, intersecting one another at all angles and in all planes. The cellular spaces of this network have been more or less filled by the later deposition of crystals of pale green andradite and clinochlore, less often vesuvianite, both lilac and yellowish, and minute white calcite prisms. Occasionally imperfect crystals are found on these specimens; these are in the form of blades, tabular parallel to a(100), which is heavily striated parallel with the vertical axis and bevelled by narrow faces of the forms f(310) and m(110); b(010) is small or absent. These crystals are comparatively large, measuring 1 cm. or more across the blades and several centimetres in length, and they are only slightly translucent. No crystals of this type were found showing terminations.

Bright Honey-yellow Crystals.

Small transparent crystals of a honey-yellow colour are fairly common at the Montreal chrome pit. They have the usual prismatic diopside habit; inspection indicated that no new or unusual forms were present, and the crystals were not measured.

Crystallography.

Only the colourless, or slightly yellowish, crystals from the Montreal chrome pit are dealt with in this section; the specimens collected at other localities have the more normal diopside habit, are in general poorly crystallized, and present no unusual forms.

A large number of crystals were measured independently by both writers, and upon these there were observed thirty-nine forms;[1] of these, twenty-eight have been previously recorded, while the remaining eleven are new for diopside. These forms are given in the following list, which also indicates the frequency with which they occur on the crystals.

---

[1] Seventy-eight forms are listed in Goldschmidt's Winkeltabellen (1897) and eighty-six by Zambonini (Zeits f. Kryst. u. Min., 46, 1909, p. 39); fourteen additional forms are recorded by Whitlock as having been observed up to 1910 (School of Mines Quarterly, XXXII, No. 1, p. 73).

Crystal Forms of Diopside from Montreal Chrome Pit

Letter	Symbol	Occurs on all crystals.	Occurs on most crystals	Rare; times observed	Remarks
c	001	—	x	—	Rare on tabular crystals.
b	010	x	—	—	Usually very small.
a	100	x	—	—	—
χ	510	—	x	—	Always narrow.
f	310	x	—	—	—
g	210	—	—	2	Very narrow.
m	110	x	—	—	—
i	130	—	x	—	Always narrow.
$\mathfrak{k}$	140	—	—	1	Perfect face on crystal of flat habit.
e	011	—	—	1	—
z	021	—	x	—	—
F	301	—	—	1	—
I	702	—	—	1	—
M	401	—	—	1	—
ψ	501	—	—	3	—
p	$\bar{1}01$	—	—	1	See Figure 6.
n	$\bar{1}02$	—	—	2	Very small, see Figure 13.
u	111	x	—	—	—
s	$\bar{1}11$	—	x	—	Rare on tabular crystals.
x	$\bar{2}21$	x	—	—	—
λ	$\bar{3}31$	x	—	—	—
W	$\bar{4}41$	—	—	2	See Figures 7 and 8.
ρ	$\bar{3}32$	—	—	Several	See Figure 11.
τ	$\bar{1}12$	—	x	—	—
k	$\bar{3}12$	—	x	Several	See Figures 7, 8, 9.
ε	$\bar{1}21$	—	—	Several	—
L	$\bar{1}31$	—	—	1	—
λ_1	$\bar{5}52$	—	—	1	—
			New Forms.		
χ_1	610	—	—	3	—
D_1	13·0·4	—	—	Several	—
J_1	902	—	—	1	—
I_1	701	—	—	1	—
Y	$\bar{4}23$	—	—	3	See Figures 7 and 8.
r.	$\overline{15}$·4·10	—	—	Several	See Figure 6.
s.	$\bar{5}34$	—	—	Several	See Figure 6.
x_1	$\bar{7}73$	—	—	1	—
δ_1	$\bar{8}$·11·4.	—	—	1	—
N_1	$\bar{1}$.9.1	—	—	1	—
O_1	$\overline{10}$·13·3	—	—	1	—

New Forms. The crystals are very perfect and the faces, including the basal plane, are unusually bright and yield single-image reflections. The averages of the measured angles agree exactly, or to within a few minutes, with the accepted values (for $p_o = 0 \cdot 5390$, $q_o = 0 \cdot 5670$ or $a : b : c = 1 \cdot 0934 : 1 : 0 \cdot 5894$; $\beta = 74° 9'$) and it has not been thought necessary to tabulate those for commonly occurring forms; those for the new forms are as follows:

Letter	Symbol	Calculated values	Measured angles, mean
χ_1	610................	$\varphi =$ 80° 17′ $\rho =$ 90 00	= 80° 25′ = 89 55
D_1	13·0·4.............	$\varphi =$ 90 00 $\rho =$ 64 35	= 90 00 = 64 38
J_1	902................	$\varphi =$ 90 00 $\rho =$ 70 23	= 90 00 = 70 20
I_1	701................	$\varphi =$ 90 00 $\rho =$ 76 07	= 89 20 = 76 15
Y	$\bar{4}23$................	$\varphi =$ −49 37 $\rho =$ 31 18	= −49 38 = 31 17
r.	$\overline{15}\cdot4\cdot10$............	$\varphi =$ −67 01 $\rho =$ 31 09	= −66 52 = 31 18
s.	$\bar{5}34$................	$\varphi =$ −43 18 $\rho =$ 31 17	= −43 38 = 31 20
x_1	$\bar{7}73$................	$\varphi =$ −36 39½ $\rho =$ 58 46	= −36 59 = 59 15
δ_1	$\bar{8}\cdot11\cdot4$..............	$\varphi =$ −27 18 $\rho =$ 60 20	= −27 44 = 60 37
N_1	$\bar{1}91$................	$\varphi =$ − 2 59 $\rho =$ 78 55½	= − 3 10½ = 79 05
O_1	$\overline{10}\cdot13\cdot3$.............	$\varphi =$ −31 48 $\rho =$ 70 55	= −31 29 = 71 06

The following particulars are added as indicating the manner in which these new forms were present on the crystals:

χ_1...........(610)	Observed three times, on two crystals, one of which was a twin in each case, the prism zone was heavily striated vertically, but the faces (610) were fairly well defined.
D_1........(13·0·4)	This form was observed independently by both writers on two crystals, as small, but fairly bright faces.
J_1............(902)	Occurs on one exceptionally fine crystal as a very brilliant face of appreciable size (see Figure 7).
I_1............(701)	Observed on one of the crystals of flat habit.
Y...........($\bar{4}23$)	This form was observed independently on three crystals, one of which is shown in Figures 7 and 8; the faces are small, but sufficiently bright to admit of accurate measurement.
r.........($\overline{15}\cdot\underline{4}\cdot10$)	These forms were present on several crystals, and are shown in Figure 6. The faces are in each case very minute, and did not yield very bright signals, but as will be seen from the table above, the mean measured angles agree closely with the values calculated for forms having these indices.
s............($\bar{5}34$)	

The remaining new forms (x_1 δ_1 N_1 O_1) were observed on one crystal only in each case; all were very narrow line faces, which did not yield very bright signals.

Rare Forms. Although about one hundred forms have been recorded for diopside, the crystals of this mineral are usually of fairly simple habit. A large majority of the recorded forms are rare and have been observed only on one or two occasions, or, in the case of many of them, only on crystals from one locality. Several such rare forms have been noted on the crystals from the Montreal chrome pit, and the history of these is given below; these particulars are abstracted from Zambonini's exhaustive monograph on diopside[1] and only those are here included which at that time (1909) had not been recorded from more than two or three localities.

g............(210)	First observed by Michel-Levy; recorded by Lewis on crystals from Thierälpeli a Tschevwandune, and by Zambonini and Sjögren on crystals from Kafveltorp; is present also on crystals from Testa Ciarva, Alatale. *Montreal chrome pit*: As a line face on two crystals, one of them the twin shown in Figure 13.
ℜ............(140)	Observed first by Schmidt, from Schwarzenstein-Alp (Zillertale). *Montreal chrome pit*: Noted on one crystal of tabular habit as a perfectly definite form of fair dimensions.
F............(301)	(S of Zambonini). First observed by vom Rath, and later by Zambonini on crystals from Testa Ciarva. *Montreal chrome pit*: Observed once on a twin crystal as a face of fair size.
I............(702)	(J of Zambonini). Noted by LaValle; locality, Testa Ciarva. *Montreal chrome pit*: Occurs as a face of fair dimensions on the same crystal which bears the face F(301).
M...........(401)	Observed by Götz, and later by Zambonini; both Testa Ciarva. *Montreal chrome pit*: On one crystal as a face of fair size and shown in Figure 7.
Ψ...........(501)	First by vom Rath, later by Zambonini; both on crystals from Testa Ciarva. Also by Lavalle on crystals from Borne de Brous which is opposite Testa Ciarva, on the other side of Alatale. *Montreal chrome pit*: On several crystals, some of which are shown in Figures 7, 10, 13.
n............($\bar{1}02$)	By several observers, on crystals from Testa Ciarva. *Montreal chrome pit*: Present on the twin crystal shown in Figure 13; also observed on one other crystal, Figure 9.
ρ............($\bar{3}32$)	On Testa Ciarva crystals. *Montreal chrome pit*: Observed on several crystals.
W...........($\bar{4}41$)	First observed by Cathrein on crystal from Pinzgau, Austria.[2] *Montreal chrome pit*: Two faces of this very acute hemi-pyramid occur on the same crystal, which presents the new orthodome J_1 (902); they are perfect faces and as will be seen from Figures 7 and 8 they are very prominently developed. The angles were:

Measured	Calculated
$\varphi = -40°\ 00'$................	$-39°\ 42'$
$\rho = \quad 71\ \ 56$................	$72\ \ 01$

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[1] Op. cit.

[2] Neue Krystallformen an Pinzgauer Pyroxen, Von A. Cathrein, Annalen Der K. K. Naturhist., Hofmuseums, Vienna, 1889, p. 181.

L...........(131)	(f of Zambonini). First by Dana from Testa Ciarva; later by LaValle from Borne de Brous. *Montreal chrome pit*: Observed once on twin crystal as a very small face.
ε...........$(\bar{1}21)$	Given in Goldschmidt's Winkeltabellen, but is not mentioned in Zambonini's work on diopside. *Montreal chrome pit*: Observed on several crystals, one of them the twin crystal having the form L$(\bar{1}31)$ as a small face.
λ_1..........$(\bar{5}52)$	Has been noted on green crystals of diopside from Rotenkopf, Zillertale. *Montreal chrome pit*: On one crystal as a line face truncating the edge $(\bar{3}31:\bar{2}21)$.

Chemical Composition.

The material selected for analysis had a specific gravity of 3·267. The melt, after fusion, was coloured bluish-green, indicating the presence of manganese. The result of the analysis is given in column 1 below.

Analyses of Diopside.

	1 Montreal chrome pit (colourless)	2 Alatale (colourless)	3 Nordmark (limpid) (Flink's type V)	4 Calumet island (white)	5 Near Ottawa (white)
SiO_2...........	54·77	54·74	54·59	54·90	54·50
Al_2O_3..........	—	—	—	—	—
Fe_2O_3..........	0·17	—	0·11	—	—
FeO...........	0·89	2·91	2·49	—	1·98
MnO..........	0·11	—	0·14	—	—
MgO..........	18·46	17·02	17·42	16·76	18·14
CaO...........	26·33	26·03	25·70	27·67	25·87
Volatile........	—	—	—	0·80	0·40
	100·73	100·70	100·45	100·13	100·89

2. Doelter, Tscherm. Mitth., 1877, 289.
3. Flink, Groth's Zietschr., 11, 476.
4. T. Sterry Hunt, Geol. of Canada, 1863, p. 468.
5. Ibid., p. 467; white, semi-transparent, sp. gr. = 3·26—3·27, from the vicinity of Ottawa.

The diopside thus approaches very closely to the theoretical composition, $CaMg(SiO_3)_2$; there is very little ferrous oxide present, replacing magnesia, and alumina appears to be entirely absent. It is possible that a slight error in the determination of the ferrous oxide is responsible for the small percentage of ferric oxide shown in the analysis. Diopside with this degree of freedom from iron (and alumina) is somewhat rare. The analyses of two other Canadian examples are given in columns 4 and 5 above. In addition, columns 2 and 3 show the composition of colourless diopside from Alatale (Piedmont) and from Nordmark (Sweden), the latter representing Flink's type V; these are included for comparison, and also owing to the close correspondence in optical characters between the material from these localities, and the crystals from the Montreal chrome pit, as detailed below.

Optical Characters.

Optically, the colourless crystals of diopside are interesting in possessing unusually low indices of refraction, as might have been expected in view of the almost complete absence of iron from the mineral.

The orientation of the indicatrix relative to the crystal axes is as usual in diopside. The mean line, β, coincides with the crystallographic axis of symmetry, and the axial plane lies in the plane of symmetry, with the acute bisectrix emerging in the obtuse angle between the crystal axes *a* and *c*.

The indices α and γ were determined by the minimum deviation method, using the natural prism $130 \wedge 1\bar{3}0$ ($= 35° \ 12\frac{1}{2}'$). By the same method, using the prism $310 \wedge \bar{3}10$ ($=38° \ 36'$), the index β was obtained, and also the value, between α and γ, for light vibrating vertically, along the *c*-axis, in the crystal. The two latter values were also determined by the total reflection method; the crystal in this case was mounted with the zone axis (100 : 001) vertical, immersed in Thoulet solution of index 1·7344, and the angle of total reflection from the face (100) measured. The indices thus obtained are as follows:

Method	α	γ	β	Light vibrating along *c*-axis
M.D., using prism $130 \wedge \underline{1}\bar{3}0$ ..	1·6691	1·6983	——	——
M.D., using prism $310 \wedge \bar{3}10$ ..	——	——	1·6765	1·6873
T.R. from face (100).........	——	——	1·6761	1·6811

In each case, yellow (sodium) light was used, and the same applies to the determinations of the other optical characters referred to below.

Owing to the small size of the prism faces, the illumination was somewhat poor in the minimum deviation determinations, but from the close agreement in the values found for β by the two methods, it is believed that the figures may be relied on to the third place of decimals, and the refractive indices may be taken as

$$\alpha = 1{\cdot}669, \beta = 1{\cdot}676, \gamma = 1{\cdot}698.$$

The birefringence is thus strong ($\gamma - \alpha = 0{\cdot}029$) and positive.

One of the optic axes is nearly normal to (001), while the other is inclined at an angle of about 20 degrees to the normal of (100). The angle between the optic axes, as they emerge from these faces, was measured with the crystal mounted and immersed in Thoulet solution as before, and was found to be 59° 48′. From this value the true internal optic axial angle (2V), the apparent angle in air (2E), and the position of the acute bisectrix (giving the extinction angle on (010)), were calculated to be as follows:

$$2V = 59° 15', 2E = 111° 54', Bx_a \wedge c\text{-axis} = 38° 21'.$$

The axial angle for red light is greater than for yellow ($\rho > v$), but it was not measured. Judging from the appearance, in ordinary white light, of the rings surrounding the optic axes, there seems to be a dispersion of the bisectrices in the plane of symmetry (inclined dispersion), but the effect may be due, in part at least, to a distortion of the interference figure under the conditions of the experiment.

The value of 2V, calculated directly from the refractive indices α, β, γ, is 59° 29′, giving also 2E = 112° 30′; these are not very different from the corresponding angles as derived from the actual measurement. From this angle 2V, together with a knowledge of the extinction angle on (010) (=38° 21′) and the angle 010 $\wedge$ 110 (=43° 35′), the extinction angle on (110) is found, by the usual formula, to be 32° 19½′. A large number of measurements of this angle, made on cleavage fragments, fell within the limits 32¼°—33°. It was not possible to measure the extinction angle on (010) directly, owing to the small size of this face on the crystals.

The acute bisectrix is inclined at 51° 39′ to the normal of (100), and at 22° 31′ to the normal of (001).

The value calculated for the refractive index for light vibrating in the crystal along the c-axis (using, as data, α, γ, and the angle $Bx_a \wedge c$-axis) is 1·686; this is in fair agreement with the observed values noted above.

As will appear from the above description, the main interest of the colourless crystals, from an optical standpoint, lies in the refractive indices, which are as low as, or lower than, any which have hitherto been recorded for this mineral. The optical characters of diopside naturally vary with the chemical composition, and this is especially true with regard to the relative amounts of FeO, Fe_2O_3, and Al_2O_3 which may be present. In general it has been found that the nearer the mineral approaches to the theoretical composition, $CaMg(SiO_3)_2$, the lower are the indices. In this respect, the Montreal chrome pit crystals may be compared with the limpid crystals from Nordmark, Sweden (Flink's type V), and also with certain colourless crystals from Alatale, Piedmont. Analyses of these are reproduced above, and their principal optical characters are tabulated on page 44. No. 1 refers to the Montreal chrome pit crystals, Nos. 2, 3, and 4 to crystals from Alatale, and Nos. 5 and 6 to crystals from Nordmark.

No.	α	β	γ	2V	2E	$Bx_a \wedge c$-axis
1	1·669	1·676	1·698	59° 29′	112° 30′	38° 21′
2	$1\cdot6707_D$	$1\cdot6776_D$	$1\cdot6996_D$	59 09	111 47	——
3	——	1·6751	——	59 18	111 55	38 49
4	——	1·6768 1·6758	——	59 15	——	38 41½
5	1·6710	1·6780	1·7000	58 43	——	39 06½
6	—	1·69359	——	58 52	——	38 03½

All the above are for yellow (sodium) light, with the exception of 2 which gives the values for the D line.

2. Dufet, Bull. Soc. Min., Paris, 1887, 10, 221.
3. A. Schmidt, Groth's Zeitschr, 21, 11.
4 and 5, Wulfing, Beitr. Pyroxenfam, Heidelb., 1891, 17.
6. Flink, Groth's Zeitschr., 11, 485.

AUGITE.

Augite and diallage are not found in the area except as rock-forming minerals, being essential constituents of the pyroxenite, gabbro, and diabase masses.

AMPHIBOLE.

The minerals of this group occur only sparingly in the area. The typical granite is a hornblende variety, and the hornblende is frequently altered in a very peculiar manner, which was first described by F. D. Adams.[1] Three stages of alteration were distinguished by Adams, as follows: "(1) The hornblende changes to a scaly mass having all the appearance of chlorite. This zone is not always present. (2) There is a zone of fine needles, generally in tufts, with parallel extinction, and which have a brown or yellow colour. This colour, however, does not belong to the needles themselves, but is due to the separation of hydrated oxide of iron on the decomposition of the hornblende molecule. (3) Running out from these tufts are long and exceedingly fine, hair-like needles which penetrate the quartz. These are colourless, and probably the same as those of the yellow zone, but longer and finer."

Hornblende having a clove-brown colour, in which respect it somewhat resembles edenite, is found in the gabbro-diorite which forms a ridge to the right of a section of the Quebec Central Railway line between Black Lake and Thetford about a mile from the former place. In thin section the rock is seen to be a quartz-diorite; the hornblende has a pale brown colour, and each crystal individual is surrounded by a zone of

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[1] Geol. Surv., Can., Ann. Rept. 1880, 1881, 1882, p. 8A.

secondary actinolitic material, in the form of very pale green to colourless shreds or fibres.

Short fibres, often radially grouped, of pale green actinolite, are associated with the colerainite in the specimens from the old Standard mine described on page 66.

GARNET.

From a crystallographic standpoint the garnets are amongst the most interesting minerals occurring in this area. Crystals exhibiting two quite exceptional features have been noted; these are amber-coloured grossularite, fairly rich in forms which present the very unusual cube faces, and pale rose crystals, which occur as simple six-faced octahedra. Still another point of interest is the occurrence of grossularite in colourless crystals.

Garnets were found at most of the localities visited, and are of two varieties, grossularite (calcium-aluminum garnet), and andradite (calcium-iron garnet). Only the colourless grossularite occurring at the Southwark pit has been completely analysed; beyond this, the classification of the crystals as grossularite and andradite is here based on their behaviour with hydrochloric acid and before the blowpipe. Crystals which are partially soluble in concentrated hydrochloric acid and yield gelatinous silica on evaporation, and which also fuse to a globule that is strongly magnetic, have been classed as andradite; those which do not give these reactions, as grossularite. Subdivided in this way it has been found that the colourless, rose, and certain greenish-yellow crystals are referable to grossularite, while the andradite is always olive to apple-green in colour; the former crystals moreover are usually transparent and dodecahedral in habit, while the andradite is inclined to be opaque and invariably exhibits the trapezohedron as the dominant form.

The crystals are all rather small, none having been observed with a diameter greater than 1 cm. A description of the principal occurrences follows:

Occurrences.

Union Pit. Cavities in a fairly compact, rose-coloured, grossular-garnet rock are lined with well crystallized garnet of the same or paler colour, accompanied in many places by a little aragonite and brown diopside.

Many of these crystals are simple dodecahedra, while on others the trapezohedron $n(211)$ is also present as narrow truncating faces. The dodecahedron faces are frequently striated parallel to the shorter diagonal, and, in the case of some of the crystals, each dodecahedron face is seen to be in reality double, being made up of two very slightly inclined faces, whose edge is the shorter diagonal, and which belong to a very steep four-faced cube.

Other crystals on the same specimens are more complex; as before, the dodecahedron is the main form, and its edges are tuncated by n(211), but there are also present the four-faced cube, g(320), and six-faced octahedron. The faces of the latter form are curved, rendering a determination of the indices impossible.

Perhaps the most interesting crystals occurring on these specimens, however, are those which exhibit the rare six-faced octahedron, u(853). This form occurs practically uncombined on the crystals, being accompanied only by very minute faces of the dodecahedron and the four-faced cube g(320), as illustrated in Figure 14. The faces of the six-faced octahedron are usually striated parallel to their intersections with the dodecahedron; in other cases they are curved and the form of the crystal then approaches a sphere, whose surface is generally drusy.

Garnet is apparently the only cubic mineral whose crystals have been observed to bear the form u(853), and, so far as the writers are aware, even with garnet it has only been recorded once previously. This was in the case of garnets from Rothenkopf, Tyrol, described by Cathrein,[1] who states that the crystals were combinations of (110), (211), and (321), with faces of the new form (853) lying in the zone (110:101) on both sides of the dodecahedron faces.

In the case of the Union pit crystals, this rare six-faced octahedron is found, as already stated, practically as a simple form; crystals were selected whose faces yielded good single images, and the mean measured angles were found to agree closely with the calculated values, as follows:

Angle	Measured	Calculated
$853 : 83\underline{5}$	16° 29½′	16° 25½′
$853 : 85\bar{3}$	35 02	35 17
853 : 583	24 31	24 44¾

The rose-coloured garnets have diameters up to half a centimetre, but the more complex crystals and the simple six-faced octahedra are usually smaller than this.

Andradite, both apple green and pale yellowish, is also found in the Union pit, but the crystals call for no special description.

Southwark Pit. The grossular garnet in the Southwark pit is remarkable in that it is colourless and transparent; it forms granular, somewhat cavernous, crystalline masses, composed almost entirely of grossularite, with a little reddish-brown vesuvianite in prismatic crystals, and minute

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[1] Min. Mitth., 10, 55, 1888.

six-sided flakes of clinochlore. Within the cavities, where the garnet has had an opportunity to crystallize freely, fine crystals occur plentifully, some of which attain a diameter of half a centimetre. In habit they are always dodecahedral; occasionally this form occurs alone, but as a general rule its edges are truncated by narrow faces of the trapezohedron n(211). In addition to these forms, the four-faced cube δ(610) and the trapezohedron m(311) were observed on one of the crystals measured; but in each case these latter forms were present only as minute facets, which did not yield bright signals.

An analysis of these crystals gave the results shown in the last column of the following table:

Analyses of Grossularite.

	Theoretical composition	1 Wakefield (white)	3 Hull (colourless)	4 Orford (yellowish-white)	5 Southwark pit, Black lake	Molecular ratio
SiO_2..........	40·00	38·80	39·85	38·60	39·49	·658...3
Al_2O_3.........	22·70	22·66	22·07	22·71	22·35	·219...1
Fe_2O_3.........	——	1·75	1·13	——	——	——
FeO..........	——	——	——	1·60	1·00	·014 ..3
CaO..........	37·30	35·00	36·31	34·83	36·62	·654
MgO..........	——	0·68	0·68	0·49	0·28	·007
MnO..........	——	0·30	——	——	0·15	·002
K_2O..........	——	——	——	0·47	——	——
H_2O..........	——	——	——	1·10	——	——
	100·00	99·19	100·04	99·80	99·89	
Sp. gravity.....	——	3·525	——	3·52–3·53	3·60	
Refractive index.......	——	1·7438[2]	——	——	1·734	

1. Bullman, Am. Jour. Sc., 27, 1884, p. 306.
2. Wulfing,
3. Priv. com. M. D. Munn (cited by Dana, p. 440).
4. Hunt, Sterry, Geol. of Can., 1863, p. 496. (The 1·60 FeO includes some MnO).
5. Graham.

The composition of colourless garnet from Hull and of white garnet from Wakefield and from Orford are given for comparison.

The refractive index was determined by the minimum deviation method using sodium light and taking the dodecahedron faces for the prism.

Hall Chrome Pit. Specimens of grossularite were collected from the Hall chrome pit by J. Obalski[1] many years ago, and are now in the mineral collections of the Geological Survey. Many specimens from this pit were collected by the writers. The crystals have an amber colour

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[1] Geol. Surv., Can., Ann. Rept., vol. X, 1897, p. 123A.

and dodecahedral habit, with minor development of the trapezohedron n(211). Small druses in some of the specimens contain thin blades of aragonite.

The garnet occurs at the contact between aplite and serpentinized peridotite. Plate III illustrates the mode of occurrence of one of these aplitic intrusions at the Hall pit; in other places they have a more regular dyke-like form.

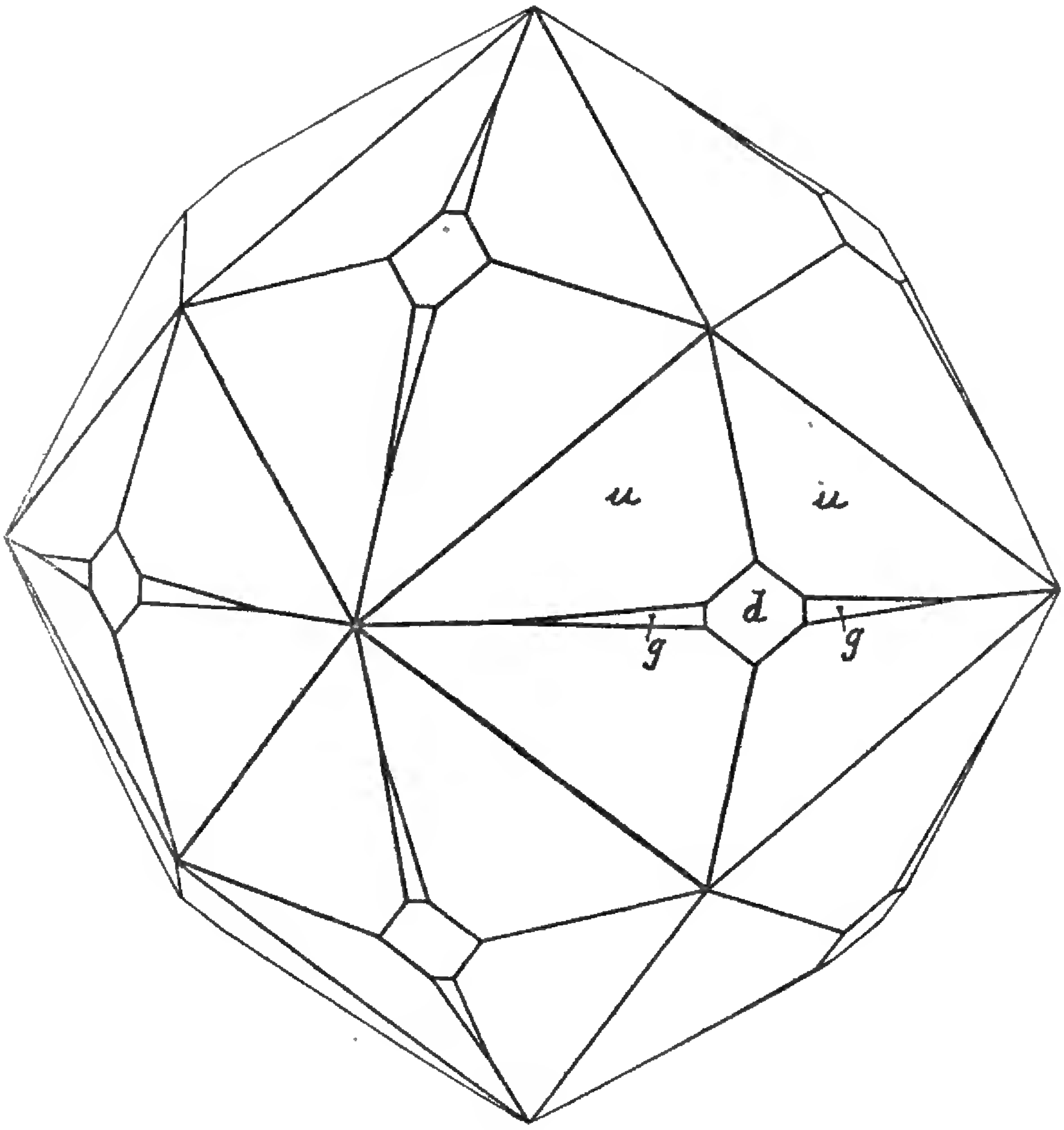


Figure 14. Grossularite, rose-coloured crystal from the Union pit; has the form of the rare six-faced octahedron *u*(853), with minor development of the dodecahedron and the four-faced cube *g*(320).

Old Standard Mine. Small reddish-brown crystals of garnet occur here, associated with tourmaline, in a pegmatite dyke.

American Chrome Pit. The crystals obtained from this pit are rich in forms, and are of especial interest in that they exhibit faces of the cube, a form very rarely found on crystals of garnet. In general the habit is dodecahedral, modified by the forms n(211) and r(332) which are about equally developed; the remaining forms, s(321), e(210), and g(320) appear only as narrow truncating faces; the cube faces also are quite small. Figure 15 shows the average habit of these crystals. It should be mentioned that although many of the crystals were examined under the binocular microscope, only five or six were completely measured, and it is possible that additional forms would be found if a special investigation were made; this remark applies also to the other garnet occurrences described here.

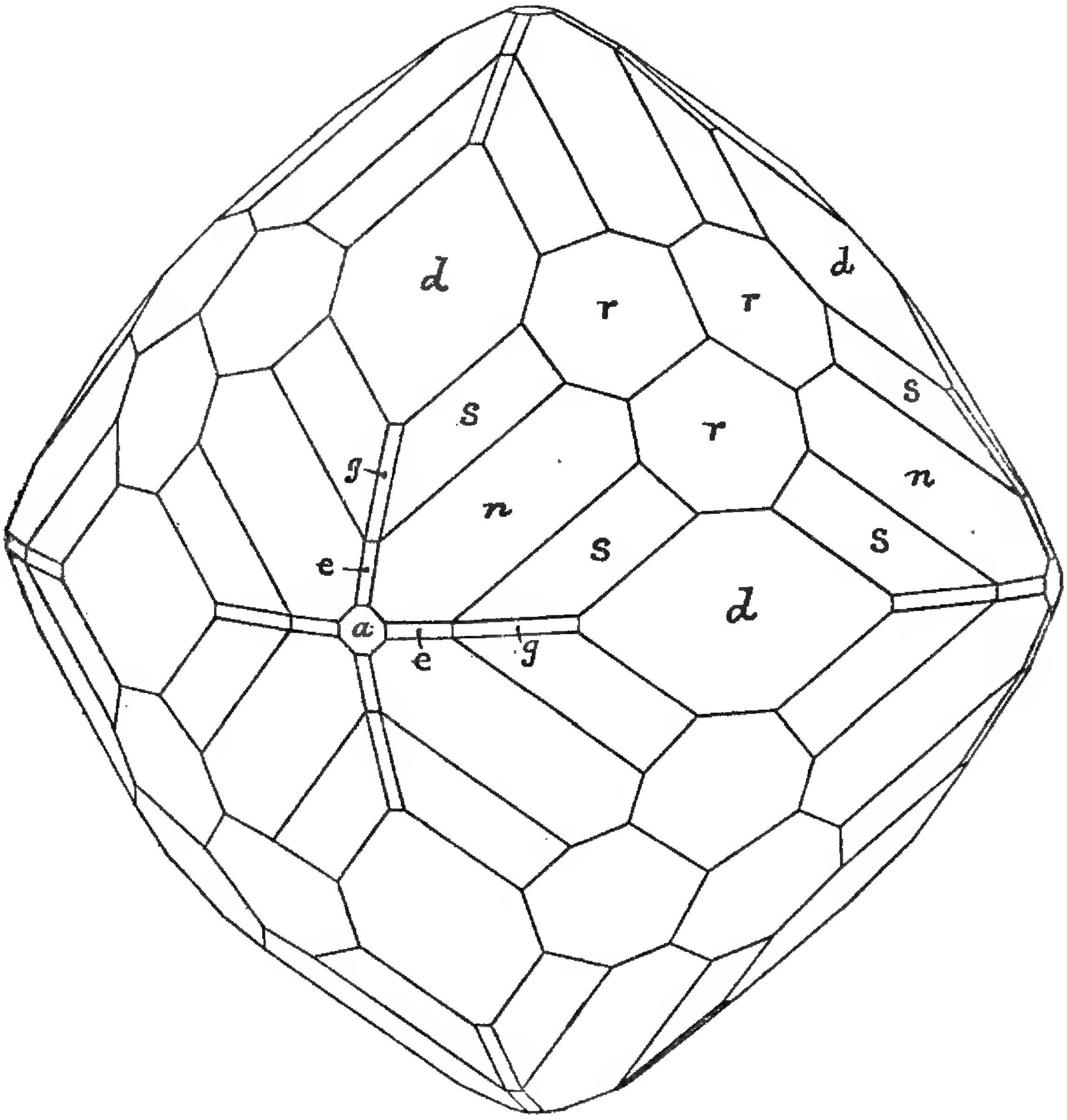


Figure 15. Grossularite, pale amber (succinite) coloured crystal from the American chrome pit; rich in forms, and especially interesting in that it exhibits faces of the cube, a form rarely found on garnet crystals.

These garnets are grossularite of pale amber (succinite) colour, and usually they are about 2 mm. in diameter; they are associated with white massive calcite in a compact, granular, olive-green diopside rock.

Montreal Chrome Pit. Andradite is the only variety of garnet noted at this locality. Most frequently it is associated with pale green clinochlore of rather pronounced prismatic habit, and platy masses of white to pale lilac-coloured diopside; the order of crystallization is diopside, garnet, clinochlore, and there is usually also some later calcite in minute, white, prismatic crystals. The garnets are olive-green in colour and almost opaque; some crystals measure as much as 1 cm., but the more perfect ones are not more than 3 mm. in diameter.

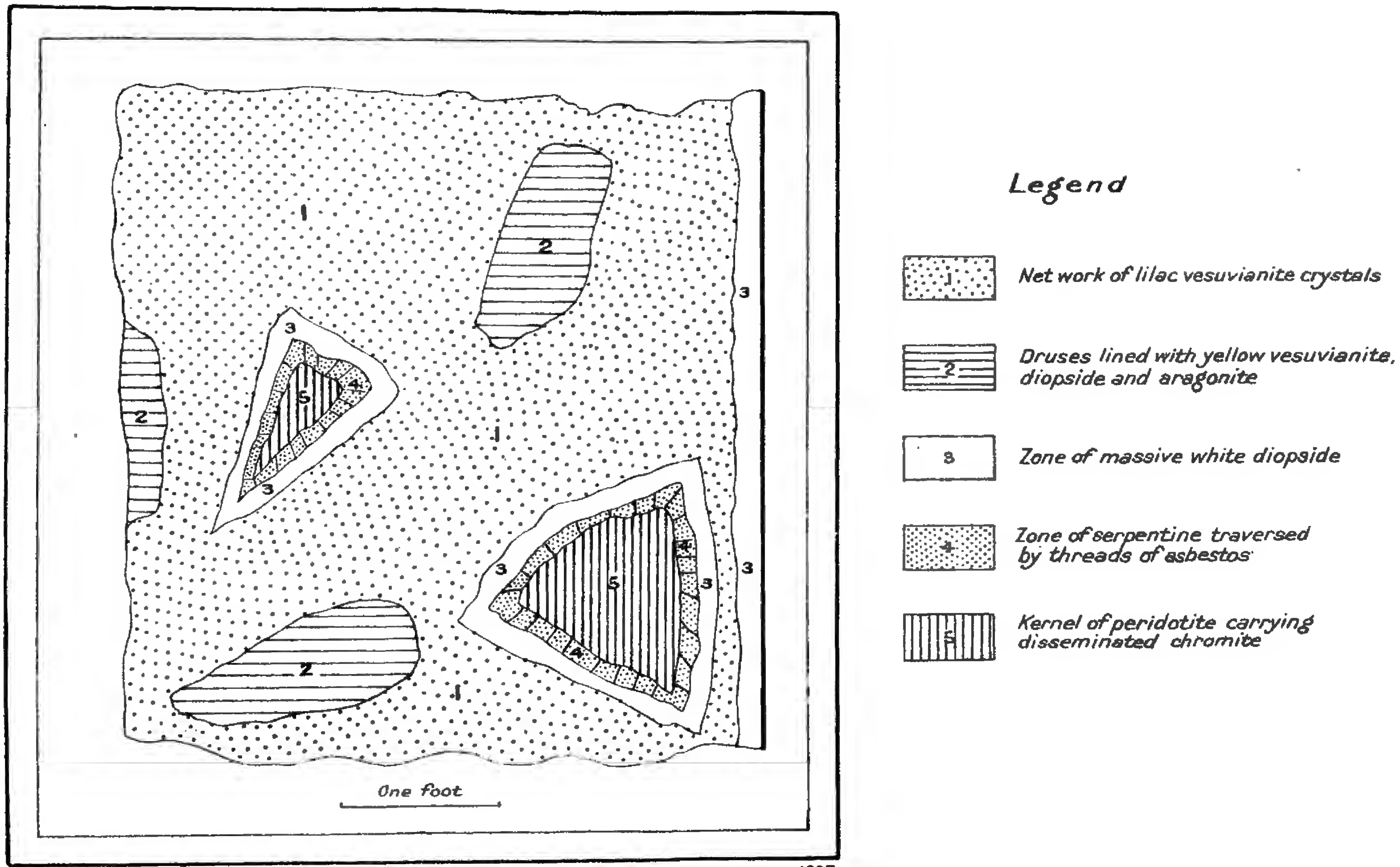
Andradite of pale greenish-yellow colour is also associated here with the massive white diopside, at the immediate contact of the latter with the serpentine; the crystals are smaller than the above, averaging about 2 mm. in diameter, and they are also more brilliant and transparent. The diopside crystals associated with these garnets have the habit described elsewhere in which the acute hemi-pyramid $\lambda(\bar{3}31)$ is so abnormally developed as to simulate a square prism.

In each case the andradite crystals are quite simple; they are all trapezohedral in habit, the form n(211) often occurring uncombined; otherwise it is modified by small faces of the dodecahedron, and occasionally also of the three-faced octahedron r(332).

A single isolated crystal found at the Montreal chrome pit has a deep emerald-green colour and might be classified as ouvarovite.

Caribou Pit. Fissures in a fine-grained, aplitic granite are here found filled with colourless or pale pinkish, very compact, granular grossularite; no definite crystals have been observed. A microphotograph of the aplite in ordinary light is shown in Plate IX. Orthoclase, in fairly large individuals, is the principal mineral present, quartz being subordinate. Plentifully scattered through the orthoclase are small grains of colourless garnet; these may be isolated, or packed closely together in granular looking clumps, but their most characteristic arrangement is in the form of straight strings, along which the little garnets are strung out like beads. Some of these strings may be traced completely across the thin section, traversing in their course several feldspar individuals. It is very evident, therefore, that the garnet is later than the feldspar, and apparently it replaces that mineral. The only other mineral present in the section is colourless clinochlore, in small amount, and this appears to have been introduced at the same time as the garnet. It was in this aplitic dyke that the molybdenite referred to on page 14 was found.

Black Lake Chrome and Asbestos Company's Pit, No. [18]. The occurrence of garnet at this pit is similar to the last. It is a colourless to pale rose grossularite, seldom observed in well-defined crystals, and it occurs in association with a granitic rock which is itself very highly garnetiferous. A thin section of the rock was found to consist for the most part of garnet in comparatively large colourless individuals. Quartz and feldspar, both orthoclase and plagioclase, are present, but only in minor amount. The rock as examined is not very fresh; there is a fair amount of calcite and also some chlorite, the latter in places being much stained



Geological Survey, Canada.

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Figure 16. Section showing distribution of vein matter, Montreal Chrome Pit.

To accompany Bulletin by
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by hydrous ferric oxide. Some serpentine is also present in the section, being, no doubt, a portion of the dyke wall.

Crystal Forms. The forms observed on the garnet crystals from the various pits, as far as they were examined, are as follows:

Form	Locality	Colour
Cube....................a(100)	American chrome pit	Amber
Dodecahedron....................d(110)	On all crystals	
Four-faced cube....................δ(610)	Southwark pit	Colourless
“ “ “ ....e(210)	American chrome pit	Amber
“ “ “ ....g(320)	American chrome pit	Amber; Union pit, rose
Three-faced octahedron..........r(332)	American chrome pit	Amber
Trapezohedron....................m(311)	Southwark pit	Colourless
“ ....n(211)	On all crystals	
Six-faced octahedron............u(853)	Union pit	Rose
“ “ ....s(321)	American chrome pit	Amber

CHRYSOLITE.

Chrysolite, or olivine, occurs only as a constituent of the peridotite and pyroxenite, and is described in the section dealing with these rocks.

VESUVIANITE.

Very finely crystallized specimens of vesuvianite are found at several localities in the area. The crystals have a brilliant lustre, are for the most part quite transparent, and display a wide range of colour, including pink or lilac, emerald-green, various shades of yellow, clove, and reddish-brown, and in some cases they are colourless; with the exception of the brown variety the crystals seldom exceed one millimetre in diameter.

Occurrences.

Montreal Chrome Pit. This locality (Plates VI and VII and Figure 16) has furnished some of the best material examined by the writers, lilac, emerald-green, yellow, and colourless varieties all occurring in fair abundance.

The lilac vesuvianite forms compact, fine-grained, crystalline masses, having a deep tint which renders the specimens very striking and pleasing to the eye; it has been found that the colour fades somewhat after exposure to air and light. Examination of thin sections shows that the rock does not always possess the same structure. The vesuvianite has the usual high index of refraction and very low birefringence. If the section is somewhat thick, a faint, but quite distinct pleochroism is noticeable, the crystals appearing colourless for light vibrating in the direction of the prism edge, and pale lilac for light vibrating normal thereto.

In some sections the rock displays a fine, even-grained, granitic texture, being composed entirely of fairly stout interlocking prisms of vesuvianite. Small druses are seen here and there. The prisms frequently interpenetrate one another completely, and when this feature is pronounced, owing to the intersection of several prisms at a single point, it forms a transition from the granitic texture to that now to be described.

In this second type, a radial grouping of the vesuvianite individuals is characteristic. The radially orientated prisms dovetail into one another at their common point of intersection and give rise to spheres, or, in section, to circular aggregates. The spaces between these radial groups may be filled with vesuvianite showing the ordinary massive intergrowth, or may be left vacant as druses; many of them, however, contain rather coarsely crystallized colourless diopside, as well as some smaller grains of colourless garnet, both of which are contemporaneous with, or slightly later than, the vesuvianite. Plate X is reproduced from microphotographs of this rock, and clearly illustrates the various features referred to.

Druses within this rock are lined with beautiful lustrous crystals of vesuvianite, paler in tint than the rock mass, and rather like kunzite in colour; with a further decrease in the depth of tint, the crystals are sensibly colourless.

The crystals are fairly rich in forms, those usually present being c(001), a(010), m(110), f(120), p(111), s(131), z(121), i(133), and t(331) (see table on page 58); h(130) and d occur less frequently and for the most part their development is relatively smaller. The average habit of these crystals is shown in Figures 17 and 18. The basal plane is always present, but small, and, especially in the more deeply coloured crystals, it has a drusy surface. The prisms a(010) and m(110) are both prominent and vary in relative size, sometimes the former and sometimes the latter being the larger form. Of the pyramids which terminate the crystals, the unit pyramid, p(111), is invariably the most prominent, with the ditetragonal pyramid, s(131), rather smaller. Faces of the latter form are usually heavily striated in the zone [a s], as shown in Figure 19, and the same striæ appear on the prism faces. When such crystals are examined on the goniometer, this feature gives rise to a continuous string of images connecting the bright signals from a(010) and s(131) and readings taken at the brighter points in such chains of light on a large number of crystals show a tendency to the development of the forms v(151), (272), and y(141). The first of these occurs as a true form on some of the pale yellow crystals described below, but (272) and (141) were not observed as well established forms on any of the crystals measured from this area; the form (272) would be new for vesuvianite. In many of these crystals, the faces of the prism a(010) are not simple, but each is made up of two planes, inclined to one another at angles varying up to half a degree, their line of intersection being parallel to the prism edge. Faces of the unit pyramid are usually striated parallel to their longer diagonal, *i.e.*, in the direction of the apex of the crystal, as indicated in Figure 19. The paler crystals are typically freer from striæ than are those of a deeper lilac colour; these nearly

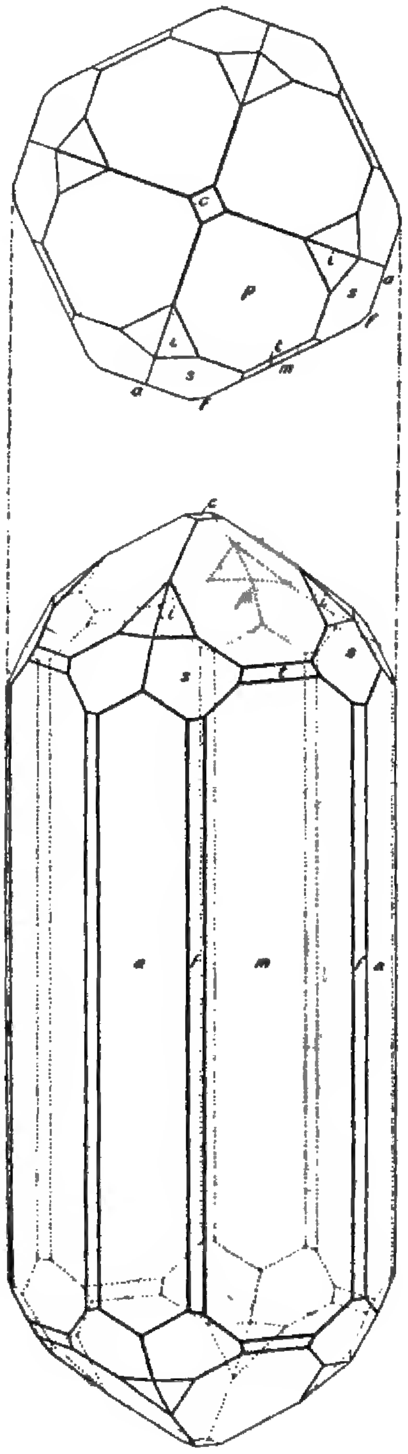


Figure 17. Vesuvianite, lilac crystal from the Montreal chrome pit; average habit when *m*(110) is larger than *a*(100).

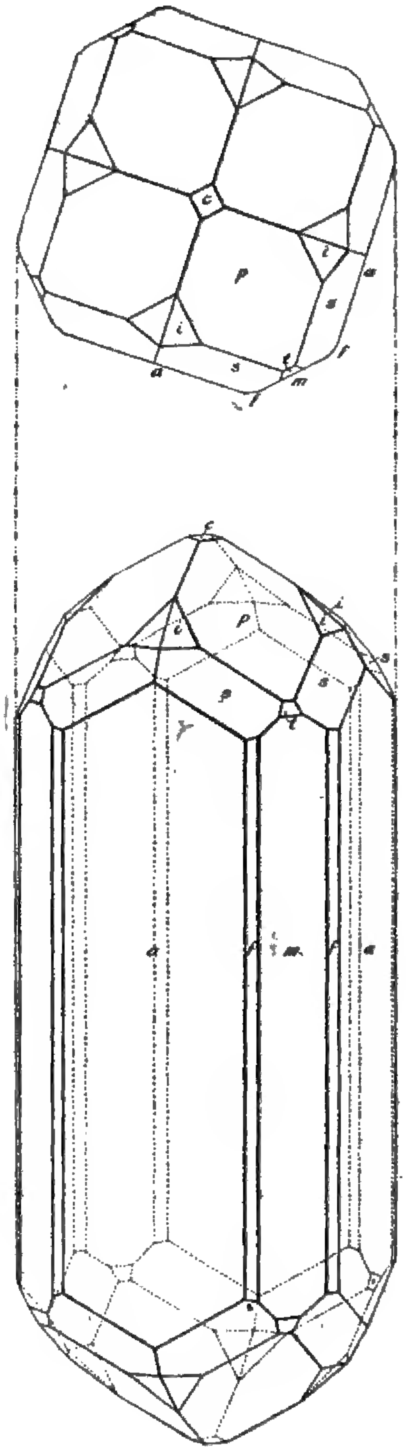


Figure 18. Vesuvianite, lilac crystal from the Montreal chrome pit; average habit when *a*(100) is larger than *m*(110).

colourless crystals were the only ones on which the form O(011) was observed.

Some of the druses in the deep lilac massive material are lined instead with crystals of a wine-yellow colour. As will appear below, analysis of the lilac crystals shows them to contain small percentages of both manganese and iron; the association of these crystals with the yellow variety might be explained by assuming that, under the conditions prevailing, the most highly manganiferous variety crystallized out first, as indeed appears to have been clearly the case from an inspection of the specimens; the mother liquor thus became gradually impoverished in manganese, until there remained just sufficient of this element to counterbalance the effect of the iron, and colourless crystals then separated; finally the mother liquor having become nearly or quite free from manganese, the colouring property of the iron made itself felt, with the consequent formation of yellow crystals. It is interesting to note that the habit of the latter is somewhat different from that of the lilac crystals. The dominating forms are the prism a and the pyramid s, the other forms present, m, p, and t, having a relatively small development, and the basal plane is either absent or of trifling size. Figure 18, omitting the basal plane, would represent an average type.

The minerals most frequently associated with the vesuvianite described above are calcite and aragonite, the latter in tufted groups of flat bladed crystals; less frequently there are also present diopside, both colourless and yellow, and a white, amorphous material, possibly porcellophite, a variety of serpentine.

The emerald-green crystals are always associated with white, compact diopside. The latter material, as already stated on page 31, forms the walls and outer portions of certain dyke-like bodies which cut the serpentine at this locality, and it also occurs as a network of irregular veins traversing the massive chromite, giving to the ore a brecciated appearance. The vesuvianite occurs as brilliant green crystals resting on crystals of colourless or pale diopside lining cavities in this compact rock; similar crystals are also found along fissures in the chromite, directly attached to the ore, but as a rule these are poorer and almost microscopic. The usual habit of the crystals is illustrated in Figure 20 and Figure 22. The prisms are square in outline, owing to the invariable predominance of a(100) as compared with m(110); the base, though small, is always present. The main pyramid in this variety is the ditetragonal form s(311), and the steep pyramid t(331) is also well developed. Owing to the large relative size of these pyramidal forms, the termination of the emerald-green crystals is, on the whole, more acute than in the other varieties. A complete list of the forms observed on these crystals is set forth in the table on page 58.

It may be noted here that emerald-green chromiferous vesuvianite also occurs on the Monetnaja estate, Ekaterinburg, Urals.

Pale yellow crystals also occur with the diopside in a manner similar to the above, but they are of a different habit (see Figure 21). The basal plane was absent in eight crystals which were measured, and was not observed on others which were examined with a lens. The prisms a and m have about the same development, sometimes one, sometimes the other, being the larger, and the edge between them is invariably truncated by narrow faces of the form f(210). The crystals are terminated by the unit pyramid p(111) as dominant form, with s(311) somewhat smaller; faces belonging to other forms, as listed in the table below, are minute and not universally present. Although these and the emerald-green crystals are obviously later than the diopside with which they occur,

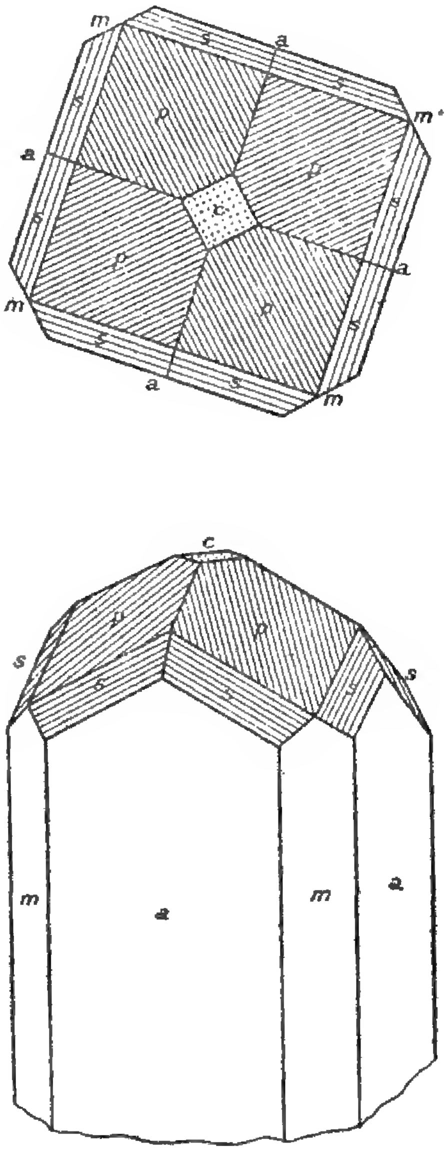


Figure 19. Vesuvianite from the Montreal chrome pit; illustrates the way in which some of the lilac crystals are striated.

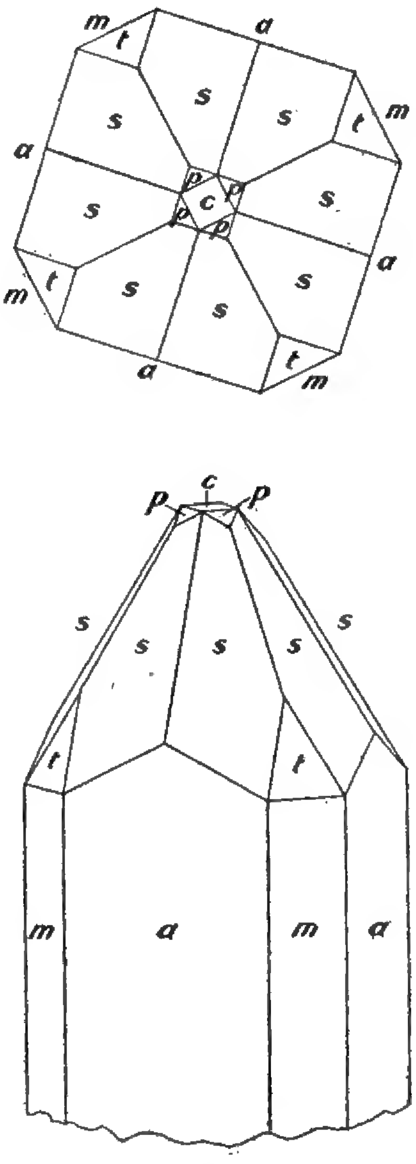


Figure 20. Vesuvianite from the Montreal chrome pit; emerald-green crystal.

they were not found associated, in the specimens collected, in such a way as would render it possible to determine whether or not they are strictly contemporaneous and formed under the same conditions. The difference in crystal habit, however, is interesting, as possibly indicating the influence of the presence or absence of chromium in determining the forms developed on the crystals.

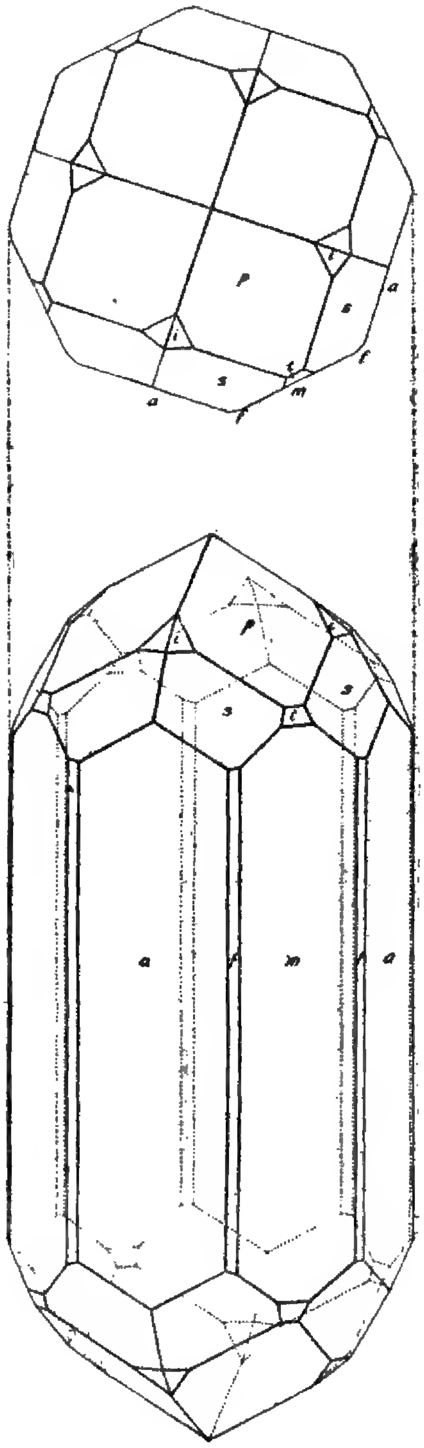


Figure 21. Vesuvianite from the Montreal chrome pit; average habit of the pale yellowish crystals.

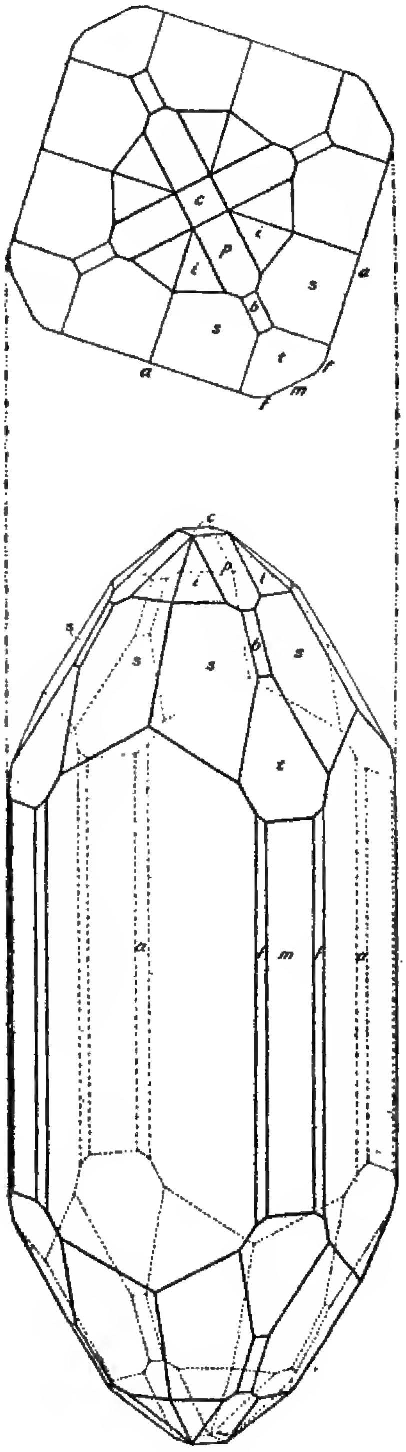


Figure 22. Vesuvianite from the Montreal chrome pit; average habit of the emerald-green crystals.

Calcite, aragonite, clinochlore, and porcellophite are the minerals most commonly associated with the emerald-green crystals; the yellow variety has in addition andradite associated with it.

Southwark Pit. Clove-brown and reddish-brown crystals are associated with the colourless grossular garnet described on page 46; the largest crystals observed have a length of 1·5 cm., and measure 4 mm. across the prism. Several crystals were measured and on these the forms tabulated on page 58 were noted; the habit is usually determined by the forms a(010) and s(311); p(111) is sometimes fairly large and the base is absent.

Caribou Chrome Pit. This locality yields reddish-brown crystals of habit similar to the last.

American Chrome Pit. Vesuvianite occurs here in compact masses of pale yellow colour; where more coarsely crystallized, it forms a network of prisms, but well terminated crystals were not seen.

Union Pit. Bottle-green, as well as reddish-brown, vesuvianite occurs at the Union pit, but in neither case was it found to be well crystallized; the former is usually associated with clinochlore and brownish diopside, the latter with colourless, rose, and pale green grossularite.

Hall Chrome Pit. At this pit there is found a massive vesuvianite rock, almost uncoloured, associated with which are crystals having an emerald-green colour.

Table of Occurrences. For convenience of reference, the differently coloured varieties of vesuvianite occurring in the area at the principal localities visited are tabulated below:

Pit	Emerald-green	Lilac to colourless	Pale yellow	Reddish-brown	Bottle-green
Montreal chrome..........	x	x	x	——	——
Southwark..............	——	——	——	x	——
Caribou..................	——	——	——	x	——
American...............	——	——	x	——	——
Union..................	——	——	——	x	x
Hall.....................	x	——	x	——	——

Crystallography.

About sixty of the crystals were measured, these being chiefly of the lilac, emerald-green, and pale yellow coloured varieties, which, owing to the brilliance of their faces, present almost perfect material for goniometric work. The total number of forms observed in this series of crystals was sixteen; these forms are given in the following table, which also shows how they were distributed among the differently coloured crystals.

Crystal Forms of Vesuvianite.

Letter	Symbol	Lilac to colourless	Emerald-green	Pale yellow	Reddish-brown
c	001	x	x	—	—
a	010	x	x	x	x
m	110	x	x	x	x
f	120	x	x	x	x
h	130	x	—	—	—
φ	350	—	—	—	x
t	331	x	x	x	—
b	221	—	x	x	—
p	111	x	x	x	x
s	131	x	x	x	x
i	132	x	x	x	—
d	241	x	x	x	—
z	121	x	—	—	—
o	011	x	—	—	—
r	461	—	x	—	—
v	151	—	—	—	x

No new forms were noted, and all those observed are commonly occurring and well established forms for vesuvianite, with the possible exception of the two last. Of these, v(151) has been observed as a rare form, and has also been recently recorded by Schaller[1] on brown-green crystals from Alaska. In the present case it was observed as very minute facets on the pale yellow crystals from the Montreal chrome pit, the mean measured and the calculated angles being as follows:

	Measured	Calculated
v(151)	$\varphi = 11°27'$	$11°18'$
	$\rho = 69\ 44$	$69\ 57$

As has already been noted the same form probably occurs on the lilac crystals from this locality, together with y(411) and (272), these three all lying in the striated zone (100): (311).

The other form, r(461), is marked as doubtful in Goldschmidt's Tabellen. It was here observed on one of the emerald-green crystals, and although quite small, the measured angles agree so nearly with the calculated values that the form may be considered as well established.

	Measured	Calculated
r(461)	$\varphi = 33°49'$	$33°41'$
	$\rho = 75\ 33$	$75\ 32$

It has not been thought necessary to give the means of the angles, as measured, for the other forms, since they agree in every case, within a few minutes, with the accepted values, using the co-ordinate $p_0 = q_0 = 0{\cdot}5376$ or the axial ratio $a : c = 1 : 0{\cdot}5376$.

Min. notes, Ser. I, U.S. Geol. Surv., Bull. No. 490, p. 9.

It was at first thought that slight variations might be observed in the angles of the differently coloured crystals, due to a difference in chemical composition, and with a view to testing this, the means of the angles of the severally coloured varieties have been assembled together for comparison. For the three principal pyramids on the lilac, emerald, and pale yellow crystals the mean values for φ and ρ were as follows:

Colour of crystal	No. of angles	p(111)		No. of angles	s(311)		No. of angles	i(312)	
		φ	ρ		φ	ρ		φ	ρ
Lilac....	31	45°01′	37°15⅓′	37	18°25½′	59°35′	22	182°7′	40°23½′
Emerald.	63	44 59¾	37 15⅓	112	18 23¼	59 34¾	15	18 29½	40 23
Yellow...	19	45 02	37 16	46	18 26½	59 33	—	—	—
Gdt. value..	—	45 00	37 14	—	18 26	59 32	—	18 26	40 22

The results are of a negative character, since the differences observed between the corresponding angles for the severally coloured varieties are only of the same order as those met with in a number of crystals of the same colour. As will have appeared from the foregoing description, however, it would seem possible that the slight differences in composition, which have given rise to the several colours, have at least been sufficient to influence the habit of the crystals; in other words, the habit is, in general, constant in crystals of the same colour and distinctly different in crystals of different colours.

Chemical Composition.

Heating at 105 degrees C. produces no apparent change in the mineral, and there is practically no loss in weight (about 0·05 per cent); in one instance the finely powdered material was kept at 165 degrees C. for an hour, with the same result. At a higher temperature fusion with intumescence takes place, and if the material is in the form of a powder it cakes and turns a bath-brick colour, losing in weight at the same time to the extent of about 3 per cent. The melt obtained after fusion with sodium carbonate is green, indicating manganese, which is always present, though only in very small amount. The mineral is not acted on by acids. A qualitative test for chlorine and fluorine gave negative results.

Several analyses were made of the lilac crystals, with the following results:

Analyses of Lilac Crystals of Vesuvianite.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MnO	MgO
1	36·67	20·35	1·01	37·35	0·18	2·49
2	36·74	19·95	0·60	——	——	——
3	36·94	19·95	0·87	——	0·21	——
4	36·72	20·07	0·82	37·59	——	——
5	37·31	19·83	0·97	37·90	0·29	1·85
Mean....	36·88	20·03	0·85	37·61	0·23	2·17

In each case the total iron present has been calculated as Fe_2O_3; no seperate determination was made for ferrous iron. The water was estimated indirectly from the loss in weight after heating; at 105 degrees C. this loss was 0·03 per cent and there was a further decrease of 3·06 per cent after prolonged ignition. A second determination on another selected sample gave a total loss in weight of 3·33 per cent. The mean of the above analyses is given in column 2 in the following table. The specific gravity of the lilac crystals is 3·32.

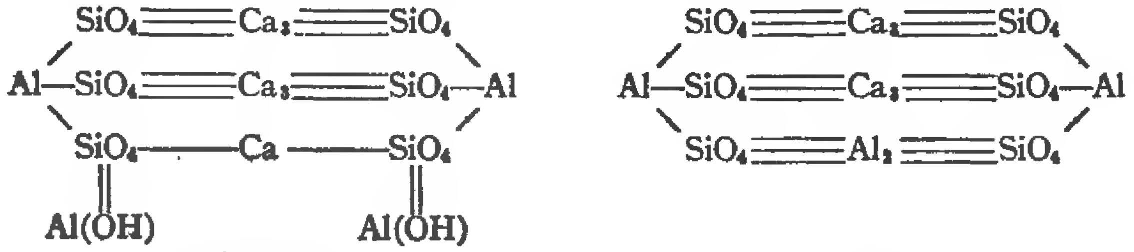
A single analysis of the pale yellowish-green crystals from the Montreal chrome pit gave the result shown in column 3; as will be noted there is a close correspondence in the composition of the two varieties, the only essential difference being, that in the yellowish-green crystals about 4 per cent of the Al_2O_3 has been replaced by its equivalent of Fe_2O_3.

Analyses of Vesuvianite.

	Calculated for Clarke's formula	Lilac crystals.	Yellowish-green crystals.
SiO_2............	36·96	36·88	36·62
Al_2O_3...........	20·94	20·03	15·96
Fe_2O_3..........	——	0·85	4·30
FeO............	——	——	0·54
CaO...........	40·25	37·61	38·66
MnO...........	——	0·23	trace
MgO...........	——	2·17	1·25
H_2O-105°C....	——	0·03	0·07
H_2O+105°C....	1·85	3·06	3·11
	100·00	100·86	100·51

Analyses of vesuvianite do not, as a rule, lead to any simple formula for the mineral, and specimens from different localities may vary considerably in composition. It is, broadly speaking, a calcium-aluminum silicate, in which varying proportions of the calcium may be replaced by equivalent amounts of other metals, especially magnesium and ferrous iron, and ferric iron may at the same time take the place of some of the aluminum. Water of constitution appears to be an essential component of the mineral, and in thirty-six analyses quoted in Dana's Mineralogy, the percentage of water ranges from 0·55 to 3·41.

Clarke[1] regards vesuvianite as an orthosilicate with composition essentially $Ca_7(OH)_2Al_4(SiO_4)_6$, and he assigns to the mineral the constitutional formula reproduced below. The percentage composition calculated for this formula is given in column 1 of the preceding table.



Vesuvianite *Garnet*

Constitutional formulæ of vesuvianite and garnet (after Clarke).

In the occurrences here described, garnet is frequently associated with vesuvianite, but at many localities in the area it is also found alone, forming dykes under conditions which suggest that its mode of origin must have been similar to that of the vesuvianite in the dykes of this mineral noted at the Montreal chrome pit and elsewhere. A comparison of the graphic formulæ of the two minerals (after Clarke) is thus instructive, as indicating that their molecules are very similar, both as regards composition and constitution; from this it might be inferred that the genetic relation between these two species would be very close.

Optical Characters.

The crystals always exhibit both the first and second order prisms; and, although one of these, usually (100), generally has a large development relatively to the other, it is possible to select crystals in which the faces of both forms have an appreciable width, and to use these as prisms, with internal angle of 45 degrees, for the determination of the refractive indices by the minimum deviation method. A series of trials, however, showed that no great degree of accuracy could be attained. This is in part owing to the fact that perfect prism faces are found only on very small crystals; the prisms used consist of two faces, of which one belongs to the form (100) and the other to (110), and it usually happens that one or other of these is extremely narrow, so that the light from a sodium flame refracted through the prism is so feeble that the images cannot be very accurately adjusted on the cross hairs. On the other hand, if larger crystals are employed, the images, while being sufficiently bright, are multiple; this is the result of a feature which has already been referred

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[1] Clarke, F. W., "The constitution of the natural silicates," U. S. Geol. Surv., Bull. 588, p. 30.

to in dealing with the crystallography, viz., the faces of the prism (100), even when free from vertical striæ, are in general not simple, but each is made up of two parts inclined to one another at an angle varying up to half a degree or more, their edge being parallel to the principal axis of the crystal. It is possible also that the variable values found for the refractive indices may be partly due to a slight non-homogeneity in the material of the crystals, such as has been frequently observed in the case of vesuvianite.

The crystals are always optically negative, and the double refraction is weak. The average of ten fairly good determinations on the lilac crystals gave for the refractive indices:

$$\omega = 1{\cdot}708,\ \epsilon = 1{\cdot}705, \text{ and } \epsilon\text{-}\omega = -0{\cdot}003$$

As an indication of the limits which were observed, the eight possible 45-degree prisms in one crystal examined, and on which the first and second order tetragonal prisms were about equally developed, gave values ranging from

$$\omega = 1{\cdot}705,\ \epsilon = 1{\cdot}702 \text{ to } \omega = 1{\cdot}711,\ \epsilon = 1{\cdot}709.$$

The indices of the emerald-green and yellowish-green crystals also fall within these limits, and approach closely to the above mean values, from which it would appear that the effect on the refractive power of their slight differences in chemical composition is not very pronounced.

Although it has not been possible to determine the refractive indices very exactly, the results are sufficient to show that the crystals have an appreciably lower refractive power than is usual in vesuvianite, and this is no doubt owing to their relative freedom from iron. The highest observed limits for these crystals ($\omega = 1{\cdot}711$, $\epsilon = 1{\cdot}709$) are lower than the generally recorded values for vesuvianite, which range from $\omega = 1{\cdot}712$ to $1{\cdot}732$ and $\epsilon = 1{\cdot}7108$ to $1{\cdot}726$; although Iddings[1] quotes one exceptional case in which green-brown crystals from Sandford, Maine, were found by Hlawatsch to have the values $\omega = 1{\cdot}705$, $\epsilon = 1{\cdot}701$. In each case the refractive indices given above refer to yellow (sodium) light.

Examined with the dichroscope, the crystals exhibit a noticeable pleochroism, which, although weak, is fairly well marked in the stouter crystals; this is as follows:

Colour of crystals.	For light vibrating along horizontal axis (ω).	For light vibrating along vertical axis (ϵ).
Lilac	pink	colourless
Emerald-green	bottle-green	bluish-green
Clove-brown	deep brown	paler brown

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[1] Iddings, J. P., "Rock minerals," 1906, p. 378.

ZIRCON.

A few scattered crystals of zircon were observed on specimens, from the old Standard mine, of the new mineral, colerainite, which is described on page 66.

The crystals, measuring 2 mm. in length by 1 mm. in width, have a reddish-brown colour, and a brilliant lustre; they are simple combinations of the second order prism, a(100), with the first order pyramid, p(111), and in most cases they are doubly terminated.

EPIDOTE.

Epidote occurs only as a secondary rock constituent, being especially abundant in some of the diabase masses.

TOURMALINE.

A few specimens bearing crystals of tourmaline were collected from the dump at the old Standard mine. These specimens doubtless came from a pegmatite dyke, and they consist mainly of plagioclase, optically near albite, with a little muscovite. The flakes of muscovite measure up to one cm. in diameter and are much contorted; microscopic crystals of reddish-brown garnet are also present, especially in the vicinity of the mica.

The tourmaline has a greenish-black colour, and the largest crystal observed measures 4 mm. in width, by 1·5 cm. in length. The crystals were not measured on the goniometer but by inspection they are seen to be trigonal prisms, heavily striated along their length, terminated by the rhombohedron.

HYDROUS SILICATES.

SCOLECITE.

Scolecite was reported from this area as long ago as 1890, in which year the Annual Report of the Geological Survey[1] refers to a specimen from "Black Lake, township of Coleraine" as having been presented to the mineral collection by Dr. J. T. Donald. The following description of these specimens is given by Robert H. Jones[2]: "In one of the granulitic dykes on the Glasgow and Montreal Company's property, Professor Donald found and sent to me a sample of scolecite, which occurs in transparent glassy needles, filling minute veins, and in masses of white, grey, and colourless radiating fibres."

A specimen collected in 1913 by Robert Harvie from the Glasgow pit of the British American Asbestos, now the Asbestos Corporation, was identified by one of the writers as scolecite. The mineral occurs

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[1] Geol. Surv., Can., Ann. Rept., vol. V, pt. I, 1890-1, p. 68A.

[2] Jones, Robt. H., "Asbestos and asbestic, their properties, occurrence, and uses," published by Crosby Lockwood and Son, London, 1897, p. 150.

lining narrow fissures in an aplitic rock, and has the form of slender prismatic crystals arranged in divergent groups; they attain a size of 2 cm. in length by about 3 mm. in width, but are commonly narrower than this, and they have a silky lustre. Examined under the microscope the crystals are found to be biaxial, negative, with weak double refraction, and the extinction angle, $Bx_a \wedge c$-axis, was measured as 17 degrees.

MICA.

The minerals of the mica group are not at all common in the area, either as constituents of the principal rocks or otherwise. Biotite is occasionally present in some abundance in the granite, but in general this rock is essentially hornblendic and contains no biotite. A brown coloured mica is associated with the colerainite at the old Standard mine, and specimens of a tourmaline-bearing pegmatite from the dump at the same mine carry crystal flakes of muscovite (damourite).

CLINOCHLORE.

Clinochlore is fairly widespread, and sometimes occurs in very sharply defined crystals, as for example at the Montreal chrome pit. These crystals are tabular in habit, quite transparent, and have a deep bluish-green colour by transmitted light, the tint being paler in the thinner crystals; when extremely thin they are colourless. More commonly the mineral forms irregular cleavable masses, with colour varying from green to white, and these at times display a massive or compact structure.

The best crystals collected have a width of 1 cm. or less and are not more than 2 mm. in thickness, though poorer and opaque crystals of larger size occur. In form they are six-sided plates with bevelled edges; the base has the usual pearly to vitreous lustre, is usually faintly striated parallel to its edges, and is seldom sufficiently flat to yield a single-image reflection. The faces of the other forms are also found on examination to be, for the most part, very imperfect; occasionally a crystal will display between the two basal planes one or more faces which are perfectly sharp and have a high and somewhat greasy lustre, but it generally happens that these planes are heavily striated, have a dull lustre, and yield continuous strings of images when examined on the reflecting goniometer. Some crystals exhibit as many as six of such imperfect planes lying in a zone; but owing to their character and also to the fact that most of the crystals are found, both by the presence of reentrant angles and by optical tests, to be repeatedly twinned, it has not been possible to determine these forms with accuracy. The following forms seem to be well established, however, as occurring on crystals from the Montreal chrome pit.

c	(001)	u	(227)	μ	$(\bar{1}12)$	t	(043)
i	$(\bar{1}01)$	d	(225)	v	(132)		
y	$(\bar{2}05)$	m_o	(112)	β	(0·11·24)		
f	$(\bar{4}01)$	n	$(\bar{2}25)$	δ	(059)		

These were determined by measurement, mainly with the contact goniometer, of selected crystals which were first oriented by means of interference figures.

The crystals have a specific gravity of 2·60—2·65. Optically they are invariably biaxial, positive, with dispersion $\rho < v$. The acute bisectrix is slightly inclined to the normal to c(001), and the axial angle is variable, some crystals being nearly uniaxial. Most of the crystals, even when apparently simple, are seen to be multiple twins, on the *Mica law* (twin plane $\perp$c in the zone cm_o), the planes of the optic axes in the several individuals composing the twin being inclined to one another at about 60 degrees. The mean refractive index is about 1·58, and the birefringence of medium strength, near that of quartz.

No complete analysis of the material has been made. It is here designated clinochlore (as against penninite) on the strength of the various criteria referred to above, viz. the tabular crystal habit, the relatively high birefringence with its invariable positive sign, the distinctly biaxial character, and the very common twinning on the Mica law as observed under the microscope.

Most of the specimens examined came from the Montreal chrome pit where the clinochlore occurs associated with vesuvianite, andradite, and diopside, as referred to under those species. The clinochlore, so far as observed, is later than the diopside and vesuvianite, but older than the andradite, calcite, and aragonite. Another mode of occurrence at the same locality shows the clinochlore as extremely thin, colourless, transparent, scale-like crystals of roughly hexagonal or rounded outline, associated with similar material of matted appearance; this variety has a rather small optic axial angle. It occurs filling fissures in a dark, brownish-black, chromite-bearing serpentine, and is at times stained emerald-green through reaction with the chromite; there is also a little associated calcite.

At the Southwark pit, clinochlore occurs as minute hexagonal plates associated with colourless grossularite and reddish-brown vesuvianite.

Clinochlore of deep greenish-blue colour, similar to that of the Montreal chrome pit, but not so well crystallized, was also noted at the Union pit, where it occurs with bottle-green vesuvianite, brown diopside, and garnet.

Kotschubeite. A rose-red chromiferous mineral, possessing the general characters of this variety of clinochlore, has been met with at the Montreal chrome pit, where it forms very small veinlets in the massive chromite and in places occupies fissures in dark brownish-black serpentine. It exhibits a very distinct biaxial figure, is optically positive, and has a comparatively high birefringence.

Alteration Products. The fresh clinochlore is very easily cleavable into flakes, which are highly flexible; but altered forms occur in which the cleavage is poor, and the flakes become increasingly brittle; at the same time, the crystals lose their bright bluish colour and exhibit instead paler green tints, until the most highly altered form is almost white, with a pale greenish tinge. Optically, these behave in the same way as the unaltered material, being biaxial with variable angle, but always positive in sign. Under the microscope, in parallel light, they are seen to be composed of the clear transparent clinochlore more or less filled with an opaque, granular or dusty decomposition product, which is white, and claylike by reflected light. All gradations are met with from the fresh crystalline material to that of this alteration product, which transmits practically no light. The fusibility becomes easier as the alteration proceeds, the fresh mineral being fusible with difficulty and only on the edges of thin flakes, while the yellowish-white material is fairly easily fusible, the result in each case being a white enamel.

COLERAINITE.

The area has afforded one new mineral species which occurs in definite, though minute, crystals in a pegmatitic vein at the old Standard mine and also in specimens collected from a dump near the Union pit. To this, the name colerainite has been given in reference to the locality of discovery.

The best specimens were obtained from the dump at the old Standard mine, (Plate VIII B) and the following description refers more particularly to these.

Crystals of colerainite have the form of extremely thin, hexagonal plates or flakes. In the best specimens collected these have a rather uniform diameter of about one mm., and they are so thin, that even when examined with a high power under the binocular microscope, no crystal facets can be seen between the two basal planes. As a rule the plates have a somewhat rounded outline, and are curved with a slightly concave upper surface; smaller flakes being arranged in more or less parallel position upon these, give rise to rosettes, which being frequently aggregated together in the form of spheres, give to the specimens a characteristically botryoidal structure. Less frequently, the crystals are attached to the matrix by an edge, and individuals have been able to develop more freely and perfectly. These are perfectly flat plates with a sharp hexagonal outline, and they often completely interpenetrate one another, but whether as a result of twinning or not could not be determined.

The crystals occur, lining irregular and, in many places, large druses in a somewhat cavernous pegmatitic material, no doubt from a vein which intersected massive serpentine. They appear as a crust, 1 or

2 mm. thick, upon a fine granular to compact matrix, which also forms the nucleus of each little sphere where the structure is botryoidal. Frequently these small spheres of colerainite are themselves coated by a dolomitic film, so delicate that it can only be detected under the microscope with a very high power. The analysis on page 68 as well as the general blowpipe and other characters, indicate that this matrix is very nearly related to, if not actually identical with, the crystals themselves. The entire vein is composed almost exclusively of this compact material, there being only a little associated brown platy mica (biaxial, negative, with small axial angle), an occasional small crystal of garnet and zircon, and some pale green actinolite in short radiated fibres.

Individual crystals of colerainite are essentially colourless and transparent with a vitreous lustre; actually, the lustre is more generally pearly, due to the curvature and superposition of the plates, and possibly also to a basal cleavage. In bulk, the pure mineral appears white, with a glistening or dull lustre, depending on the size of the crystals; other colours exhibited are faint pink and pale brown, due to isomorphous replacement or staining. The compact matrix is generally white with a dull "matte" lustre; adjacent to the crystals there is usually a narrow zone which is translucent and nearly colourless, and there is thus a tendency for the material to be banded, although this feature is not very pronounced.

The hardness is 2½ to 3; the specific gravity of the crystals is 2·51 and of the matrix about 2·44.

Examined under the microscope between crossed nicols, crystal flakes are isotropic, and in convergent light they yield a uniaxial figure, the optic axis emerging normal to the flake. The birefringence is positive and weak, with mean refractive index about 1·56. The matrix is very finely crystalline and has similar optical characters.

Microphotographs of a thin section of the rock are reproduced in Plates XI and XII. Examined in ordinary light, the rock is seen to have a drusy character, and to be composed almost entirely of a colourless mineral of fairly low refractive index (colerainite) through which are scattered dusty patches and streaks of a white, opaque, clay-like substance, which appear black in the photograph. One or two minute flakes of a pale brown mica are also present in the section examined.

The structure is best observed between crossed nicols. The drusy cavities are seen to be everywhere bordered by aggregates of colerainite crystals. These are almost without exception wedge-shaped, each little wedge having its base facing toward the open druse; a number of wedges being arranged side by side in this manner produce spherical, or in section circular, groups of individuals. The simultaneous extinction, in such groups, of four component wedges inclined at 90 degrees to one another, gives rise to a black cross which revolves as the section is turned on the stage. Frequently these wedges are traversed by a series of fine lines parallel to their base, a feature which is well shown in Plate XII. These indicate that colerainite probably has a basal cleavage, although it is also possible they may be due to the parallel superposition of very thin plates of the mineral.

This relatively coarsely crystallized material forms a zone of fairly uniform width around the margin of each druse. Below this, the structure abruptly becomes very fine-grained, although under a higher power the material is seen to be similar and to display the same radial arrangement. Within this, the clay-like substance is dispersed as dusty particles, or in blotches and streaks, and it is found especially at the centres of the circular radial groups of crystals. Throughout the fine-grained material, also, there are many more coarsely crystallized patches and veinlets, representing small druses and crevices within the rock which have been completely filled.

The following analyses of the matrix (column 1) and crystals (column 2) were made by M. F. Connor:

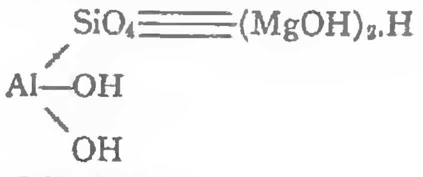
Analyses of Colerainite.

	Matrix	Crystals	Molecular ratio	Percentage composition, calculated
SiO_2	26·98	24·40	406·6...2	25·42
Al_2O_3	16·10	22·77	223·2 ..1	21·61
Fe_2O_3	0·22	0·45	3·0	
FeO	None	Not det'd		
MgO	36·56	32·70	817·5 ..4	33·90
CaO	0·12	0·10	2·0	
$(NaK)_2O$	0·28	0·30	4·0	
MnO	0·20	0·09	1·0	
H_2O	19·91	19·63	1090·5...5	19·07
	100·37	100·44		100·00

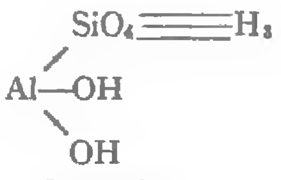
The mineral is thus a hydrated magnesian aluminous silicate. In the case of the crystals the molecular ratios approximate to $4MgO.Al_2O_3.2SiO_2.5H_2O$ and the percentage composition calculated for such a compound is given in the last column above. The calculated values are in fair agreement with those given in the analysis, and the formula $4MgO.Al_2O_3.2SiO_2.5H_2O$ or $H_6Mg_2AlSiO_8$ is, therefore, adopted for colerainite.

The massive character of the matrix naturally renders it impossible to be certain that the material selected for analysis was free from foreign admixture, but the analysis at least serves to indicate that it has essentially the same composition as the crystals. The approximate composition of the matrix, as calculated from the analysis, would be near $6MgO.Al_2O_3.3SiO_2.7H_2O$; if it is composed in part of colerainite of composition $4MgO.Al_2O_3.2SiO_2.5H_2O$, it is necessary to assume the presence also of some admixed hydrous magnesian silicate, near serpentine.

Colerainite may be regarded as a basic orthosilicate, with the constitutional formula shown below; it may be compared with newtonite[1] from which it differs in having the two monovalent radicles $(MgOH)_2$ in place of two hydrogen atoms.



Colerainite



Newtonite

When heated at first gently to dehydration, and then strongly in the blowpipe flame, the mineral whitens, disintegrates, and falls to pieces, showing a tendency to exfoliate, and finally it fuses with little or no intumescence to a white, rather lustreless, glass. Moistened with cobalt nitrate and heated, the mass becomes blue. Heated in a closed tube, the mineral whitens, decrepitates, and flies to pieces, and at a high temperature gives off much water. It is decomposed with difficulty by hydrochloric acid with separation of flocculent silica, but apparently without going entirely into solution.

The behaviour of the compact matrix is similar, with the exception that it does not fall to pieces to the same extent on heating, and as a consequence it appears to fuse more easily.

In some specimens, the crystals are in part covered with a later deposit of a cream coloured amorphous substance, which has the lustre and rather the appearance of polished meerschaum. In one specimen collected, two nearly adjacent druses, which are lined with crystals of colerainite, are partly filled with this material, the flat surfaces of the deposits in the two druses being parallel to one another. This material was not analysed. It has a hardness rather below 3, and the specific gravity is 2·45. Thin splinters fuse quietly in the bunsen flame to a white opaque globule, and the substance becomes pink when moistened with cobalt nitrate and heated.

Colerainite was observed at only one other locality in the area, specimens having been collected on a dump near the Union pit, from which they doubtless came. The specimens have the same botryoidal form as those from the old Standard mine described above, but they are not nearly as well crystallized. The botryoidal spheres vary in diameter

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[1] Clarke, F. W., "The constitution of the natural silicates;" U. S. Geol. Surv., Bull. No. 588, 1914, p. 83.

from one-eighth to half an inch; they are composed of compact material, with only a very thin, imperfectly crystalline crust on their surface. No individual crystal flakes were observed on any of the specimens, but the crust was identified with certainty as colerainite, by its optical characters.

Much of the compact matrix is white with a surface recalling unglazed porcelain, as in the old Standard mine specimens, but here it shows a greater tendency to concentric banding. Immediately adjacent to the crystalline crust the material is commonly translucent and nearly colourless, and this zone is followed by banding in white, pale cream, and pink. Altogether, the specimens have very much the appearance of banded chalcedony and at first, indeed, they were assumed to be this mineral. The lustre is either dull, like that of chalcedony, or waxy, like common opal. The hardness is 2½ to 3 and the specific gravity, as determined on several pieces by the heavy liquid method, is 2·34–2·35.

The compact material, with as little as possible of the crystalline crust attached, was analysed by M. F. Connor with the result given in column 1 below.

	Union pit	Loganite, Calumet falls	Pseudophite, Berg Zdjar
SiO_2	33·00	33·28	33·42
Al_2O_3	13·12	13·30	15·42
Fe_2O_3	——	1·92	——
FeO	——	——	2·58
CaO	Trace	——	——
MgO	35·30	35·50	34·04
K_2O	0·11	——	——
Na_2O	0·15	——	——
$H_2O-108°$	2·55	16·00	12·68
$H_2O+108°$	16·12		
	100·35	100·00	98·14

This analysis differs from those of the old Standard mine material mainly in showing a higher content of SiO_2 and lower Al_2O_3. There can be no doubt, however, that this material is closely related to that which forms the matrix of the old Standard mine specimens, and it is very probable that in both cases it is not a homogenous mineral. The composition, as calculated from the analysis, is roughly $8MgO.Al_2O_3.5SiO_2.9H_2O$; if it is assumed that the material analysed was in part colerainite, then this might have been mixed with a hydrous magnesian silicate of composition $4MgO.3SiO_2.4H_2O$, near serpentine, or "aphrodite," which approximates to $MgO.SiO_2.H_2O$. In its blowpipe characters and behaviour towards hydrochloric acid, the Union pit material resembles that from the old Standard mine; this further suggests the essential identity of the two occurrences.

The analysis of the original loganite[1] is reproduced in column 2 above, and it is interesting to note the close correspondence in composition between this and the Union pit material; the SiO_2, Al_2O_3, and MgO content is almost identical in the two substances, but loganite contains appreciably less water and further has nearly 2 per cent Fe_2O_3, whereas the other is essentially free from iron. The resemblance between the two substances ceases here, however; they are widely different in their physical characters, loganite being described as follows: "Hydrated aluminous magnesian minerals, sparry in crystallization ..... are met with in several localities among the Laurentian limestone in Canada. The first one to be mentioned occurs at the Calumet falls. It is associated with pale green serpentine, brown phlogopite, and apatite, in a white crystalline limestone, and has been described by the name of loganite. It occurs in short thick oblique rhombic prisms, replaced on the edges or on the acute solid angles. The crystals are generally rounded, but present a prism of 124 degrees, or near to that of hornblende. There is a distinct cleavage with the sides and the base of the prism, and an imperfect one with the longer diagonal. The hardness of the mineral is about that of calcareous spar, and its specific gravity is from 2·60 to 2·64. The surface of the crystals is dull, but the lustre of the cleavages is vitreous and shining. The colour is clove-brown or chocolate-brown, and the mineral is sub-translucent, brittle, and with an uneven fracture. The crystals, which are seldom more than one-fourth of an inch in diameter, are penetrated by carbonate of lime, from which they are with difficulty freed. The mineral is infusible before the blowpipe, and partially decomposed by acids.... The composition [in the analysis reproduced above] is calculated for 100 parts, excluding the carbonate of lime."

Loganite is generally regarded as a member of the chlorite group of minerals, and, more particularly, as a variety of penninite. It is nearly related to, or identical with, pseudophite, which has a very similar composition, but contains 2 or 3 per cent less water (see analysis in column 3 above). Pseudophite, which occurs associated with enstatite at the Berg Zdjar in Aloisthal, Moravia, and elsewhere, is described[2] as being a compact massive substance, without cleavage, which resembles serpentine (whence the name from *πσευδος* false, and *ophite* or serpentine); H = 2·5; sp. gr. = 2·75–2·77; lustre, weak; colour, greyish-green, olive-green, pistachio-green; feel, unctuous.

The present material thus somewhat resembles pseudophite in its general physical characters, except as regards colour and specific gravity, but it contains considerably more water.

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[1] Geol. of Can., 1863, p. 490.

[2] Dana, Mineralogy, 6th edition, p. 652.

In view of the very compact and almost amorphous condition of the material from the Union pit, and also to a lesser degree of the matrix of the old Standard mine specimens, with the consequent uncertainty as to the constitution of the material selected for analysis, it has not been deemed advisable to assign special names to these substances. Even in the Union pit specimens, which have an extremely compact structure like chalcedony, it is usually possible to see some small glistening flakes of colerainite distributed through the material, and sometimes these are arranged in very narrow streaks. When crushed and examined in oil under the microscope, the fragments are found to be all perfectly transparent, with low index of refraction, and for the most part they are weakly birefringent with a concentrically banded spherulitic structure; occasionally also, a flake is found which gives the uniaxial positive interference figure. Other fragments, however, appear to be perfectly isotropic and amorphous. It is believed that the crystalline material is in all cases colerainite, and that there is probably associated with this some amorphous hydrous magnesian silicate, perhaps also aluminous, of indefinite and possibly variable composition. In some cases the latter may have a composition approaching that of pseudophite or loganite, and in others near serpentine.

Although the colerainite specimens, both from the old Standard mine and also from the Union pit, were collected from dumps, and the material was not actually seen in place, it doubtless originally formed veins traversing the massive serpentine in each case; and, judging by the size of the specimens, especially those on the old Standard mine dump, these veins must have had a width of 2 or 3 feet at least, and may have been very much wider than this. As has already been stated, examination shows that this vein material is composed almost entirely of colerainite alone, with probably some associated amorphous hydrous magnesian silicate. The mode of occurrence would thus be very similar to that of the veins or dykes composed of other minerals, such as diopside and vesuvianite, which have been noted at several localities and described in earlier pages, and it is believed that the colerainite veins have originated in a similar way to them. The conclusions arrived at by the writers regarding the genesis of these various mineral veins have been set forth in a section dealing with the origin of the minerals (page 10). Briefly stated, it is believed that the extremely acid and aqueous granitic magma which formed the last phase of intrusion of the igneous rocks of the serpentine belt, acted as a powerful solvent on the basic rocks as it was injected through fissures traversing them; this solvent action being largely due to the extreme difference in chemical composition between the magma and the invaded rocks. As a result, the magma, or the magmatic residue, was enriched in certain constituents derived from these rocks, and, on crystallization, it formed dykes or veins of such minerals as diopside, grossularite, and vesuvianite. Present observations indicate that veins of these minerals, containing high percentages of lime, are of more frequent occurrence in the chromite pits than elsewhere; that is, they are associated with a rock which was originally near pyroxenite in composition, and which contained an appreciable amount of lime.

It is believed that the genesis of the colerainite veins is to be explained in a similar manner. In this case, however, a hydrous silicate of aluminum and magnesium has been formed, containing no lime, and it is interesting to note that colerainite has been found only at asbestos pits, where the original country rock was a peridotite, containing little or no lime.

SERPENTINE.

Serpentine is the mineral most commonly met with in the various quarries and pits of the area. In its fibrous form, chrysotile-asbestos, it constitutes a product of great economic value. Several other varieties of the mineral occur and are described below, but they are only of mineralogical interest.

Mode of Occurrence of the Massive Serpentine and Chrysotile.

Full descriptions of the mode of occurrence of the massive serpentine and chrysotile in the area may be found by referring to the report of Cirkel[1] and more especially to that of Dresser. The outstanding features may be summarized as follows:

The massive serpentine occurs within the peridotite masses, in the form of zones or bands, whose boundaries against the peridotite are fairly sharp and are roughly parallel to one another, *i.e.*, they rather resemble dykes in outline, and assume all attitudes from vertical to horizontal.

The more prominent bands fall into roughly rectilinear sets, which follow the same directions as the main system of joints in the peridotite. Others, which are in general narrower and more irregular in their course, intersect these and one another at all angles, so that, in some places, the peridotite presents a remarkably intricate network of such serpentine bands. Of these minor bands, Dresser believes some follow strain fractures due to regional compression, and others, cracks caused by exfoliation.

Although these bands are fairly well defined, the peridotite for some distance on each side of them is serpentinized to a fairly considerable, and gradually decreasing, degree.

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[1] Cirkel, Fritz, "Chrysotile-asbestos, its occurrence, exploitation, milling, and uses;" Mines Branch, Can., report No. 69, 1910.

The central part of the massive serpentine bands is usually occupied by the fibrous variety, chrysotile; this also is dyke-like in shape, *i.e.*, its boundaries against the massive serpentine are roughly parallel to one another, and are rather sharply defined.

There appears to be a fairly constant relation between the total width of any massive serpentine band and that of the chrysotile vein which it encloses. Attention was first called to this feature by Dresser, who, from a number (49) of measurements, found that the entire serpentine band is about 6·6 times as wide as the asbestos vein within it.

The chrysotile fibres are all arranged parallel to one another, and lie in directions normal to the walls of the vein. Usually the fibres are not continuous right across the vein, especially in the wider ones, but there is a parting, or sometimes more than one, at or near the middle, which is occupied by a film of granular iron ore, usually magnetite.

Carbonates of lime and magnesia occur only in very small amount in the serpentine and associated rocks of the area, either in the form of veins or otherwise.

Lastly, granite is frequently found in the vicinity of good asbestos deposits, or, stated in another way, an accumulation of asbestos veins (and, therefore, also of serpentine bands) can very frequently be noticed in approaching the granite dykes.

Mode of Origin of the Massive Serpentine.

As has already been stated, the principal rock of the serpentine belt in the Black Lake area is peridotite, or a rock intermediate between this and pyroxenite, and it is generally agreed that the massive serpentine has resulted from the metamorphism of this rock; it is further believed that the serpentinization commenced along joints and other cracks, from which it proceeded outward in opposite directions. Field evidence points to the joints being more or less contemporaneous with the granite dykes; in other words, the rocks were shattered during the last phases of igneous activity, joint systems were developed, and along some of the fissures so formed, the granitic magma was injected. This correlates the commencement of the change from peridotite to serpentine with the period of granitic intrusion, or some time subsequent thereto.

While the actual source of the serpentine is thus well established, there may still remain some doubt as to the mode by which the change has been brought about. The production of serpentine from olivine involves, in general, either an addition of SiO_2 or a removal of MgO, in addition, of course, to hydration. If the reaction was of the first type, siliceous waters would supply the necessary reagent; in the second type, the excess of MgO must enter into some new form of combination, such as carbonate, in which case it would be necessary to asume that the solutions producing the metamorphism were charged with CO_2. These two types of serpentinization may be represented by the equations

$$(1)\quad 3Mg_2SiO_4 + SiO_2 + 4H_2O \rightarrow 2H_4Mg_3Si_2O_9$$
$$(2)\quad 2Mg_2SiO_4 + CO_2 + 2H_2O \rightarrow H_4Mg_3Si_2O_9 + MgCO_3.$$

If the metamorphism takes place through the agency of siliceous waters, serpentine is the only product necessarily formed, with perhaps some iron oxide (magnetite) if the olivine of the peridotite is an iron-bearing variety; but serpentinization by means of carbonated waters necessitates the simultaneous formation of a considerable amount of magnesium carbonate. Since the rocks of the area are free from carbonate, except in very minor amounts, the evidence points to siliceous and not carbonated waters as the reagent which has been responsible for the serpentinization.

There yet remains the question as to the source of these waters, whether they were of meteoric or magmatic origin; and here again there is no certain proof for either of these alternatives. The field evidence, however, points to a connexion between the granite dykes and the amount of serpentinization; and it seems most probable that the metamorphism was brought about by magmatic solutions which accompanied the injection of these dykes, or which were not required in the composition of the dykes and were expelled as the latter consolidated.

Mode of Origin of the Chrysotile.

Various theories have been advanced to explain the origin of the chrysotile veins, and references to the literature dealing with this subject will be found in the reports of Cirkel and Dresser. It will be sufficient to reproduce here the conclusions arrived at by the latter author as the result of an extended examination of the district:[1]

"The position, size, and number of asbestos veins in rich ground, make it inconceivable that the spaces they now occupy were once open fissures, and especially that many of them were open at the same time. Open fissures up to 2 inches in width, running in all directions from vertical to horizontal, extending 100 feet or more in length, and occupying in places as much as 10 per cent of the entire rock, would be a mechanical impossibility. The possibility remains of crevices having been enlarged and filled by replacement.

"But the asbestos of the veins is practically identical in chemical composition with the serpentine of the walls, which is strong evidence against the material composing the veins having been brought in either from above or below. Segregation from the walls also would imply a difference in chemical composition, which does not exist. In other

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[1] Op. cit., p. 65.

words, the material removed would have been replaced by material of exactly the same chemical composition, which is altogether improbable if not impossible.

"It is, therefore, concluded that the veins are crystallized portions of the serpentine walls, and that the crystals (fibres) have grown outwards from the original crevices which are now represented by partings of iron ore found near the centre of the veins. In cases where there is no such parting, the growth of the crystals has taken place on one side of the fracture only. In most cases, however, there has been crystallization on both sides of the fracture, thus leaving a parting in the vein."

It is probably safe to say that the weight of modern opinion is in favour of the above hypothesis, that the chrysotile has been formed ***in situ***, by direct replacement of the massive serpentine.

Common Massive Serpentine.

The serpentine of the area is for the most part massive, and this variety has already been described on page 7. The fresh material displays a very uniform green colour, and weathers to a creamy brown. The specific gravity ranges from 2·55 to 2·58 and the hardness is usually about 3½. The composition of an average specimen is given in column 1 of the following table, the analysis, by M. F. Connor, being reproduced from Dresser's report.

The massive serpentine has not been found to possess any economic value as an ornamental stone, owing partly to its very fractured condition.

Analyses of Serpentine.

	Massive serpentine, near Black Lake station	Precious serpentine, Megantic mine	Chrysotile, near Black Lake station
SiO_2	40·08	43·31	39·62
Al_2O_3	2·11	0·38	0·81
Fe_2O_3	1·13	0·27	4·52†
FeO	1·70	None	1·90
MnO	—	Trace	—
CaO	0·20	0·12	Trace
MgO	37·90*	40·03	39·73
$(K,Na)_2O$	0·10	0·28	Not det'd
H_2O-110°	1·35	15·77	0·43
H_2O+110°	13·89		13·32
	98·46	100·16	100·33

*Probably low. †Probably admixed magnetite.

"Precious" or "Noble" Serpentine.

Specimens of massive serpentine collected at the pits of the Megantic mine[1] are translucent, and have a somewhat waxy or greasy lustre and chrysoprase-green colour. The hardness is about 3½. Although the material appears quite compact, a determination of the specific gravity indicates that it is in reality somewhat porous. The value found immediately after immersion in water is 2·39, but the apparent weight of the substance continues to increase at a comparatively rapid rate, rendering an accurate weighing impossible. After boiling for about two hours, and allowing to remain overnight, still immersed in the water, the specific gravity was found to be 2·51, and it is possible that the true value is somewhat higher than this, and the same as that for the ordinary massive serpentine.

Small veins of chromite are to be seen scattered through some specimens of this translucent material. The serpentine, in the vicinity of these chromite grains sometimes includes small patches or narrow veinlets of a deep lilac coloured mineral, which has been identified as stichtite, a rare chrome-bearing magnesium hydroxycarbonate, hitherto only recorded from Dundas, Tasmania. This mineral has been described on page 27.

The composition of the precious serpentine is given in column 2 above. So far as observed, this variety is rare within the area, and occurs only as very narrow veins. It has been previously recorded both by Cirkel[2] and by Jones,[3] the specimens in each case having come from the same locality as those here described.

Porcellophite.

A white, cream, or pale coloured material, usually very compact and clay-like, has been observed at several localities as one of the latest minerals to be formed. Its blowpipe and general physical characters indicate that it is a hydrous magnesian silicate, and, in many instances at least, it is probably to be referred to porcellophite, or some nearly related variety of serpentine. Among such occurrences may be mentioned that at the Montreal chrome pit, where it is associated with the lilac vesuvianite and colourless diopside. A similar substance, having a cream colour, is also found partly filling some of the druses in specimens of colerainite from the old Standard mine.

Two specimens of this material have been analysed. One, from the Megantic mine, has a very pale grey colour, and the other, from the Hall chrome pit, is pale brown. Both are very compact, resembling dried

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[1] Indicated by (2) on Dresser's map 23A, "Thetford-Black Lake Mining district."

[2] Chrysotile-asbestos, Op. cit. p. 24.

[3] Chrysotile-asbestos, Op. cit., p. 159

clay, with a smooth flat-conchoidal porcelain-like fracture, giving a surface with a dull lustre. The hardness is about 2½, and the material is impressible by the finger nail, which leaves a mark with an oily lustre. The substances adhere to the tongue. When thrown on water, they float, only sinking after being left to stand for half an hour or so. In many respects, therefore, these two occurrences closely resemble sepiolite (meerschaum), but in chemical composition they are found to approach more nearly to serpentine than to sepiolite, and they are comparable with such hydrous magnesian silicates as aphrodite, which is described as being a soft, earthy, snow-white substance. The analyses are somewhat approximate, having been carried through rapidly, mainly for the purpose of identifying the material. The Al_2O_3 was not determined, but, judging from its colour, the precipitate with ammonium hydrate was mainly Fe_2O_3.

Analyses of Magnesian Silicates near Aphrodite.

	Megantic mine	Hall chrome pit
SiO_2	50·29	48·88
Al_2O_3 Fe_2O_3	6·23	3·56
FeO	1·00	1·36
CaO	None	None
MgO	29·99	31·41
$H_2O-110°$	3·10	3·05
$H_2O+110°$	10·20	12·62
	100·81	100·88

Williamsite.

A massive, translucent serpentine, possessing a rich apple-green colour, and having the same general physical characters as the williamsite from Lancaster county, Pennsylvania, occurs filling narrow fissures in the dark green serpentinized pyroxenite at the Montreal chrome pit.

Chrysotile-Asbestos.

There is a greater known development of this variety of serpentine in the Black Lake and neighbouring areas of the Eastern Townships of Quebec than in any other part of the world. The chrysotile is in the form of perfectly flexible, and easily separable silky fibres which, in bulk, have a sea-green or even darker colour, but individually are practically pure white. The silky or oily lustre and somewhat greasy feel serve to distinguish this variety of serpentine from the very similar hornblende asbestos, to which it is also inferior in hardness (3 to 3½) and specific gravity (2·57). The prevailing mode of occurrence at Black lake is also different from that typical of hornblende asbestos. The latter either occurs associated with, and often completely coating other minerals, such as epidote, in which case the fibres have no regular arrangement; or it may occur in veins and fissures, where the fibres are invariably elongated in the plane of the fissure. (This does not apply to crocidolite which, of course, is distinct from ordinary hornblende asbestos, and usually has a deep blue colour.)

The chrysotile-asbestos, on the other hand, in its typical mode of occurrence, forms veins in which the fibres, all packed parallel to one another, stretch transversely across from wall to wall of massive serpentine. The veins range in width from a mere fraction of an inch ($\frac{1}{16}$ or less) up to 4 or 5 inches, and rarely even more, the majority of them being less than half an inch across. Chrysotile occurring in this way is known as "vein fibre" or "cross fibre," and almost the entire output of the Black Lake-Thetford mines is of this type.

Sometimes, however, the chrysotile lies along slip planes in the massive serpentine, and then the fibres, instead of being transverse, lie lengthwise in the fissure; such chrysotile, termed "slip fibre," is, as a rule, not of such good quality as the cross fibre, being less flexible and harsher. Owing to the manner of occurrence, these fibres may appear to have a very considerable length, but this is due to the overlapping of a number of short fibres which are all matted together, more or less in parallel position, and in reality the slip fibre is usually shorter than the average cross fibre. This type is not so common in the Black Lake area as it is farther northeast, in East Broughton, where it forms the principal product mined.

The analysis given on page 76 in column 3 shows the composition of the chrysotile; this analysis was made by M. F. Connor, and is reproduced from Dresser's report.

Picrolite.

The slip fibre just referred to has frequently been described under the name picrolite; the latter term, however, is more properly restricted to those fibrous, or columnar, varieties of serpentine, in which the fibres are difficultly separable and not very flexible, breaking with a splintery fracture. True picrolite, as thus defined, is not at all uncommon. It passes over into a rather massive, lamellar variety which might be classed as antigorite; this, however, does not separate into folia, but splits only along certain parallel zones of parting whose surfaces are often highly slickensided. This variety usually has an olive-green to bluish-green colour, and the same specific gravity and hardness as ordinary massive serpentine.

Comparison with Russian Deposits.

A very close resemblance between the mode of occurrence of the chrysotile-asbestos in Quebec and in the Urals is indicated by the published descriptions of the latter deposits, and the following notes concerning them are of interest as affording a comparison of the two.[1]

The Russian deposits are situated about 80 miles northwest of Ekaterinburg, where serpentine and allied rocks form a belt 2 to 3 miles wide, extending for 30 miles with a very regular north and south trend. The rocks of the belt lie wholly within granite and they consist of chloritic and talc schists (in places carrying emeralds and other gems), diabase, porphyrite, and serpentine. The serpentine forms a series of elliptical masses with their longer axes running north and south, parallel to the trend of the belt, and one of the largest of these masses is a mile long by about 1,000 feet wide. Some narrow portions of the belt consist only of diabase and porphyrite, and veins (dykes ?) of the latter traverse the serpentine in places. As in Quebec, the asbestos is mainly in veins of cross fibre, and these attain a width of as much as 8 inches; but there is also some fibre, up to a yard in length, running parallel to the fissure walls. The associated minerals are stated to include magnetite, well crystallized, in veins and small aggregates; garnet, including grossularite, ouvarovite, and andradite; vesuvianite, sometimes emerald-green and chromiferous; chlorite; crystalline quartz, chalcedony, and rarely milky opal; and occasionaly aragonite and a calcium-iron-magnesium carbonate.

The writers have not been able to obtain any information regarding the actual mode of occurrence of these minerals in the Russian deposits, but it will be observed that the mineral association is, in the main, the same as that of the Black Lake area; the most notable differences are the absence of diopside from the Urals and the occurrence there of quartz, chalcedony, and opal. It may be added, however, that the matrix of the colerainite on the specimens from the Union pit so closely resembles chalcedony or common opal that the specimens collected were at first wrongly labelled as such.

As an additional point of resemblance between the Quebec and Russian asbestos deposits, it is interesting to note that, in the description of the latter, as given in the abstract referred to, no mention is made of the occurrence of limestone in association with the rocks of the serpentine belt.

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[1] Kryshanofsky, W. F., Serpentine absestos deposits in the Berezowa, Kamenskaja, and Manetnaja estates, Ural, Russia, 1904; translated abstract by A. Anrep in the Trans. Can. Min. Inst., vol. XV, 1912, pp. 270-272.

KAOLIN.

Kaolin occurs sparingly in some of the rocks, as an alteration product of the feldspar.

Titano-Silicate.

LEUCOXENE.

The diabase which occurs in the area is, as a rule, very much altered, and leucoxene forms one of the secondary products usually present.

Phosphate.

APATITE.

Specimens bearing well crystallized apatite were obtained about 5 miles northwest of Black lake, near the road leading to St. Ferdinand de Halifax. They were not found in place, but in some boulders used in the construction of a stone fence, and their original location has not been traced.

The first, and also the finest, specimens received by the writers, were collected in 1912 by D. A. Nicol, of the Geological Survey, whose attention was attracted to the boulders by some bright quartz crystals they contained. The quartz crystals in these boulders had been observed prior to this by Mr. A. Nadeau, of Black Lake, who, at the suggestion of R. Harvie, collected a number of specimens for the Geological Survey. The locality was later visited by one of the writers.

The boulders, which are in many cases cavernous or drusy, consist mainly of massive white quartz, and have, doubtless, come from some quartz or pegmatitic veins in the immediate vicinity. A considerable amount of mica in small scales, more or less altered, is sometimes present, especially in the cavernous boulders, and, associated with it, are pyrite and siderite (page 24), both in small amount, together with their alteration product, a soft earthy limonite with which the druses are more or less filled. When this deposit is removed, the walls of the cavities are found to be lined with crystals of colourless quartz, usually small, but sometimes attaining a length of one centimetre; these are described on page 15. Further inspection shows that many of the quartz crystals are superposed upon crystals of colourless, transparent apatite, which, in turn, rest on the massive white quartz, indicating that the apatite crystals are later than the massive quartz, but older than the quartz crystals.

Owing to their manner of occurrence, it was not possible to remove any complete crystals of apatite from the specimens; nevertheless, a considerable amount of material was obtained, consisting of partially broken crystals, but eminently suitable for goniometric measurement.

The crystals, which, as already noted, are perfectly colourless and transparent, are mostly very minute, but some measured up to one centimetre in diameter. The habit is invariably tabular parallel to the base, and the crystal plates are quite thin, even the largest crystals not exceeding 2 mm. in thickness. They are generally doubly terminated. Irregularities on the basal plane in all the crystals measured indicate that parallel growth is very prevalent.

Owing to the habit, the basal pinacoid is by far the most prominent form on all the crystals. Otherwise, they are of two types, characterized in general by the presence or absence of the prism of the first order, m($10\bar{1}0$). In the first type, the principal forms present, in addition to the basal pinacoid, are the prism of the first order m($10\bar{1}0$), and the two pyramids of the second order s($11\bar{2}1$) and v($11\bar{2}2$). Other forms noted on these crystals, in the order of their relative development, are the first order pyramids, y($20\bar{2}1$), x($10\bar{1}1$), and r($10\bar{1}2$); the third order pyramids, μ($21\bar{3}1$), n($31\bar{4}1$), and o($31\bar{4}2$); and the third order prism, h($21\bar{3}0$). In addition to these, the first order pyramid, α($30\bar{3}2$) was noted as small faces on some of these crystals.

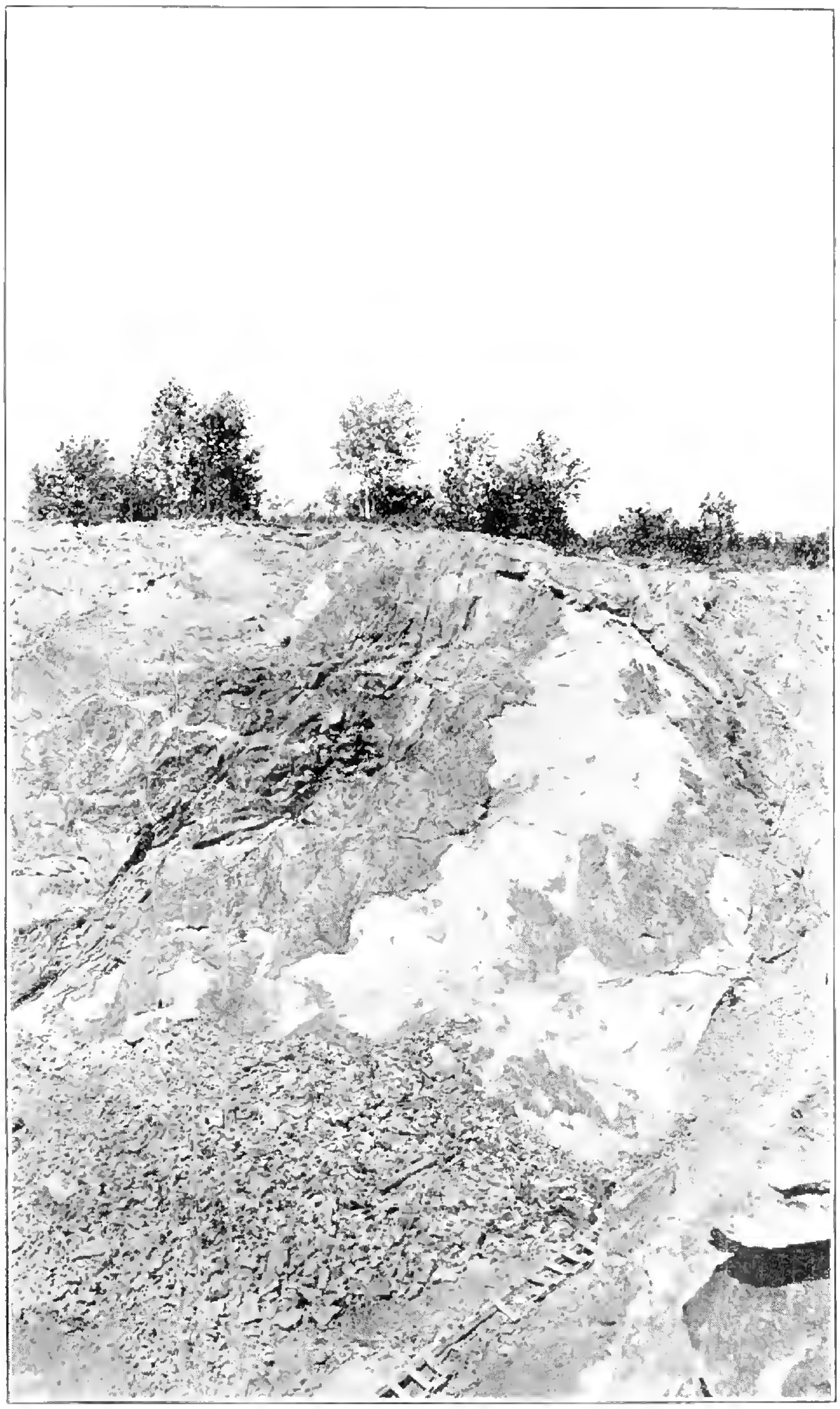
In the second type, the largest form, after the base, is the first order pyramid, r($10\bar{1}2$); the second order prism, a($11\bar{2}0$) is present as narrow faces, but the first order prism is lacking.

A complete list of forms observed, together with the measured and calculated angles, is given below:

Crystal Forms of Apatite.

Letter		Symbol	Measured		Calculated	
Dana	Gold-schmidt		φ	ρ	φ	ρ
......c.....	.......c.....	0001	....	....	....	....
......m....	.......a.....	$10\bar{1}0$	....	....	....	....
......a.....	......b.....	$11\bar{2}0$	....	....	....	....
......h.....	......h.....	$21\bar{3}0$	19° 06′	90° 00′	19° 06′	90° 00′
......r.....	.......r.....	$10\bar{1}2$	0 00	23 00	0 00	22 57
......x.....	......x.....	$10\bar{1}1$	0 00	40 18	0 00	40 16
......*α*.....	.......*a*.....	$30\bar{3}2$	0 00	51 46	0 00	51 48
......y.....	......y.....	$20\bar{2}1$	0 00	59 30	0 00	59 27
......v.....	......v.....	$11\bar{2}2$	30 00	36 16	30 00	36 16
......s.....	......s......	$11\bar{2}1$	30 00	55 45	30 00	55 43
......n.....	.......n.....	$31\bar{4}1$	13 52	71 54	13 54	71 52
......o.....	.......o.....	$31\bar{4}2$	13 52	56 43	13 54	56 47
......μ.....	.......m.....	$21\bar{3}1$	19 00	66 00	19 06	65 57

North end of Black lake. (Page 1.)



Granitic intrusion in peridotite, grossurlaite is found at the contact; Hall chrome pit, Thetford quarry of the Dominion Mines and Quarries, Limited. (Page 48.)

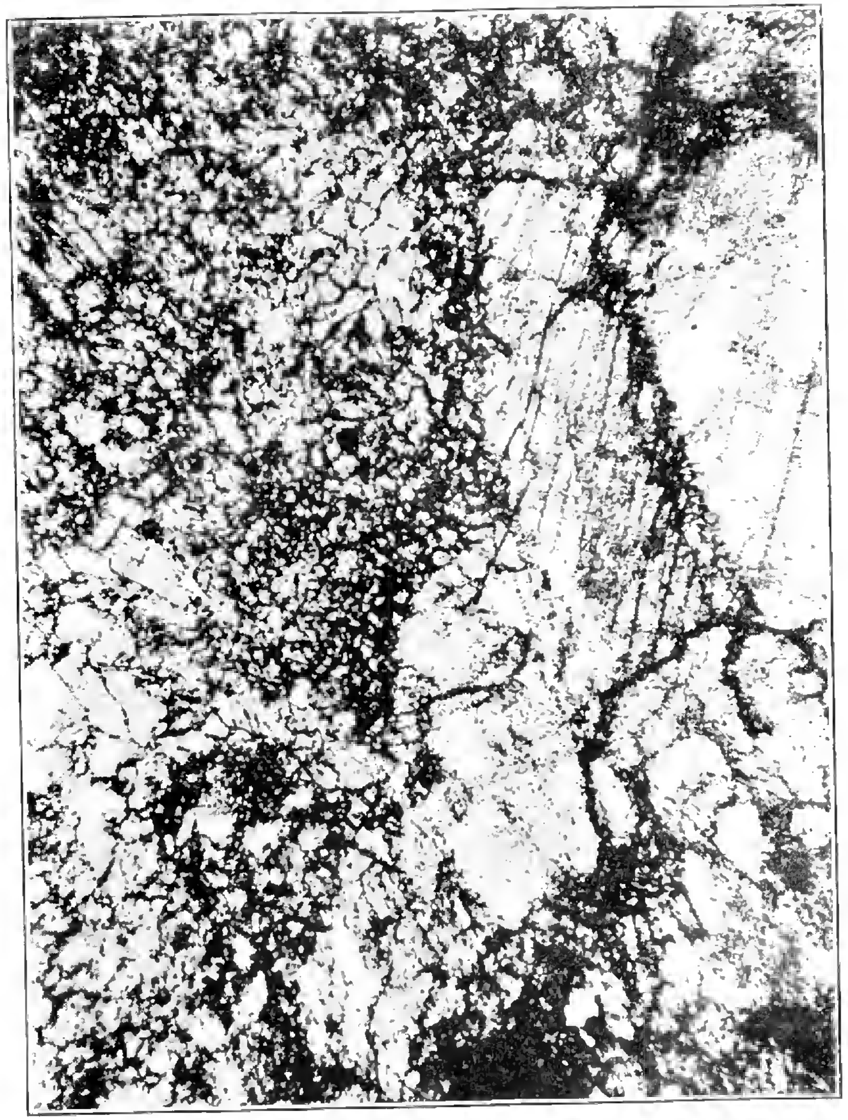
Ridges of serpentinized peridotite, southwest shore of Black lake. (Page 7.)

Chromite pocket of Hall chrome pit, Thetford quarry of the Dominion Mines and Quarries, Limited. (Page 17.)

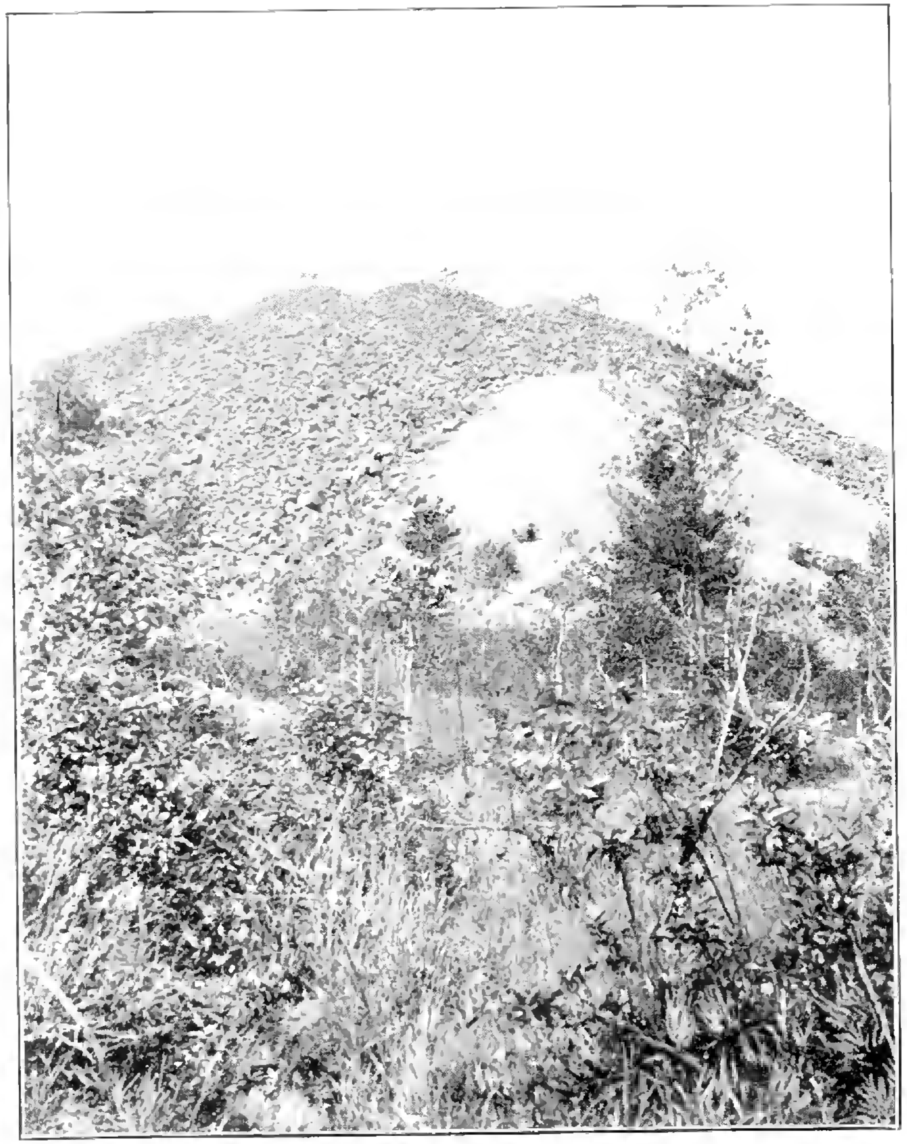
General view of the Montreal chrome pits. (Page 19.)

The main Montreal chrome pit, showing chromite pockets. (Page 19.)

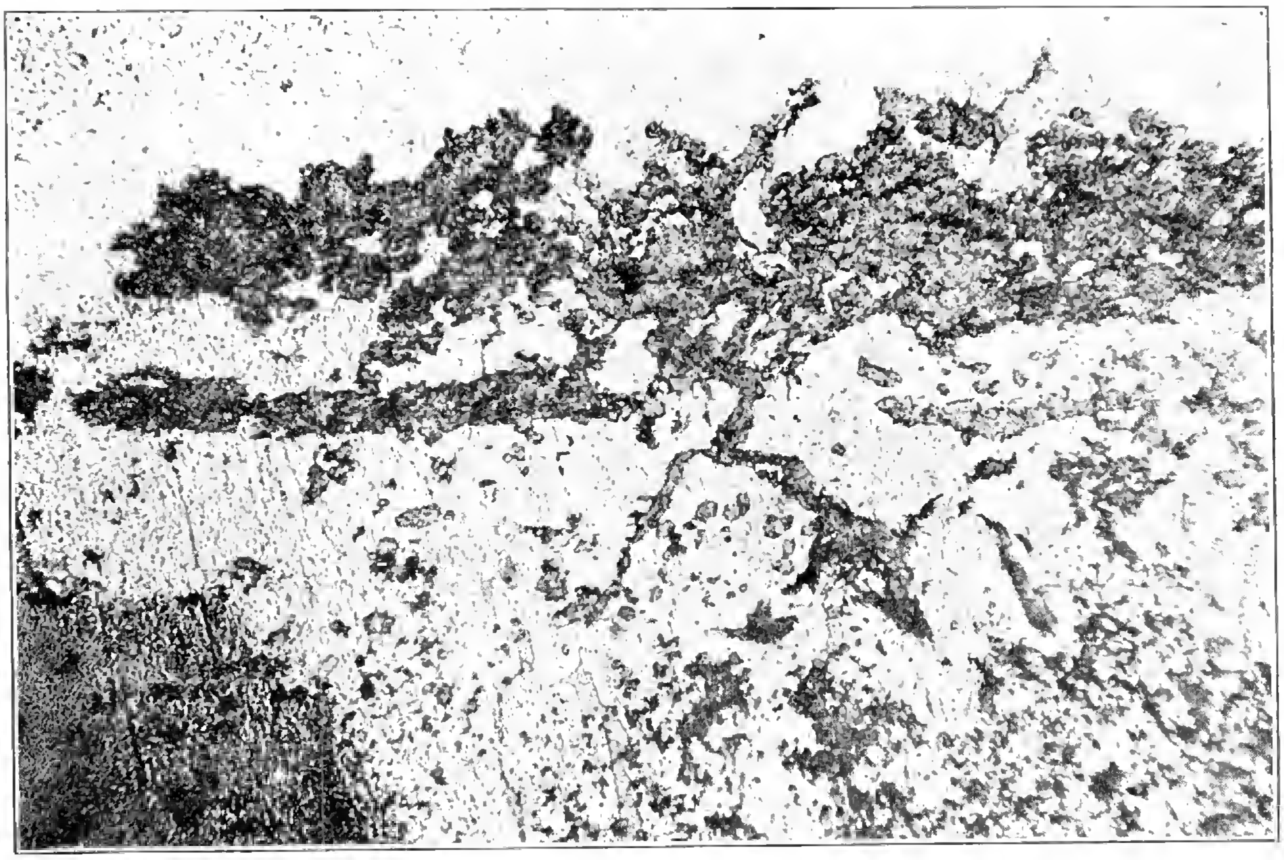
PLATE VIII.



A. Microphotograph of white diopside rock, magnified 40 diameters, natural light; Montreal chrome pit. (Page 31.)



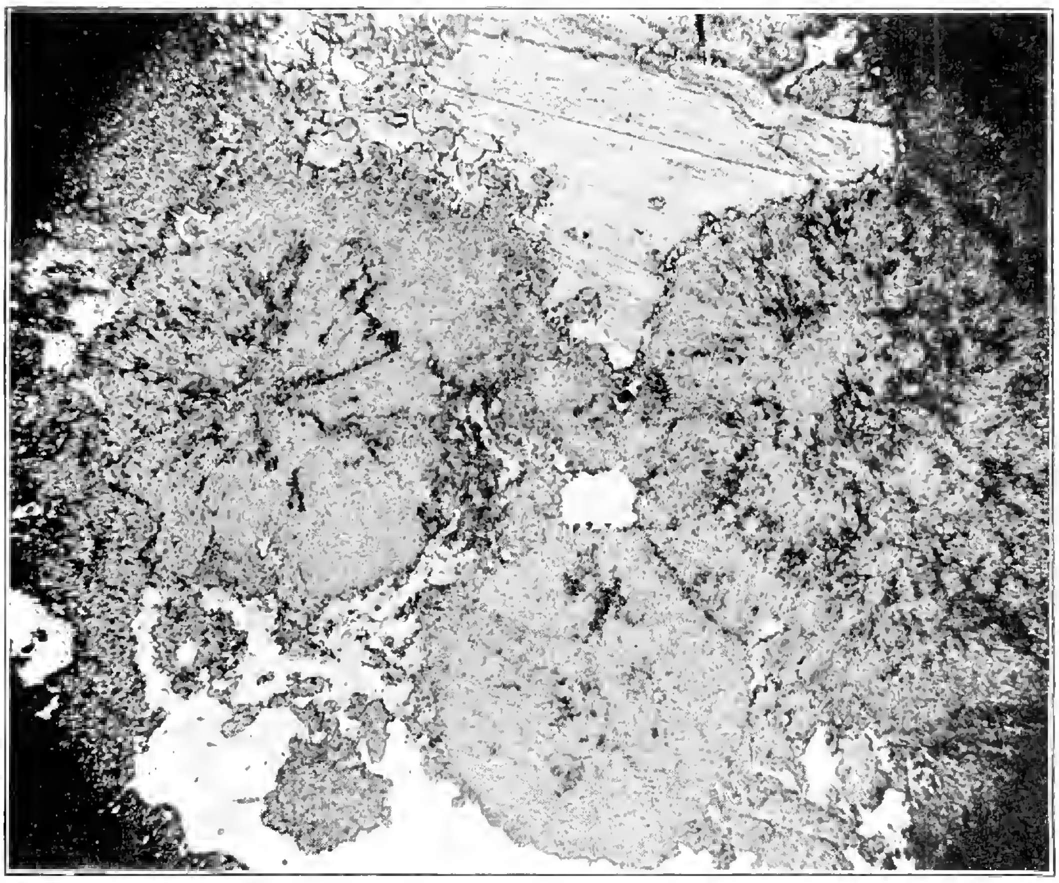
B. Dump of the Standard Asbestos mine where colerainite was found. (Page 66.)



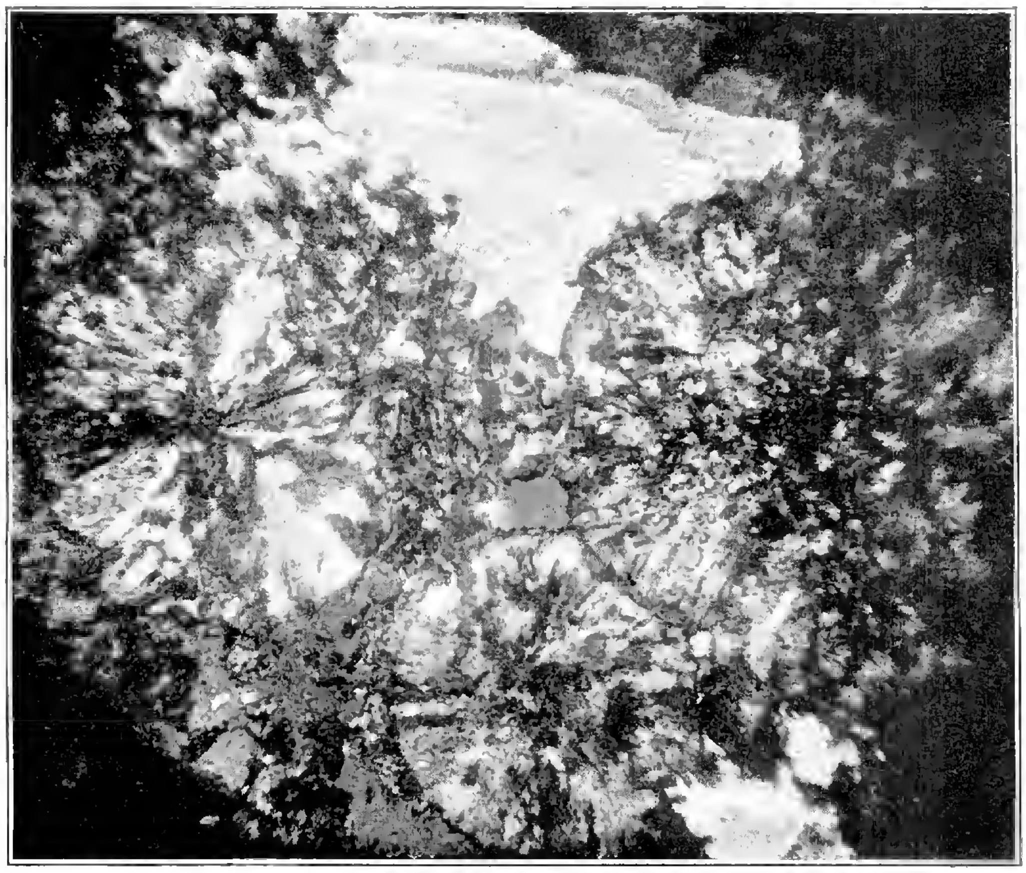
A.

B.

A. and B. Microphotographs of ropes of garnet in feldspar in a garnetiferous aplite, magnified 30 diameters, natural light; Caribou chrome pit. (Page 50.)



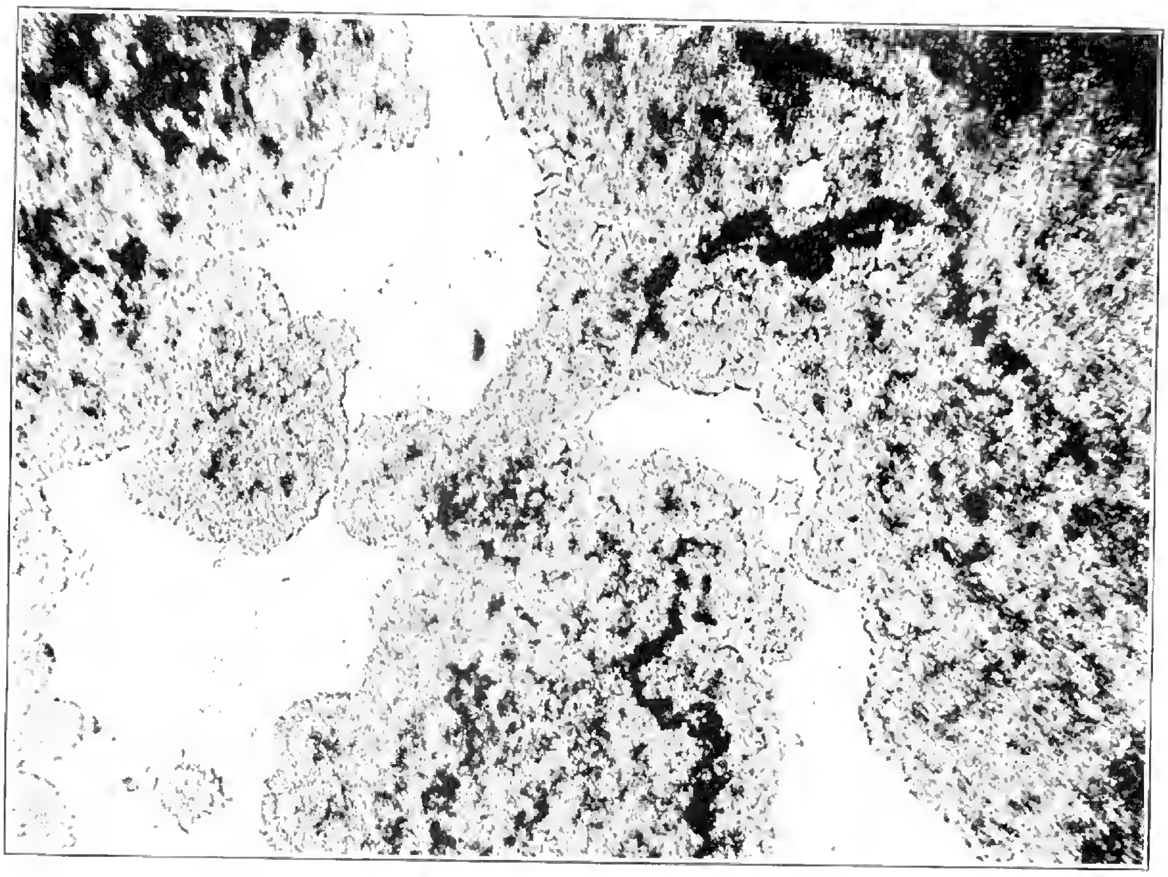
A.



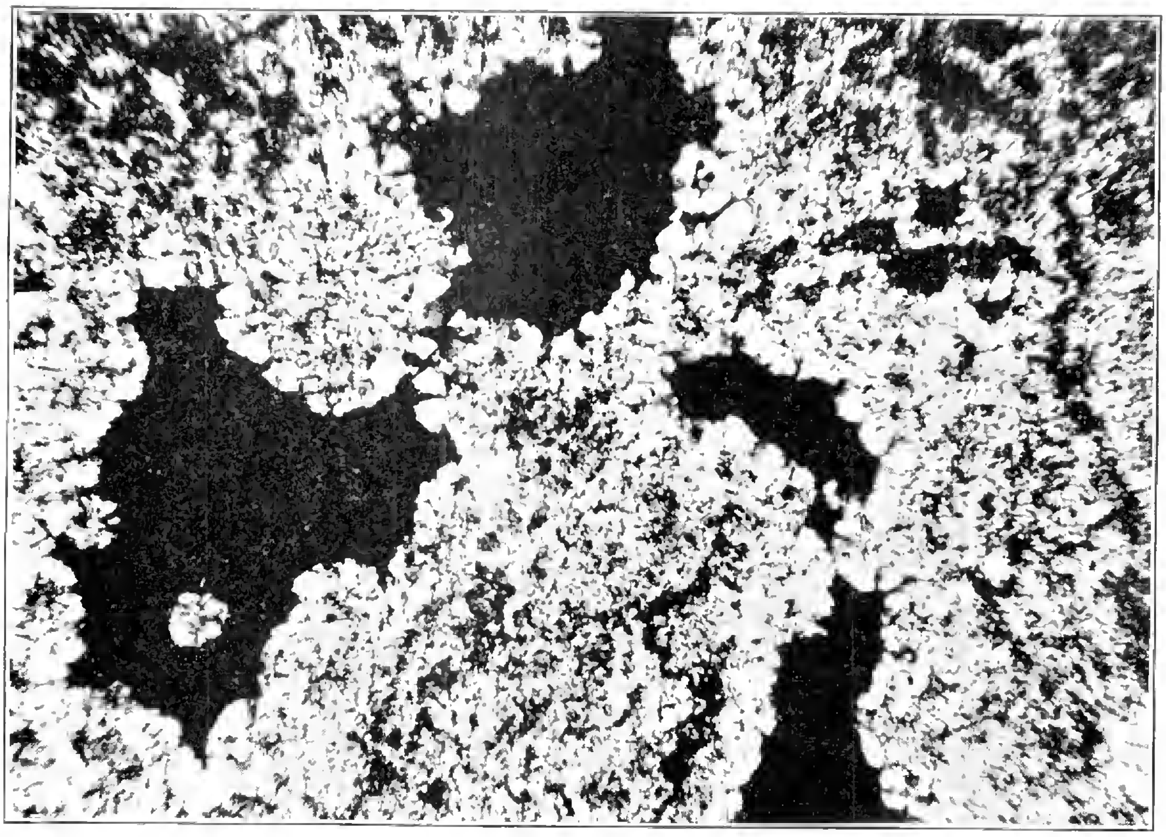
B.

A. Microphotograph of radiated vesuvianite with diopside, magnified 30 diameters, natural light; Montreal chrome pit. (Page 52.)

B. Microphotograph of radiated vesuvianite with diopside, magnified 30 diameters, polarized light, Montreal chrome pit. (Page 52.)



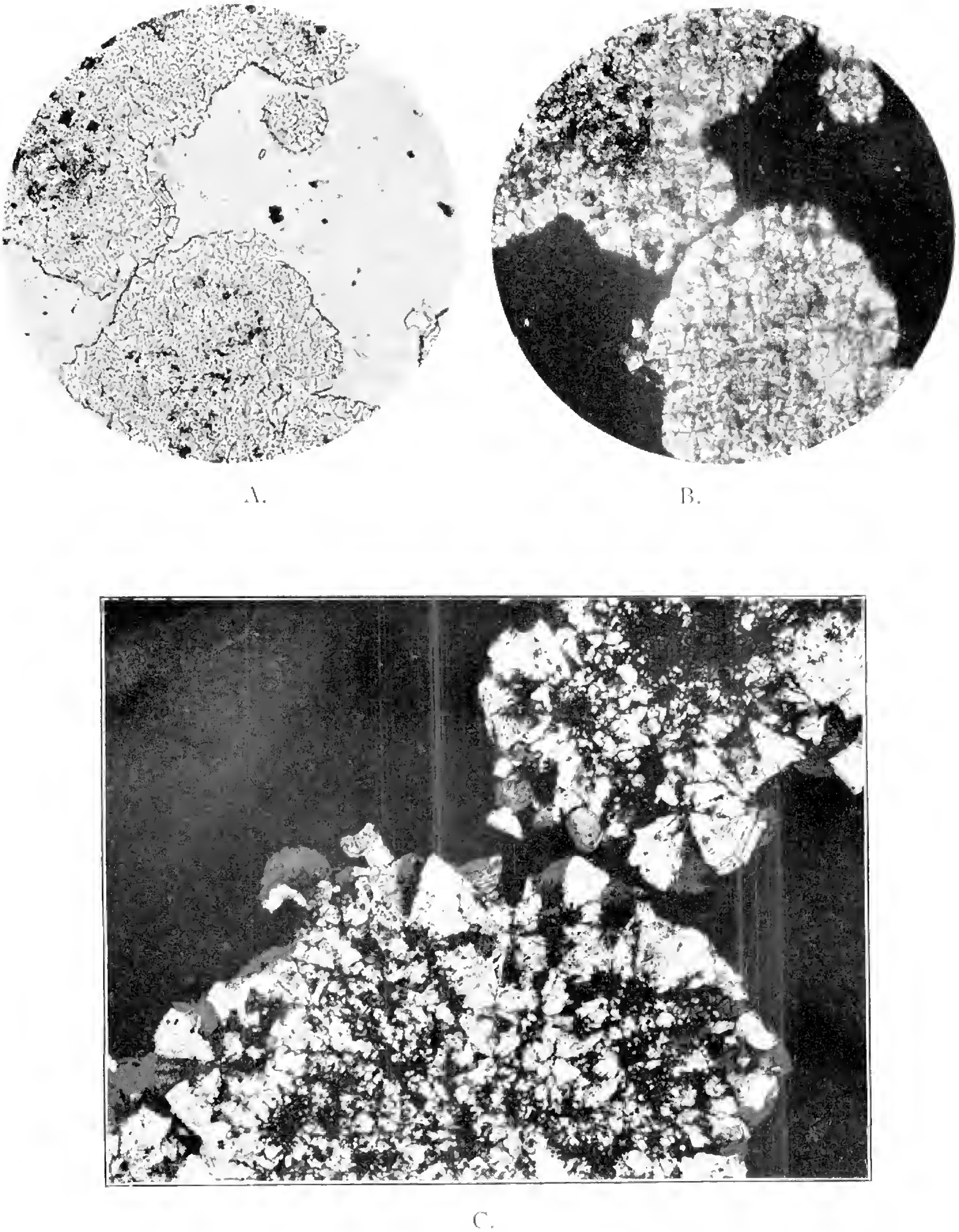
A.



B.

A. Microphotograph showing drusy character of colerainite-bearing rock, magnified 30 diameters, natural light; Standard asbestos mine. (Page 67.)

B. Microphotograph showing drusy character of colerainite-bearing rock, magnified 30 diameters, polarized light; Standard asbestos mine. (Page 67.)



Microphotographs of aggregates of wedge-shaped colerainite crystals; Standard asbestos mine. Note lines parallel to the base of the wedges. (Page 67.)

A. Magnified 50 diameters, natural light.
B. Magnified 50 diameters, polarized light.
C. Magnified 100 d'ameters, polarized light.