CANADA
DEPARTMENT OF MINES
HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

Summary Report, 1931, Part D

CONTENTS

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1932

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NOTE. Part B of the Summary Report formerly included reports relating to the provinces of Manitoba, Saskatchewan, and Alberta, and to the part of the North West Territories lying north of these provinces. It now contains only reports that deal with the southern and western parts of this region, underlain chiefly by Palæozoic and later formations. Part C is a new part comprising reports that relate to the northern and eastern portions of the same region, which are underlain chiefly by Precambrian formations. What has hitherto been called Part C is now Part D. It relates to the provinces of Ontario, Quebec, New Brunswick, Prince Edward Island, and Nova Scotia, and to the part of the North West Territories lying north of these provinces and east of Hudson bay.

SUMMARY REPORT, 1931, PART D

ASBESTOS DEPOSITS OF THETFORD AREA, QUEBEC

By H. C. Cooke

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INTRODUCTION

The geological examination of Thetford one-mile quadrangle (latitudes 46° to 46° 15′, longitudes 71° to 71° 30′), begun in 1930, was continued during 1931. Geologic mapping of the area was completed, and considerable time devoted to the study of the asbestos deposits. In addition, some study of the magnetic properties of the serpentine bodies and asbestos deposits was carried on by A. H. Miller, of the Dominion Observatory, and the writer.

Although it has not been possible as yet to make petrographical examinations of the different rocks or to obtain necessary chemical analyses, it seems desirable that the broader results gained by field study should be given at once to those interested in the district. The following preliminary statement will, therefore, have to be amplified, and possibly also altered, when the results of the studies mentioned, and those of further field examinations, are obtained; but it is believed that the broad, general conclusions here given will prove in the main correct. Briefly stated, these results are as follows:

The Bennett schists, instead of being Precambrian as formerly supposed, appear to be the lower, metamorphosed part of the Caldwell series, which is probably of Cambrian age.

No evidence was found in this area to support the older view that the basic intrusives were injected as thick sills which were afterwards differentiated in place to yield a series of rock types grading from dunite at the base through peridotite and pyroxenite to gabbro. Instead, it appears that the intrusives were stock-like masses which came into the anticlines after the main axes of folding were established; and that such differentiation as exists was not effected by gravitation after intrusion.

The source of the asbestos veins has been generally supposed to be siliceous solutions emanating from cooling granite masses. Evidence is brought forward to prove that such an origin is impossible, or at least unlikely. The alternative suggestion is advanced that the asbestos was formed by the siliceous solutions depositing the quartz veins so numerous in the rocks north of the intrusive masses. The same solutions, probably, at an earlier stage of alteration, converted some of the peridotites into soapstone.

Although the asbestos veins have all the characteristics of ordinary fissure veins, many earlier writers have been forced to consider them as replacement veins because it seemed impossible that open fissures could exist. To meet the difficulties, the writer advances the hypothesis that the fissures were forced open, and held open, by solutions injected under great pressure; and shows that facts previously unexplained may be interpreted by this hypothesis.

The writer has found it impossible, as yet, to make his conclusions tally with those of Mr. J. A. Dresser, whose classic work on the asbestos deposits has been accepted for many years. Mr. Dresser's long experience, together with the fact that he has carried his studies over a much larger region than the writer, renders his opinions worthy of the highest respect; and it may well prove, eventually, that his interpretations of the differentiation of the intrusives and the origin of the asbestos are correct.

GENERAL GEOLOGY

In 1930 the succession for the area was determined as follows:[1]

Post-Ordovician		Serpentinized dunite, peridotite, pyroxenite, and granite
Ordovician (?)	Beauceville	Black slates, impure quartzites
Cambrian (?)	Caldwell series	Quartzites, basaltic lavas, grey, green, and red slates
Precambrian (?)	Bennett schists	Sericitic and chloritic schists

The season of 1930 was devoted mainly to the study of the southeastern part of the map-area and the structures and relations of the Caldwell and Beauceville series. Little study was given to the Bennett schists. In 1931 the whole of the area of Bennett schist, comprising the entire northwestern half of Thetford area, was mapped, and the nature and relations of the schists were studied in detail. It was concluded, finally, that there is no evidence, in Thetford area, to warrant the decision that the Bennett schists are Precambrian and older than the Caldwell series; on the other hand, all the available evidence suggests that the schists are merely the schistose, lower part of the Caldwell series. The revised section, therefore, becomes

Post-Ordovician		Serpentinized dunite and related intrusives
Ordovician (?)	Beauceville series	Black slates, impure quartzites
Cambrian (?)	Caldwell series	Bennett schists, quartzites, basaltic lavas, grey, green, and red slates

[1] Geol. Surv., Canada, Sum. Rept. 1930, pt. D, p. 3.

The name "Bennett schists" is retained for these rocks, however, as a convenient designation.

STRUCTURE OF THE BENNETT SCHISTS

The area of Bennett schists extends from the northwest corner of the map-area to a line that runs about 1½ miles northwest of Thetford Mines, so that they have a width, across the strike, of 12½ miles. The general structure is that of a broad anticline. Throughout the southeastern 1½ miles the strike is northeast and the schists dip southeast at angles up to 60 degrees. The dip then flattens, and across the next 4 miles the schists dip gently, generally at less than 20 degrees, to the northwest or southeast, i.e., at right angles to the main folding. Across the northwesterly 8 miles the strike is again northeast, and the dip averages about 50 degrees northwest. The schists are not, therefore, symmetrically grouped about the axis of the anticline, but the axis lies much closer to the southeastern than to the northwestern border. To be precise, the anticlinal axis is only about 3½ miles from the southeastern limit of the schists, and about 9 miles from their northwestern limit.

One reason for this peculiarity is, apparently, that a greater thickness of strata has been rendered schistose on the northwest side of the anticline. The writer carried the exploration a couple of miles beyond the northwest corner of the map-area, and found that the first rocks to outcrop above the schists are green and grey slates identical petrographically with the slates of the Caldwell series. On the southeast, non-schistose Caldwell quartzites outcrop between the Bennett schists and the slates, over a width of about a mile. It seems, therefore, that on the north side of the anticline the full thickness of the quartzites has been rendered schistose, whereas on the south side only a part of them have been thus affected.

This conclusion, however, only in part explains the great existing difference between the width of the schists on the two sides of the anticline; but the solution of this problem must await further and more extended studies.

The structure of the anticline affords the reason for some of the peculiarities of the region. Thus, the dykes of talc and serpentine that intrude the schists have been largely controlled, during injection, by the structure of the schists. These dykes consequently strike northeast and dip steeply to the northeast or southwest in the corresponding parts of the anticline; but in the central part of the anticline they strike northwest and commonly have rather flat dips, like the schist. Again, various observers have been puzzled to account for the prominent northwest-trending valleys that cut through this range of hills, because these valleys, though at right angles to the normal valley trend, are yet as well developed as the normal valleys. The northwesterly trend of the strata in the centre of the range makes it evident, however, that such valleys could be initiated and developed by normal processes of erosion controlled by structure, without the necessity of assuming the existence of faults or other abnormalities. There is indeed some evidence that faulting may have taken place along the Palmer River valley; but no such evidence was found along the other valleys.

PETROLOGY OF THE BENNETT SCHISTS

The writer has as yet made no microscopic study of the schists, but their general nature is evident from field observation. The principal constituents have been quartzites of varying degrees of purity, which are now converted into sericitic schists. All stages of the alteration can be seen. In many places throughout the schist area, at the summits of small anticlines where movement between beds has been a minimum, massive unsheared white quartzites may be seen. These are commonly fairly pure; no instance was noted of an impure quartzite without schistosity, presumably because the impure varieties recrystallized more readily under the existing pressures to form micaceous minerals. Again, a broad zone along the northwest border of the schist area, and a very narrow zone along the southeast border may be termed transition zones, within which some beds are quite schistose and others only moderately schistose or even massive. In the broad northwestern transition zone, which begins perhaps a mile southeast of Kinnear Mills, the nature of the rocks prior to alteration is clearly evident. Here may be seen quartzites of varying degrees of purity, and in all stages of alteration. Interbedded with the less altered quartzites are thin bands of black slate, and, exceptionally, bands of red slate. Where alteration becomes more extreme, the slates are recrystallized to harder, dark, micaceous types forming phyllites and mica schists. Where metamorphism has been more extreme, larger crystal grains, presumably of the aluminous minerals, develop, forming knotty schists.

In addition to the rocks described, the Bennett schists include considerable bodies of greenish, chloritic schist. These are considered as basaltic lavas or tuffs rendered schistose by pressure. In two places where metamorphism was less extreme, identifiable lava was observed. In Inverness township, range V, northwest end of lot 2, there are outcrops of a chloritized flow breccia of basaltic composition. Nodules of amygdaloidal lava are included in a matrix of flow-textured, slightly sheared basalt. In Ireland township, range IV, lot 19, a flow about 100 feet thick was traced for some hundreds of feet, striking north 75 degrees east, dipping 80 degrees south. The lower contact, visible at the west end of the outcrop, is fine-grained and distinctly flow-textured. About 30 feet of massive and slightly flow-textured lava lies above the contact, and the remaining upper part of the flow consists of pillowed lava, the pillows packed tightly together with interpillow zones only about an eighth of an inch wide. Such lavas, or their corresponding tuffs, would give rise, when sheared, to chlorite schists of the type common in the Bennett schists, and they are the only rocks discovered which would metamorphose to chlorite schist.

Outcrops of crystalline limestone, all probably forming parts of a single band, were found in four places in Leeds township, near the north side of the map-area. These places are: range V, lot 7b; range IV, lot 3b; range III, near boundary between lots 2 and 3, at northeast end of lots; and on range line II-III just at the boundary between Inverness and Leeds townships. In the most eastern outcrop the band is not more than about 10 feet thick, and is a very pure calcium carbonate. On the west, however, it is more than 100 feet thick, and weathers to a deep brown colour characteristic of many magnesian limestones; and probably due to the presence of some iron carbonate.

Lenses of magnetite occur here and there in the Bennett schists. The most important of these are the occurrences at the so-called Leeds mine, in lots 7a and 7b of range V, Leeds township. They have been described in some detail in the "Report of Mining Operations in the Province of Quebec for 1912," pages 100-105. Lenses of magnetite up to 7 feet thick and 200 feet or less in length are interstratified with quartzite and siliceous schist. In lot 7b the magnetite layer is overlain directly by a very pure crystalline limestone about 10 feet thick. The magnetite itself contains a good deal of silica. Two analyses cited in the report above give 39·3 and 21·8 per cent of silica respectively.

Although the Bennett schists constitute the loftiest hills of the Notre Dame range, they are not well exposed. They are fairly uniformly covered with soil up to 6 or 8 feet deep, to judge from well borings; and can be seen and studied only on particularly steep hillsides, on the tops of the higher hills, and in stream beds. Quite commonly, exposure will be continuous in roadside ditches a few inches deep, although no rock is to be seen in the surrounding fields.

In the Summary Report for 1930 reference was made to the fact that the Bennett schists are highly crumpled, so much so that in places there are several crumplings to the foot. The study of the larger area during the past summer indicates that this characteristic is largely confined to the zones within which the dip changes from almost flat to steeply south or north. Outside of these zones the schist is of a more normal character.

The petrographic similarity of the original components of the Bennett schists to the upper part of the Caldwell series, the entire lack of any defined break between them, and the structural relations already described, together seem to indicate beyond a doubt that the schists are merely the lower, metamorphosed part of the Caldwell series. No satisfactory reason has yet been found, however, to account for the metamorphism. The only apparent cause would seem to be the pressure exerted, during folding, by the weight of the overlying Caldwell and Beauceville sediments. It was calculated that the non-schistose quartzites and slates of the Caldwell series, on the southeast side of the anticline, are 4,000 to 5,000 feet thick; and the additional, unknown thickness of Beauceville sediments undoubtedly brought the total thickness of overlying sediments to considerably more than a mile. In the area to the south around lake Memphremagog, T. H. Clark has determined the thickness of Cambrian and Ordovician sediments overlying the schists to be about 2 miles.[1] These thicknesses would exert pressures of nearly 6 tons a square inch. F. D. Adams has determined, experimentally, however, that pressures of 5 to 35 tons a square inch are required for deformation even of rocks like marble and slate, when these rocks are held under great pressure, as they are deep within the earth; so that the superincumbent weight of sediments in this instance seems insufficient to produce the prevailing schistosity.

[1] Personal communication.

INTRUSIVES

The intrusives of the district include dunite, peridotite, pyroxenite, gabbro, and granite, all of which may be magmatically related. In addition, two small areas of basic gabbro were found in Thetford township, range IV, lots 3 and 4, and in Broughton township, range VII, lot 18. They are fine to medium grained, very dark grey rocks, of the general composition of a basic gabbro, and they intrude the Caldwell series. They may or may not be related to the other igneous rocks mentioned.

The dunite is a rock composed, originally, entirely of olivine. It is a medium-grained rock with the texture of loaf sugar, of a dark green to yellowish green colour and weathering to a rather light grey. It is rarely to be observed, as commonly it has been more or less completely altered to serpentine. It forms occasional, small masses of irregular shape within the larger bodies of peridotite, and apparently segregated from the peridotite. The contacts are not sharp lines, as if one had been injected into the other, but on the contrary are rapid gradations, the one rock passing into the other within a distance of 3 or 4 inches. One of the best contacts for examination lies between 100 and 200 feet north of the Bennett-Martin pit, within the town limits of Thetford.

The peridotite was originally composed of olivine with a smaller or larger percentage of a pyroxene, commonly less than 10 per cent. When fresh the rocks are dark green, but commonly they are more or less serpentinized, so that the colour is that of the serpentine. Both on the fresh and the weathered surfaces, but particularly on the latter, the pyroxenes are plainly visible. The peridotites weather, commonly, to bright browns or yellows, so that bare hills and cliffs are strikingly prominent features of the landscape. Both dunite and peridotite characteristically contain more or less accessory chromite, in small grains.

The pyroxenites, as their name implies, are composed almost entirely of pyroxene. They vary in grain from coarse to very coarse, many varieties being composed of crystals one-fourth inch or more to the side. They are grey on the fresh surface, with a hint of light green, and weather commonly to brownish or reddish tints. The principal masses of pyroxenite occur in Red hills.

The rocks grouped under the general name of granite include a variety of petrographic types. The larger masses and many of the dykes are composed of an ordinary-looking, grey biotite granite of medium grain. The smaller dykes are commonly more acid. Some appear to consist almost wholly of white feldspar, others of quartz and feldspar—alaskites; and still others may contain smaller or larger proportions of ferromagnesian mineral. The petrographic study of the dykes promises to be one of great interest.

Gabbro, within the map-area, is found chiefly on the south flank of Adstock mountain. It is rather basic in composition, fine to medium in grain, and seems closely related to the pyroxenites. Its relations, however, require further study. Previous writers have tended to confuse this rock, which is a true intrusive, with the basalts of the Caldwell series, and the older maps show many bodies of "gabbro" which are more properly basalt.

The flow and pillow structures of the latter, however, and their interbedding with the sediments, serve to differentiate them from the true, coarser-textured gabbros.

The relations between the various intrusives have previously been described as indicating that they were all derived by gravitative differentiation from a single mass of intrusive, commonly termed a sill. Dunite, the heaviest of the series, is described as occurring mainly on the north side, or base, of the sill, and as followed successively by peridotite, pyroxenite, and gabbro, in order of decreasing specific gravity. So far as Thetford area is concerned, however, no evidence of the correctness of this theory was discovered. The intrusive masses were carefully examined everywhere as close to the north side, or base, as outcrops could be found, and in every case the rocks are all peridotite, not dunite. The only masses of dunite found were small bodies of irregular shape lying entirely enclosed within the peridotites and at some distance from the lower contact; and the peridotite near the contacts was no different in composition and appearance from the peridotite farther away.

The relations of the pyroxenite to the peridotite are not yet fully known. Around the town of Thetford Mines itself one of the main bodies of peridotite occurs, underlying an area roughly 2 miles in length and 1½ miles in greatest width. This body, so far as known, contains no pyroxenite except such as occurs as small dykes cutting the peridotite. These are rather numerous, and may be several feet wide, though more commonly less than 3 inches. A narrow band of tuffaceous sediments separates this mass of peridotite from the main body of peridotite which lies to the south and which extends from a point due south of Thetford for more than 7 miles southwest, continuing beyond the borders of the map-area. At the northeast end this body is about a mile wide, and it widens on the southwest to about 3 miles. It seems likely that the narrow band of sediments separating this great mass from that around the town of Thetford Mines must be broken in places by dykes connecting the two. There is, however, no direct evidence of such connexion.

Pyroxenite in large masses lies to the southeast of the main body of peridotite, but is by no means evenly distributed. Thus, on the southwest, where the peridotite is very wide, the pyroxenite body is very narrow. On the northeast, however, where the peridotite is narrowest, the pyroxenite body is at least a mile and a quarter wide, forming the mass of Red hills; and it may underlie the drift-covered country between Red hills and Poudrier hills to form a mass more than 3 miles across. If, then, the pyroxenite separated from the peridotite magma by gravitative differentiation, it must have been forced laterally, after separation, for considerable distances, in order to occupy the position it does; for, otherwise, its distribution should be uniform over the southwest side of the peridotite, except that the pyroxenite would be thickest where the peridotite was thickest, and thin where the peridotite is thin. Gravitative differentiation should also have given rise to a mass of pyroxenite at the upper side of the Thetford Mines mass; but this has not been found, although the mass has been drilled from side to side.

The pyroxenites are, however, very closely associated with the peridotites. In Red hills the pyroxenites stand up as hills, some of which are elliptical in shape, whereas the intervening valleys appear, from hillside outcrops, to be underlain by peridotite. The pyroxenites in places are strongly flow textured, indicating pronounced movements in the magma during consolidation; and here and there, particularly near the edges of the pyroxenite lenses, narrow bands of dunite are interspersed through the flow-textured pyroxenite, apparently indicating that the two phases were co-existent in the liquid or near-liquid state. Also, the dykes of pyroxenite found in the Thetford Mines peridotite, though clean-cut and linear, do not have the sharp edges characteristic of small intrusive dykes, but rather resemble fissures opened in a scarcely solidified body and filled with pegmatite.

Gabbro is found only on the south and west flanks of Adstock mountain, and on a hill about half a mile east of Poudrier hill. On Adstock mountain it extends upward about as far as the 1,700-foot contour, and the remaining, uppermost part of the hill consists of pyroxenite. No contacts were found. On the north side of the hill there is a band of serpentine secondary after dunite or peridotite, which swings around the western nose of the hill across the end of the band of pyroxenite to lie directly against the gabbro. Were it not for this behaviour, the relations might suggest a differentiated, tilted sill. Altogether, little is yet known as to the real relations of the gabbro to the other intrusives.

Granite and the allied pegmatites form dykes and small stocks. Granite hill is a stock about a quarter mile in length and about an eighth mile in width, and several of smaller size lie to the west. Large dykes, several hundred feet wide, occur on Reed and Murphy hills. Small dykes, usually of feldspathic composition, are very numerous in the peridotite of the Thetford Mines mass, and around Black Lake.

The granite and alaskite dykes were observed to cut the peridotites and pyroxenites in the various mines, so that there can be no doubt as to their being younger than the basic rocks. There remained, however, the possibility that the stock-like masses might perhaps be merely the remnants of a sheet-like mass of granite that had separated from the peridotite by gravitative differentiation. If so, the contacts of the granite and peridotite should be flat or have a comparatively gentle dip; but if the granites were true stocks or plugs, their contacts with the peridotite should dip steeply on all sides. On Granite hill the granite is in contact with peridotite on all sides except at the northwest end, where the granite disappears beneath drift. This hill was, therefore, studied in detail. The plane of contact is almost everywhere covered by drift; but when followed along the strike on the steep hillside, the contact could be traced down into gullies and other depressions, and up the hill again for 100 feet or more, without any noticeable lateral deflexion. This could happen only if the contact dipped steeply, never if the dip was low; and as this condition obtains on all sides of the mass, it is necessary to conclude that the body is a stock or plug, not the remnant of a rather flat sheet. In the smaller plugs to the west, exposures of the contact are not sufficiently complete to yield evidence as satisfactory as that obtained on granite hill, but all the evidence obtainable was of the same type.

The smaller dykes, as exposed in the open pits, display such extraordinary irregularities of shape as to defy mapping. Many seem to have filled joints in the peridotite, so that they can be followed only a short distance on a given dip and strike before they turn sharply along an entirely different course. A beautiful example of such irregularity may be observed in the Johnson mine at the entrance of the haulage tunnel. Here a dyke, about 2 feet wide, follows joints so as to box in on three sides a rectangle of peridotite some 30 or 40 feet to the side. Other dykes have been injected into sheared zones in the peridotite, evidently through fissures which closed as soon as the liquid magma had passed. The "dykes" now form a series of entirely disconnected, short lenses, more or less in line it is true, but having no connexion between them.

The question whether the granite was injected into the sheared zones after their formation, or whether shearing occurred after injection and broke the dykes into disconnected lenses, was most carefully investigated. The peridotite of the shear zones is broken down completely to little disks about the size of a silver dollar—the so-called "fish-scale" or "fish-meat" of the miners—and if these are closely examined they are found to be filled with closely-spaced planes of slip, so that they break up readily into minute fragments bounded by slip faces. The bodies of granite or alaskite in these sheared zones, however, are not at all fractured, although a few were found to be slightly jointed or sliced; and this is true even if the granites are only a few inches wide. It seems quite impossible that even a moderately soft rock like the partly serpentinized peridotite could be so thoroughly broken down by shearing and leave thin dykes unfractured; and the necessary conclusion is that intrusion took place into zones already sheared.

A second piece of evidence to the same effect was observed on the narrow tongue of rock separating the Johnson and King pits, at Thetford Mines. Here a mass of granite some 8 or 10 feet wide and perhaps 25 feet long lies within a sheared zone, almost filling it from side to side. Nearly all the granites cause a blackish alteration of the partly serpentinized peridotite, an alteration the nature of which has not been investigated. In this instance the altered band is about 6 feet wide, and extends laterally across the sheared material into the unsheared peridotite. At the end of the dyke-like mass, the altered band swings round to cross the zone of schist.

It is obvious that if the dyke had been broken into lenses by faulting, the altered zone would be similarly broken, and no such arrangement as above could possibly result. The granite must, therefore, have been injected into the already formed sheared zone, and there produced its characteristic alteration.

ALTERATIONS OF THE IGNEOUS ROCKS

The various igneous rocks exhibit an interesting series of alterations, which will here be described in so far as the field study, the only study yet made, will permit.

DUNITE AND PERIDOTITE—PRELIMINARY SERPENTINIZATION

The dunite and peridotite have undergone a very general, though partial, alteration to serpentine. The larger bodies of these rocks are now serpentinized, according to Harvie's microscopic studies, fairly uniformly throughout their entire mass. In this general alteration, from 75 to 85 per cent of the original olivine and pyroxene are converted into serpentine, he states; rarely is it possible to find a specimen containing as little as 50 per cent serpentine. The serpentine is mesh-antigorite. The field observations of the writer support Harvie's conclusions as to the fairly uniform degree of serpentinization of the larger masses. Such serpentinization seems to have been entirely independent of the presence of asbestos, being no greater near asbestos deposits than in those places where asbestos deposits are entirely lacking. Harvie concludes, and the writer is inclined to concur, that this general serpentinization probably took place very soon after the solidification of the peridotites and dunites, and possibly through the agency of waters or vapours emanating from the cooling magma itself.

The change from peridotite to serpentine might take place in three ways. (1) The olivine of the rock might combine with the pyroxene, in presence of water, to form serpentine, thus

$$\text{Enstatite} + \text{Forsterite} + \text{Water} = \text{Serpentine}$$
$$MgSiO_3 + Mg_2SiO_4 + 2H_2O = H_4Mg_3Si_2O_9$$

Any such reaction would require, however, approximately equal proportions of pyroxene and olivine to be possible, whereas in actual fact the pyroxene forms only about 10 per cent or less of the rock. Hence this possibility need not be discussed. There are also a number of further objections, which, however, can not be considered here. (2) Silica may be added, thus

$$\text{Forsterite} + \text{Silica} + \text{Water} = \text{Serpentine}$$
$$3Mg_2SiO_4 + SiO_2 + 4H_2O = 2H_4Mg_3Si_2O_9$$

This reaction requires approximately 284 pounds of silica for the conversion of one ton of forsterite into serpentine. According to Harvie's studies, however, only about 75 per cent of the average peridotite body is serpentinized; so that roughly 213 pounds of silica would be required to complete the known alteration of every ton of rock. If we assume that the serpentinization was caused by solutions emanating from the cooling magma, then, as the peridotite is uniformly altered, we must conclude that the 213 pounds of silica was formerly united with the 2,000 pounds of peridotite and an unknown weight of water to form the magma; or, to put it in another way, that the silica content of the magma was 25 per cent larger than that of the peridotite crystallizing from it. Such proportions, though large, are perhaps possible.

(3) The third possibility is the removal of part of the magnesia of the olivine by carbonated waters, thus

$$\text{Forsterite} + \text{Carbonic acid} + \text{water} = \text{Serpentine} + \text{Magnesite}$$
$$2Mg_2SiO_4 + CO_2 + 2H_2O = H_4Mg_3Si_2O_9 + MgCO_3$$

The only requirement of this reaction, be it noted, is a supply of carbonated waters, and these are known to be given off by nearly every cooling magma. Previously, this reaction had never been thought probable, because no deposits of magnesium carbonate were ever found. The drilling of the area around Thetford Mines, however, has proved that large amounts of the impure magnesium carbonate, breunnerite, occur near the edges of the intrusive; thus making it very probable that this reaction is one that actually occurred.

The volume changes during serpentinization are most puzzling. If serpentinization took place by addition of silica, as in reaction 2, then the alteration of 127 volumes of forsterite produced 210 volumes of serpentine, a volume increase of more than 65 per cent. If serpentinization occurred merely by subtraction of magnesia, as in 3, then 84·8 volumes of forsterite produced 105·3 volumes of serpentine, a volume increase of more than 24 per cent. If any such enormous increase in volume had occurred, the rocks should everywhere be full of planes of slip and other evidence of expansion; but although slippage planes are numerous in the mines themselves, they are rather conspicuously absent in the massive serpentinized peridotite elsewhere. In general, there is little or no evidence that any volume increase has taken place. If serpentinization took place according to reaction 2, there would seem to be no avoiding the necessity of a very large increase of volume. However, if reaction 3 represents the course of the alteration, then it might be supposed that some olivine was carried off completely by the carbonated solutions, without formation of serpentine, so that little or no increase of volume need have taken place; and this consideration increases the intrinsic probability that the preliminary serpentinization took place according to reaction 3. The amount of olivine thus wholly removed need not have been as great as reaction 3 might suggest; for the olivine contained some iron that separated as magnetite, hence the actual proportion of olivine required to form a given volume of serpentine was greater than if the olivine had been pure forsterite. The original peridotite is not supposed to have contained much iron, however, because, as will later be shown, the magnetometer study showed that the serpentinized peridotite is but little more magnetic than the quartzites of the region. If this conclusion is correct, only a little correction should be allowed in reaction 3 for iron content.

THE SECOND ALTERATION

The second alteration is that accompanying introduction of the asbestos. Each vein of asbestos is flanked by a zone, commonly less than 2 inches wide, of very dark serpentine, which Harvie's microscopic studies indicate to be antigorite in long blades. Dresser concluded, from an average of forty-nine measurements, that each zone is about 3·3 times the width of the central vein; but this generalization is far from being true in particular instances, for it is common to find narrow veinlets of asbestos flanked by fairly wide alteration zones, and also to find a band of similar dark bladed antigorite running through the peridotite without any central vein of asbestos at all.

Large areas of the peridotite masses are veined in this manner, and all the known asbestos deposits, of course, occur within the areas thus veined. The veined areas include all of the Thetford Mines peridotite mass, all the peridotite on Reed and Murphy hills, that of the scattered outcrops between the two localities mentioned, the outcrops around Black Lake and those around the north end of Caribou mountain, in which the Vimv and Edith mines occur. In addition, a few other small areas were mapped. It is not to be thought, however, that veining is entirely absent from the peridotite mass other than where mentioned. Scattered or widely spaced veins may occur almost everywhere; but the localities mentioned are those in which veining attains a reasonable degree of concentration.

An interesting characteristic of the veined areas is the high local magnetic attractions prevailing over them. The magnetometer results may be mentioned as illustration. The average attraction on the quartzites of the region is about 300 gammas, as the units of attraction are termed; that on the unveined peridotite is about 600 gammas. On moderately veined areas the attraction leaps to 2,000 gammas and higher, varying between that figure and 10,000 gammas. This large increase, in the writer's opinion, can only be explained by concluding that the vein-forming solutions introduced considerable quantities of magnetite. There seems to be no reason for concluding that the completer serpentinization of the small remaining proportion of the olivine, or rather of that fraction of it within the vein zones, should result in any such large increase of magnetism.

The dark serpentine of the vein zones weathers to a light grey tint, very distinctive against the brown or red-brown tints of the serpentinized peridotite.

The mapping of the veined areas brings out the fact that a close connexion of some sort exists between the veined areas and the granite intrusions. The Thetford Mines peridotite is filled with granitic dykes. Reed and Murphy hills contain several, wide, dyke-like masses of granite, and to the northeast the Granite Hill boss and and some smaller plugs pierce the peridotites. Granite bodies are numerous around Black Lake, and there is at least one near the Vimy mine. Granites are either scarce or lacking within the non-veined areas. The precise nature of the connexion will be discussed more at length when discussing the origin of the asbestos.

ALTERATIONS BY GRANITE

The granites and alaskites cause an interesting set of alterations that can best be studied in the open pits. The rock immediately adjacent to a dyke, over a width usually of a quarter or half an inch, though in some instances more, is altered to a light-coloured, soft mineral that is probably talc. In one instance, what appears to be chert has developed between the edge of the granite and the talc band; and in this instance the band of talc is about 1½ inches wide. Outside of the talc band, the serpentine has the appearance of being baked. It is altered throughout a band 4 to 10 feet wide, to a black rock rather harder than the normal serpentine. At the outer edge these bands fade into the country rock in an interesting manner. The greyish peridotite is cut by a close network of reticulating veinlets of the blacker rock, and these gradually become fewer and more widely spaced until they disappear entirely.

Veins of asbestos do not appear to develop readily within the blackish zones of alteration. Veins do occur in them, but are commonly small and widely spaced.

BROWNISH YELLOW ALTERATION

Zones of varying width are observable in the open pits, of a serpentine of brown tint in hand specimen, with a deep yellowish brown translucence in thin chips. No assignable cause has yet been found to account for this alteration. It is of special interest because little or no asbestos is found in it. Rock of this type runs as a wide band along the south sides of the King and Johnson pits, forming the boundary of the ore-bodies.

ALTERATION TO SOAPSTONE

Alteration of the peridotite masses to soapstone, an impure talc, takes place in certain instances. As already mentioned, a little talc is formed along the margins of granite and aplite dykes. Drilling around the edges of the Thetford Mines mass of intrusive has shown that a good deal of soapstone exists near the contacts. Most of the soapstone of the region, however, is found in the smaller dykes north and east of the larger intrusive masses. Some of these are converted wholly, others partly, into soapstone.

The largest of these dykes is that traceable by fairly numerous outcrops through ranges IV and V, Thetford township, from the Pennington mine, lots 16-17, range IV, to Rumpleville, lots 1-2, range V. What may be the same dyke appears again between 2 or 3 miles farther northeast, on the same line of strike, and is traceable through the Quebec Asbestos, Fraser, and Boston mines. This dyke dips southeast at angles averaging about 70 degrees.

Throughout most of its length the dyke is serpentine from wall to wall. At the Federal mine, however, in lot 9, range V, soapstone is developed along the foot-wall side, possibly by alteration of the wall-rock. In lot 6, range V, where the dyke is about 460 feet wide, there is a large width of serpentine along the foot-wall, followed by 100 feet of soapstone, and then by about 10 feet of serpentine along the hanging-wall. At the Fraser mine, lots 13-14, range VII, Broughton township, 100 feet of soapstone occurs along the foot-wall, followed by serpentine above.

The set of dykes running northwest about 5 miles through ranges X and XI of Broughton township, and across the township boundary into Leeds township, are much altered to soapstone. In lot 9 the foot-wall is soapstone. In lot 4 soapstone appears rather irregularly developed near the foot-wall. At various places the dyke is characterized by a sort of ball structure, in which the serpentine forms rounded balls about a foot in diameter in a rather sheared, talcose matrix. Near West Broughton the dykes are entirely serpentine, and fairly massive.

In Broughton township, range XI, lot 12, and in Thetford township, range III, lot 16, and range II, lot 12, there are short outcrops of dykes entirely altered to soapstone. In each case the dyke is less than about 60 feet wide.

Talc and serpentine are closely related substances, both being hydrous magnesium silicates. They differ only in that talc contains a larger proportion of silica, 63·5 per cent, as opposed to 44·1 per cent in serpentine. It would be chemically possible, therefore, to form soapstone from serpentine either by addition of silica or subtraction of magnesia. It has been shown that serpentine was formed, in all probability, from peridotite, by exactly the same processes, i.e., either by addition of silica or subtraction of magnesia. There is no reason, therefore, that the same set of reactions producing the serpentine may not also have produced the talc, where conditions favoured the reaction being carried as far as talc formation. That this conception is not mere theory is shown by the occurrence of talc edgings along granite dykes, where the serpentine must have been converted into talc by siliceous addition from the dykes.

If we assume that the quantity of solutions causing alteration was limited, as must have been true, then we might expect that great bodies of peridotite would contain no talc, except perhaps a little at the edges where exposure to solutions was most intense; the volume of peridotite to be altered would be greater than could be completely altered by the available solutions, and consequently all the solutions would be used up in making the first product, serpentine. On the contrary, where the mass of peridotite was small, all of it could be altered to serpentine, and some solutions might still be available for the further alteration to talc. These conclusions check with the field observations. The larger peridotite masses contain no talc, except a little at the edges, but the smaller ones contain talc, and some of the smallest are completely converted into talc.

If peridotite dykes, either already serpentinized or in process of being so, were attacked by solutions, presumably ascending, we would expect to find talc forming in certain definite positions. These are along the walls, particularly the foot-wall; and along zones where shearing or fissuring permitted free entry of solutions. The examples cited show that talc forms most commonly along the foot-wall sides of dykes, and also occasionally on the hanging-wall. Where the peridotite or serpentine has been sheared or broken into the ball structure, the balls consist of massive serpentine, but the matrix, more broken and hence more easily attacked, is talcose.

It seems, therefore, beyond doubt that the formation of both talc and serpentine resulted from the same series of reactions. Whether these reactions were those of the first or the second alterations described on the previous pages, is a question that will be discussed later.

ALTERATIONS OF ALASKITE AND GRANITE

Many of the granite and alaskite dykes in the asbestos pits appear to be fairly fresh, others are highly altered. The altered members are invariably, so far as observed, the more alaskitic types. Alteration appears to have gone on along joint cracks, and to have worked into the body of the rock from them. The solutions causing alteration appear to have been residual from the consolidating alaskites because they were very high in silica and soda. The commonest mineral to develop along the joint cracks is albite, of which beautifully crystallized specimens are obtainable. Other minerals high in soda, such as pectolite, are not uncommon. Some of the dykes have been so rotted by the action of solutions as to slump down to a clay upon a few weeks exposure to the weather.

In the chromite pits to the south, the alaskite dykes have been differently affected. There such minerals as garnet, diopside, and vesuvianite have been formed, in some cases in such large amount as to replace the original dyke material entirely. These alterations and the resulting minerals have already been described in detail by Graham and Poitevin.[1]

The alterations of pyroxenite and gabbro have not yet been studied by the writer.

FAULTING

Faults are prominent, particularly in the mine workings at Thetford. They are of all sizes, from simple fractures on which there has been only a few inches of movement to wide zones of shear within which the serpentine is crushed to the material termed "fish-meat" by the miners. These doubtless represent movements of considerable magnitude, but the lack of recognizable dykes or other markers makes it impossible to determine the amount of displacement. The individual slip planes exhibit wide variations in strike and dip, but the larger fall into two main sets, of which the others are probably branches. The principal set strikes about north 60 degrees east, parallel to the general strike of the rocks of the district; and the second set lies about at right angles to the first.

In some cases one effect of faulting seems to have been to convert films of serpentine into fibrous types such as picrolite, the fibres being, presumably, parallel to the direction of movement or nearly so. Where this has occurred, the fault movements can commonly be seen to have been very complicated. Fault planes are filled with successive layers of fibrous materials, like the skins of an onion, each layer with its fibres at a large angle to those of the next layer. Thus, in the Johnson pit, one small fault striking north 15 degrees west and dipping 75 degrees west has three sets of layers, the innermost with the fibres dipping northward along the fault, at an angle of 14 degrees from the horizontal; the pair of layers on each side has its fibres dipping 35 degrees toward the south end of the fault; and the outermost pair of layers has its fibres running vertically down the dip of the fault. The layers thus register repeated movements of widely varying nature.

The fault movements, particularly, we may suppose, the vertical and nearly vertical ones, produced numerous subparallel tension cracks in the adjoining serpentines, spaced a few inches to a foot or two apart. These dip at low angles, commonly from 0 degrees to 30 degrees, though higher dips are also frequent.

The faults cut the serpentinized peridotites and pyroxenites, but not the granites and aplites, although some of the latter are jointed and sliced in places as if a little movement had occurred since their intrusion. The asbestos veins were likewise formed after the faulting, as small, undeformed

[1] "Contributions to the Mineralogy of Black Lake Area, Quebec"; Geol. Surv., Canada, Mus. Bull. 27 (1918).

veinlets of asbestos cut across the crushed gouge of the larger faults. Further, the veins themselves fill joints and small slips that parallel the larger faults, and are more especially found in the tension cracks running off from the faults. This can be seen in many places, but is especially well shown in the sketches of the working faces kept as records by Asbestos Corporation.

The long dyke, or series of dykes, extending from the Pennington mine to the Boston mine, is also much sheared throughout a great part of its length. Dresser has advanced the suggestion that this deformation may indicate the "Pennington dyke," as it is locally termed, to be older than the main bodies of peridotite. However, on account of the greater softness of the serpentine rocks stresses would tend to fault or shear the serpentines rather than the more resistant rocks around them. In the wider bodies of peridotite these shears might be widely diffused, but they would be concentrated in a narrow body like the Pennington dyke, causing it to be more intensely deformed. As a matter of fact, the dyke is sheared throughout its whole width only where it is narrow; where it is wider, as at the Fraser mine and in lot 5, range V, Thetford township, only a zone 40 to 100 feet wide is deformed and the remainder is as massive as the ordinary serpentine of the larger masses. This fact indicates that the deformation of the Pennington dyke is really not extreme, and may readily be accounted for by concentration of shearing movement within the narrow dyke. It does not seem necessary, therefore, to conclude that the Pennington dyke is older than the other peridotites.

The asbestos deposits of the Pennington dyke are entirely developed within the sheared parts, and are largely slip fibre, although a little cross fibre is found in places. The lack of cross fibre seems largely due to the non-occurrence of tension cracks in the intensely sheared rock.

THE ASBESTOS VEINS

Asbestos, or chrysotile, is merely a crystallized, fibrous form of serpentine. It occurs in veins with a maximum width, in Thetford district, of about 3 inches, although wider veins have been known. Individual veins are characterized by great regularity in width, and the length is roughly proportional to the width. Veins 2 or 3 inches wide may commonly be traced for 50 feet, and sometimes for 100 feet or more. The ordinary vein, developed in a tension crack running off from a slip or fault, is usually widest at the fault and terminates at the other end by gradual reduction in width.

The chrysotile fibres are arranged parallel to one another in the veins, and at a large angle to the walls, from 45 degrees to 90 degrees. In the vertical or nearly vertical veins the fibres are at right angles to the wall or almost so; and the same is true of horizontal or nearly horizontal veins. In inclined veins, however, the angle between the fibres and the wall is commonly less than 90 degrees, and the greater the inclination of the vein, the smaller the angle between the fibres and the walls. The fibres do not, however, take a vertical position, but they do always assume a position that lies between the vertical and a line at right angles to the vein walls. The writer believes that their position, in each case, indicates the direction of minimum pressure at the time the vein was formed. In horizontal veins the direction of pressure release would be straight upwards; in steeply inclined veins the pressure would be approximately the same from both sides; hence both types have fibre at right angles to the walls. In other veins, however, movement would be easiest along some line between the vertical and the line at right angles to the vein; and we find the fibres elongated along such a line.

The asbestos veins in every case have very clearly defined walls, which have been variously described as very regular and as minutely irregular. The divergent descriptions are merely a matter of viewpoint and standards. Considered in relation to the size of grain of the vein materials and to the dimensions of the veins, the straightness and regularity of the vein walls are outstanding features. The veins never include grains or irregular remnants of the dark antigorite of the walls, nor do irregular salients of asbestos or even individual asbestos fibres project from the vein into the walls. In other words, the veins display none of the characteristics of replacement veins, but do, on the other hand, possess all the characteristics of normal fissure veins.

In the Vimy mine the asbestos fibres run from wall to wall of the veins without a break. In other places, however, the veins have a parting within them. In some instances the parting is a fairly regular plane near the middle of the vein, but in others it wanders irregularly from a position near one side to one near the other. In places the parting is an almost invisible line, and can be detected only by passing the finger nail carefully along the length of the fibre. More commonly, however, it is marked by a string of magnetite grains, accompanied in places by some very pure, light green, "colloidal" serpentine, approaching precious serpentine in quality. Strings of grains of magnetite also run out from the parting between the fibres of asbestos. The veins at Thetford contain relatively a large proportion of magnetite, whereas those at the Vimy mine have very little; in fact it is difficult to find a magnetite grain there, and where found the magnetite grains are never intermixed with the asbestos fibres, but always in the walls.

OTHER VEINS

In places, especially at the old Lambly mine, near Coleraine village, a very pure, light green, translucent serpentine occurs in veins in the serpentinized peridotite. It approaches the so-called precious serpentine closely in appearance, but has the unfortunate peculiarity of bleaching to a creamy white after about two years' exposure to the air, possibly through dehydration. The bleached products are probably those described by Poitevin and Graham as porcellophite, pseudophite, etc. This material generally includes rounded nodules made up of radiating fibres of an iron-bearing carbonate, indicating that carbonated solutions were the cause of their formation.

Irregular, vein-like masses of a very pure green "colloidal" serpentine closely resembling picrolite but without its fibrous texture, are found here and there in the asbestos pits. Small quantities of a similar serpentine occur in the central partings of the asbestos veins.

Picrolite, supposed tentatively to be a fibrous serpentine of about the same composition as the material last described, is generally developed along planes of slip; but it also occurs in veins with the fibres at a large angle to the walls, exactly like the veins of asbestos.

It seems probable that the veins of picrolite and colloidal serpentine were formed about the same time and by the same solutions, because of the similarity of the material and also because in some veins one type changes to the other along the strike. It is unlikely, however, that they had the same origin as the veins of near-precious serpentine, because of the large amounts of carbonate the latter contain. Carbonates are unknown both in the picrolite veins and in their near relatives, the asbestos veins; and it will be shown that these veins were probably formed through the interaction of the serpentinized peridotites with silica-bearing solutions. The solutions forming the veins of precious serpentine, however, were evidently highly carbonated, and, therefore, of an entirely different type.

Two possible sources of carbonated solutions are known or inferred. It was inferred that the preliminary serpentinization of the peridotites was probably accomplished by carbonated solutions from the igneous mass itself; if so, such solutions might fill fissures with veins of this type, and the veins would be older than the asbestos veins. The pegmatitic varieties of granite, also, gave off carbonated solutions in small quantity, because vugs in the dykes often contain beautiful clusters of aragonite crystals. Veins formed by these solutions might be either older or younger than the asbestos veins. The writer has not been able to observe, as yet, whether the veins of precious serpentine cut the asbestos veins or not, but Harvie states that they do. If so, the latter source for them would seem probable.

SIGNIFICANT PECULIARITIES

The writer was shown a specimen of alaskite obtained from the Bell mine, Thetford, through which cuts a vein of fibrous serpentine akin to picrolite in appearance, but of a brownish colour. The vein was about a quarter inch wide.

A granite dyke on the Beaver property, Thetford, contains numerous inclusions of serpentine up to 3 or 4 inches in length. Each inclusion is surrounded by a band nearly one-fourth inch wide, of fibrous material apparently formed by the interaction of the granite with the serpentine. The fibres are arranged radially with respect to the inclusions.

On the Beaver property a vein crosses a granite dyke. The vein is composed of asbestos, in the serpentine; but is quartz in the granite.

In the Pennington mine, Mr. R. V. Hopper, geologist for Asbestos Corporation, found a vein of asbestos running out from the serpentine into the Bennett schists, and succeeded in securing a specimen which is now in the possession of the writer.

ORIGIN AND LOCALIZATION OF THE ASBESTOS DEPOSITS

It has been shown that the bodies of peridotite suffered a double alteration, the first a general serpentinization in which from 70 to 85 per cent of the original minerals were converted into serpentine, the second a lesser change in which veins of asbestos were formed and their margins, throughout six or seven times the width of the veins, converted into the pure bladed serpentine, antigorite. It has also been shown that the second alteration is accompanied by a great increase of local magnetic attraction. Further, parts of the peridotite bodies, particularly the thinner dykes and the edges of the larger bodies, are converted into soapstone, an impure talc.

These alterations, we have seen, required only addition of silica to the peridotite, or removal of part of the magnesia of the rock. The latter could be accomplished by carbonated waters. In either reaction large increases of volume must have taken place, unless considerable amounts of the rock constituents were carried off by the solutions. There is at present no evidence that any large volume increase has occurred.

The asbestos veins, with their accompanying alterations, are confined in general to the north side of the main peridotite mass, to the Pennington dyke, and to the area of Murphy hill, Reed hill, and Granite hill, an area filled with large granite dykes and granite plugs. The other parts of the main peridotite mass, and the northwest-trending dykes, carry no asbestos.

The facts mentioned have caused previous writers to conclude that the asbestos deposits were formed, in all probability, by siliceous solutions emanating from the cooling granite masses. The writer cannot concur with this conclusion. In the chromite areas to the south, granite dykes are numerous, but there is no asbestos whatever. In the area of Murphy, Reed, and Granite hills, where granites attain their largest development, commercial asbestos is known only on the north side of Murphy hill. There is no granite whatever along the Pennington dyke, a distance of 13 miles, although asbestos has been mined from it at intervals throughout its entire length. Further, the granites alter the serpentines to a dark rock that seems positively unfavourable to the presence of asbestos, as veins are fewer and narrower in it.

The apparent close connexion of asbestos deposits and granite bodies must, therefore, be due either to some structural conditions that controlled and localized both; or to the granite injections cracking and breaking the surrounding rocks, so that the asbestos-forming solutions found ready access. In the Thetford pits it is evident that the first alternative is true, and that both dykes and vein-forming solutions entered along pre-formed faults. The size of the veined area of Murphy, Reed, and Granite hills, the presence within it of so many large granite masses, and the fact that nowhere else is the veined area carried so far across the intrusive mass, all combine, however, to suggest that these large injections may have created fractures which were afterwards entered by the vein-forming solutions.

If these conclusions are correct, another source must be sought for the siliceous or carbonated solutions that could form the asbestos veins.

If such a source existed, the solutions that formed asbestos within the serpentine masses should deposit quartz or carbonates outside of them. One of the most prominent features of the district is the prevalence, within the Bennett schists, of quartz veins. Quartz veins literally swarm throughout these schists, and also invade the massive quartzites to the south, across a width of nearly a mile, in such abundance that bedding planes and other structural features are quite obliterated in places. If part or all of this quartz can be shown to have been deposited after the peridotites were injected, there can be no doubt that the vein-forming solutions could have furnished sufficient silica to accomplish the alterations to serpentine, asbestos, and talc.

The age of the quartz veins has been determined in two places. In range IV, lot 7b, Leeds township, about 1½ miles southeast of Kinnear Mills, the rocks are much less metamorphosed than farther south, and interbedded slates and quartzites have their structural features readily distinguishable. The slate, as usual, has a pronounced cleavage developed at a considerable angle to the bedding, and quartz veinlets have been injected between the laminæ of slate. Evidently, therefore, the veins were formed after the deformation of these rocks and the development of slaty cleavage in them. The first deformation great enough to produce slaty cleavage took place after deposition of the Beauceville series, which is supposedly of Ordovician age.

In range VIII, lots 17-18, of Thetford township, the massive Caldwell quartzites are bent so sharply that they have broken down to a crush-breccia. The somewhat schistose fragments of quartzite contain numerous veinlets of quartz, evidently formed before the brecciation, as they end sharply at the boundaries of the fragments. Two alternative conclusions may be drawn from this piece of evidence. If the bending and brecciation of the quartzite occurred during the first folding, after Beauceville time, then these quartz veins must be older than those near Kinnear Mills. In other words, there must have been two generations of quartz veins, one injected prior to the folding or at least toward the beginning of it, the other injected after the folding was largely or entirely completed. There was, however, a later severe folding in this region, after the deposition of the Devonian rocks of Chaudière valley; and it is possible that the brecciation of the quartzites might have taken place then. If so, all the quartz veins might be of the same age, namely later than the first major period of folding.

It was shown in the 1930 report on this area, that the intrusion of the peridotites was controlled by the folding, and, therefore, that it took place, in all likelihood, toward the end of the first or second periods of folding. Results of investigators in other areas favour the earlier rather than the later date for the intrusion. It is evident, therefore, that both the injection of at least some of the quartz veins and that of the peridotite masses occurred, in general, at about the same time; and it is not unreasonable to conclude, therefore, that the solutions that deposited the quartz veins afford a possible source of the silica and carbonic acid needed for serpentinization.

If this conclusion is true, we would expect to find deposits of asbestos limited mainly to the north side of the peridotite masses, close to the sections where quartz veins are numerous; and asbestos should be small in quantity or lacking farther south, as there is little or no quartz in the rocks more than a mile south of the margin of the schists. This is the relationship that actually occurs; and this concentration of the asbestos deposits along the northern edge of the peridotite masses is a fact that has long puzzled investigators. The writer believes that it is to be explained by the association of the asbestos deposits with the quartz veining of the district to the north.

It is evident, further, that under this hypothesis the solutions forming the quartz veins must have formed only the asbestos veins and the altered zones that flank the veins. They could not have been responsible for the earlier serpentinization of the peridotites, or there would have been a pronounced decrease of serpentinization from north to south, which is not the case. Some other cause of the earlier serpentinization must, therefore, be postulated.

The reasons some dykes are converted completely into soapstone with no production of asbestos are not yet entirely clear. Certain facts, discussion of which will be reserved for a more detailed report, suggest that formation of talc required somewhat hotter solutions than those necessary for asbestos deposition; if this proves true, on further investigation, then the soapstones must have been formed first, when solutions were hottest and most concentrated; and it would then, of course, be impossible for asbestos to form within the soapstone masses, as this would require subtraction of silica, and the solutions available were introducing silica. Asbestos could then form only in those parts of the peridotite masses that had not suffered alteration to soapstone.

That the asbestos veins themselves were also formed by hot solutions is indicated by the presence of magnetite, a high-temperature mineral, in the veins.

As to the origin of the asbestos veins, previous writers are divided into two schools. The first, noting the regularity of the vein walls, and the evidence afforded by the central parting and the magnetite grains there which crystallized later than the asbestos, have concluded that the asbestos crystallized in open fissures, the fibres commencing their growth at the walls and growing towards the centre. The other school considered that "the position, size, and number of asbestos veins in the 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." They, therefore, felt themselves forced to conclude that the asbestos veins are replacements, formed by solutions entering along a preformed joint or crack, and that the asbestos crystallized outward from this crack, which became the central parting of the vein.

The argument is strong, and yet the evidence that the veins are fissure fillings and not replacements is so impressive that all possibilities should be canvassed before rejecting that conclusion. A possibility that appears to have been overlooked or not seriously considered by those advocating replacement is, that the siliceous vein-forming solutions were injected into the various fault fissures and tension cracks at sufficiently high pressure to force the walls apart, approximately to their present position. The solutions could then have been held stagnant in the veins, under pressure, while reaction with the wall-rock and crystallization of the asbestos took place. That such a conception is possible is indicated by the nature of the veins themselves; they gradually narrow down and end at the extremity farthest from the fault where they originate, indicating that there was no outlet for the vein-forming solutions, through which flow might have occurred with consequent relief of pressure. Again, the presence of colloidal serpentine in the central partings of veins indicates that serpentine was taken into solution and re-deposited; and in such circumstances only the existence of stagnant solutions can explain the case described in the section " Significant Peculiarities," of the vein which is quartz in a granite dyke and asbestos in the surrounding serpentine. Had the solutions forming that vein been in motion, the deposit in that dyke must have been some form of serpentine, as it actually was in another of the peculiar cases described.

Since, therefore, the internal structure of the asbestos veins indicates that they were deposited in open fissures, and this conception affords a mechanism by which open fissures might exist; and since also there is some direct evidence both that this mechanism could function and did; the conclusion accordingly seems justified that the asbestos deposits were formed as true fissure veins and not as replacement veins.

According to this hypothesis the asbestos veins were formed as follows. Heated, siliceous solutions, which may have emanated from a magmatic source or may have acquired their silica from the underlying schists and quartzites, rose through fault fissures under great pressure and were forced into tension cracks and other pre-existing fissures, forcing the walls apart. Reaction then took place between the hot solutions and the partly serpentinized peridotite of the wall-rocks. Some of the serpentine was taken into solution, while the excess silica reacted with the wall-rock and converted it into the bands of bladed antigorite that flank the veins. The amount of rock thus altered would depend on the quantity of available silica and the extent to which the rock had previously been serpentinized; hence the more or less uniform correspondence between the width of the veins and the width of the antigorite zones, which was noted by Dresser many years ago, but has never been explained.

As the solutions cooled, the serpentine dissolved in them began to crystallize as asbestos. That serpentine or its constituents must have been in solution is shown by the occasional occurrence of picrolite or asbestos veins in rocks other than peridotite, as described under " Significant Peculiarities ". Crystallization would naturally begin at the walls, where it was coolest; and would continue inward as cooling proceeded. If the temperature dropped below the point at which asbestos would crystallize, any serpentine still remaining in solution would solidify at the centres of the veins, along the magnetite, to form the so-called " colloidal " serpentine so commonly found there.

MAGNETOMETER OBSERVATIONS

Mr. A. H. Miller, of the Dominion Observatory, and the writer, made a series of magnetometer measurements to test the possibility that the serpentine bodies could be traced through drift-covered areas with this instrument. The experiments could not, unfortunately, be continued long enough to test all the magnetic possibilities of the serpentine series, as Mr. Miller had other investigations to make during the summer; but the following results were obtained, and the experimental work will be continued, it is hoped, next summer.

In carrying on the experiments, two magnetometers were used. One was set up in camp, where readings were made and recorded every 20 minutes. In this way the changes taking place in the earth's magnetic field from hour to hour and day to day were determined, and all necessary corrections, from this cause, were applied to the readings obtained on the other instrument. In carrying on the field experiments, the positions and relative elevations of all set-ups were accurately located by transit and chain survey from known points.

Most of the experimental work was done on the " Pennington dyke ". On this dyke, cross-sections can be selected where the dyke is wide and where it is narrow; where the asbestos content is considerable, and where asbestos is entirely lacking; where the dyke is all soapstone, where it is all serpentine, and where it is partly soapstone and partly serpentine. The strike and dip of the dyke are closely known, and the positions of the edges can commonly be determined, where it is exposed, within a few feet. The boundaries of the talcose parts, the serpentine parts, and the parts containing asbestos can be also as closely determined. As the various geological factors may be thus determined with preciseness, the dyke is an ideal subject for experiment.

In addition to the measurements on the Pennington dyke, measurements were also made on some of the soapstone dykes that strike northwest, and on parts of the large, peridotite mass near the Vimy mine.

These experiments showed (*a*) that soapstone exerts no magnetic attraction beyond that of the ordinary quartzites and slates of the neighbourhood; except in one or two localities, where for some undetermined cause low attractions were registered; (*b*) that massive serpentine or partly serpentinized peridotite exerts a small attraction, too small to enable a serpentine mass to be traced through a drift-covered area. It was found that the ordinary quartzites and slates register attractions of 300 to 500 gammas, as the units of attraction are termed, and that massive serpentine exerts an average attraction of about 700 gammas; (*c*) that very strong attractions are registered in all areas where asbestos veining is developed, whether much asbestos is actually present or not; and that the amount of attraction is roughly proportional to the number of veins within a unit area. Where the veins are as numerous, roughly, as in the asbestos pits, attractions of 2,000 to 8,000 gammas are registered. To afford a rough idea of the significance of these figures, the deflexion of the compass was measured as 20 degrees in a spot where the magnetometer registered an attraction of 6,000 gammas.

Each of the above conclusions was checked by measurements from at least three to five localities; but more measurements are required before they can be assumed as invariably correct. Further experiments are also required to determine the causes of variation of magnetic intensity within the veined areas, and to learn, if possible, whether there are significant differences of intensity between areas of commercial and non-commercial veining.

SOME RECENT MINING DEVELOPMENTS IN SOUTHERN QUEBEC

By H. W. Fairbairn

In southern Quebec there are numerous localities in which sulphide minerals occur in small concentrations. These have been exploited with varying success during the past century and are described by Logan,[1] Bancroft,[2] and others. The present report is intended to supplement their observations in three localities where more recent development work has been carried on.

SOUTH STUKELY MINE

At South Stukely, on the Canadian Pacific railway about 70 miles east of Montreal, the Grand Trunk copper mine, abandoned more than sixty years ago, was reopened in 1929 by the South Stukely Copper Mine Company. Its history prior to 1916 is well presented by Bancroft[3] and need not be repeated here.

The geologic features of the locality are as follows. A coarse calcite marble is bounded on both sides by chlorite schist. The marble is of sedimentary origin with an outcrop width of less than 5 feet; the schist is a metamorphosed lava of unknown thickness. From a consideration of the stratigraphy elsewhere it is probable that the marble has been faulted into its present position. The formations strike about 35 degrees east of north and dip northwest from 40 to 60 degrees. The sulphides comprise bornite and chalcopyrite which occur disseminated throughout the marble and to a distance of at least 6 feet into the wall-rock schist. Quartz veinlets are common and the earlier reports of the property state that there is a tendency to concentration of the quartz and sulphides in the crushed schist-marble contact zone.

Mr. George Groleau, the present manager, supplied the following information. Since 1929 the old workings have been deepened to 210 feet. The marble was 3 feet wide at the surface, at the 100-foot level it had widened to 29 feet; at the present 210-foot level, its total breadth has not yet been determined. Drifts have been opened to a maximum distance of 1,900 feet along the hanging-wall and for 450 feet along the foot-wall, which show the same type and quality of sulphide mineralization as in the original workings. The ore runs 8 per cent copper, 4 to 6 ounces silver, and a trace of gold.

Development has progressed intermittently and an average of eighteen men have been employed. Despite the high freight charges, a small profit was made on 100 tons of ore shipped to New Jersey. Present plans include a diamond-drilling program and storage of ore until marketing conditions

[1] Logan, W. E.: "Geology of Canada, 1863."

[2] Bancroft, J. A.: "Copper Deposits of the Eastern Townships of Quebec"; Quebec Bureau of Mines, 1916.

[3] Ibid., p. 119.

become more favourable. The company has a contract with a Montreal firm for use of the marble gangue in artificial stone; negotiations are also in progress for its use as a flux. There is, in addition, the prospect of a small smelter being erected at the mine.

The future of the South Stukely mine is problematical. Given good management, and favourable market conditions for copper, fluxes, and artificial stone, it should yield a profit. The utilization of the marble will be the deciding factor, for as a copper producer it will probably never be important. The marble formations of this part of southern Quebec are seldom more than 100 feet thick—usually much less—and although the grade of ore is good the quantities available for large-scale mining may prove disappointing. The possibilities of the deposit, however, are largely unknown and it is worthy of careful attention from those interested in its development.

MEMPHREMAGOG MINE

The Memphremagog mine is on the northwest shoulder of Hogsback mountain, about 4 miles east of South Bolton station on the Canadian Pacific railway. A detailed description of the property and its history is given by Bancroft.[1]

A massive sulphide body, mostly pyrrhotite, lies between a black slate on the west and a fine-grained, igneous rock on the east. The latter rock has been referred to as a diabase, but detailed field work in this and others of these igneous mountains has shown that they are largely metamorphosed lavas. The pyrrhotite is accompanied by a small amount of chalcopyrite and forms on the outcrop a lenticular mass about 100 feet long and 30 feet at its maximum width. The grade of copper is not over 2 per cent.

Mr. G. S. Smith, the present owner of the property, states that in the autumn of 1929 the old workings were extended to the south about 70 feet and a small stope was opened in the side of the glory hole. No shipments were made, however, and work was discontinued after a short time.

There is insufficient chalcopyrite in this deposit to consider it a copper prospect. The known tonnage of pyrrhotite is likewise too low to warrant installation of a sulphuric acid plant. The only expenditure advisable at present would be for diamond drilling in order to learn something of the deposit at depth. Given a considerable increase in the tonnage of possible ore, the future of the property would then depend on marketing conditions for acid or on new uses for pyrrhotite.

LEADVILLE PROSPECTS

Copper-lead-zinc sulphides occur in the vicinity of Leadville, on the west side of lake Memphremagog and one-half mile north of the International Boundary. Logan[5] reported the locality to have lead-zinc only, but recent operations on the farm of W. W. Brown show copper as well. The most promising openings on this property have been made in a fine-textured mica schist of sedimentary origin, and three small pits that have

[1] Ibid., pp. 152-160.
[2] Logan, W. E.: "Geology of Canada, 1863," p. 691.

been worked recently show abundant pyrite, considerable galena, and sphalerite, with bornite and chalcopyrite in lesser amount. The sulphides are commonly associated with a calcite gangue which replaces the mica schist and forms a massive carbonate rock. In places the calcite and sulphides occur in small, lens-like pockets and appear to have pushed apart as well as replaced the laminations of mica schist.

The lead-zinc in the pits referred to above seems to average about 1 per cent and cannot be considered an ore. The mica schist is favourable to concentration of the sulphides and further stripping of this horizon would be advisable. No further development should be carried on unless there are indications of higher metallic values than are known at present.

SALT DEPOSITS OF NOVA SCOTIA AND NEW BRUNSWICK

By G. W. H. Norman

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Illustration

INTRODUCTION

It has long been suspected that valuable deposits of salt occur in the strata of the Maritime Provinces. Its presence is suggested by numerous brine springs which issue from these rocks, and which have from time to time been analysed,[1] and even utilized for the preparation of salt by evaporation.

It is only in comparatively recent times that any attempt has been made to investigate the real nature of these deposits or their distribution. In 1917 a search for salt was made at Malagash, N.S., by Mr. A. R. Chambers and Mr. George Walter McKay of New Glasgow, N.S. Here strong brine had been secured from wells drilled in search of water. Salt was discovered at a depth of 85 feet and has been mined continuously since discovery.

Proof that the salt strata are extensive and occur probably in more than one horizon in the Carboniferous rocks has been furnished lately by wells drilled in search of petroleum. Two wells at Gautreau, N.B., on the east side of Petitcodiac river opposite Hillsborough, have penetrated several hundred feet of salt. The salt strata here are not continuous with those at Malagash but lie in a separate structural basin and the available information indicates that they are older than the Malagash deposits. During the past year a well drilled by the International Petroleum Company on the general zone of the axis of the Minudie anticline,[2] near Nappan, N.S., passed through several hundred feet of salt. This well signally increases the available information regarding the potential value of the salt deposits of Cumberland basin, N.S., and a summary of the pertinent facts regarding this basin and its relation to the deposits at Gautreau, N.B., is given in the following paragraphs.

[1] Mr. L. Heber Cole has made a thorough investigation of these springs and describes them in his recent report on the "Salt Industry of Canada," Mines Branch, Dept. of Mines, Canada, No. 716 (1930).

[2] The incompetent and fluent strata in the core of this anticline suggest that the axis is a zone of intense folding.

Salt deposits are probably present in other basins in these two provinces, because brine springs also occur in Windsor and Antigonish districts of Nova Scotia and in Cape Breton. A small thickness of salt is reported in a driller's log in Windsor district. At the present time, however, data on which to base any estimate of the prospective value of the salt in these basins are lacking, although the rocks which they contain are of the same age as those that contain the salt at Gautreau and in Cumberland basin.

GENERAL GEOLOGY

STRATIGRAPHY

The rocks of the Maritime Provinces fall naturally into two major groups, the Carboniferous and the pre-Carboniferous.

Carboniferous	Pennsylvanian	Sandstone, shale, coal seams, conglomerate
	Mississippian	Shale, sandstone, limestone, dolomite, gypsum, anhydrite, salt
		Shale, sandstone, conglomerate, salt
Pre-Carboniferous		Extrusive and intrusive igneous and metamorphic rocks. Middle and Lower Palæozoic sediments

The pre-Carboniferous rocks form the cores of the major anticlinal structures and usually stand up as dominating ridges in the landscape. The Carboniferous rocks form a thick assemblage of sedimentary types deposited under shallow water conditions in a region of crustal instability. These are preserved in structural basins flanked by the ridges of the older group.

The Carboniferous may be divided for the purpose of this report into two main groups. The lower group is of Mississippian age and consists of clastic, carbonate, and saline rocks; the upper group is of Pennsylvanian age and consists of conglomerate, sandstone, shale, and coal seams.

The salt deposits of the Maritime Provinces occur as an integral part of the Mississippian strata which consist of two distinct groups of rock. The lower group is predominantly shale, sandstone, and conglomerate, prevailingly red in colour, although grey-coloured sandstone and shale occur, also, and even form members of considerable thickness. The upper group contains numerous limestone, dolomite, and lime-mud rocks deposited under marine conditions. Gypsum, anhydrite, and salt are associated with the carbonate rocks, which suggests for them, also, a marine origin. The clastic rocks of this group, which form a considerable part of the whole, are sandstone, siltstone, and shale, predominantly red in colour.

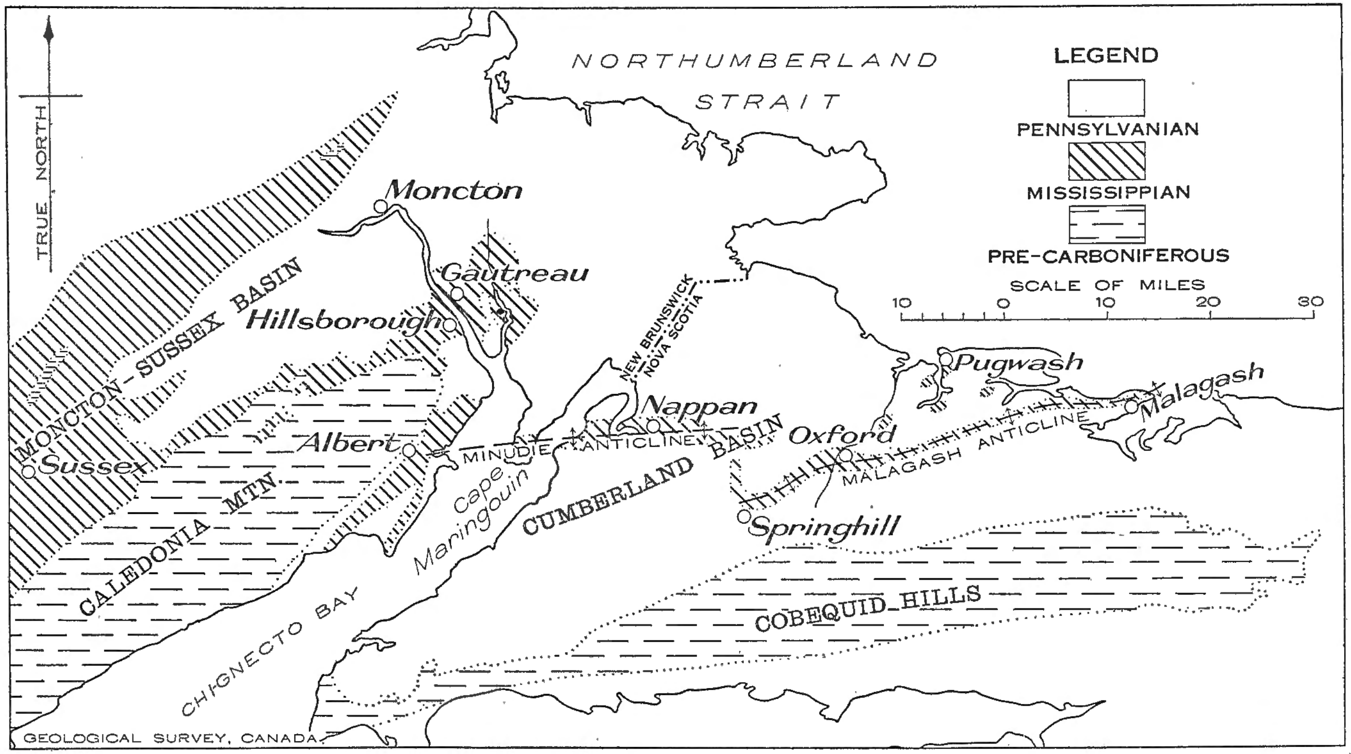

Figure 1. Cumberland, and Moncton-Sussex basins, Nova Scotia and New Brunswick.

The overlying Pennsylvanian rocks have been allocated to several series which are separated by unconformities. The sedimentation during this and the preceding period was interrupted by uplift and erosion, producing unconformable relations between the various series. The Pennsylvanian rocks are several thousand feet thick so that it is only where folding, faulting, or a combination of both has brought the older rocks upwards, that the salt beds are accessible.

STRUCTURE

The major structural features that need to be considered here are the two geosynclinal basins (*See* Figure 1) which lie on either side of Caledonia mountain. This mountain forms a long, narrow tableland, stretching from St. John, N.B., to within a few miles of Hillsborough, N.B. It is underlain by pre-Carboniferous rocks. The basin which lies to the north may for want of a name be called the Moncton-Sussex basin. The Cumberland basin flanks Caledonia mountain to the south and extends into Nova Scotia, where it is bounded on its south side by Cobequid hills.

These geosynclinal basins are composed of a series of anticlinal and synclinal folds. Faulting both parallel to and at right angles to the folds has occurred. Their history differs in that the upper Mississippian and lower Pennsylvanian rocks of the Moncton-Sussex basin are only slightly disturbed and lie with gentle dips, whereas in Cumberland basin, rocks of this age are folded together with the older rocks, and lie with characteristically steep dips.

SALT DEPOSITS

CUMBERLAND BASIN

In this basin the Mississippian rocks are brought up to the surface along two major folds, known as the Malagash and the Minudie anticlines; elsewhere in the basin they are concealed by a thick covering of younger rocks. Along the Malagash anticline, the larger of these folds, the Mississippian rocks are exposed from Springhill to Malagash point, a distance of about 42 miles along the strike and for about 1 mile across. The Minudie anticline lies *en échelon* to the northwest from the Malagash anticline. This structure stretches from Nappan westwards across cape Maringouin to Albert, N.B. Mississippian rocks are exposed along the central zone of this structure for 12 miles in Nova Scotia; they outcrop in a belt crossing cape Maringouin and appear on the west side of Shepody bay at Riverside near Albert. South of Pugwash, several isolated areas of Mississippian rocks form "islands" surrounded by younger rocks. They may represent the high points on another northeast linear structure, but proof of this has not as yet been ascertained.

Exploration of the salt strata of the basins must depend largely on the drill, since natural exposures of these soluble rocks are lacking. Drilling should be confined to the regions of Mississippian rocks outlined above in which the salt strata, if present, will lie nearer to the surface than elsewhere.

Very little data regarding either the sequence or the structure of the salt strata have at present been secured. The fact that a thick group of salt beds has been discovered at Nappan, which lies 50 miles west of Malagash, and that between these points numerous salt springs occur, suggests continuity of the beds and indicates an extensive basin of salt deposition.

At Malagash about 300 feet of salt strata have been explored for about 1,000 feet along the strike and about 350 feet down the dip. The strata here dip steeply to the south and are folded transversely to their strike, producing a corrugated structure. Thinning of the strata along the limbs of these minor folds and a concomitant thickening along the axes of these folds have taken place. Three horizons in the mine carry magnesian and potash salts.

Near Nappan the International Petroleum Company's well, Amherst No. 1, which went to a depth of 4,132 feet, passed through a series consisting principally of gypsum and anhydrite with associated shale, sandstone, dolomite, and grit to a depth of 920 feet. Below 920 feet the series consisted predominantly of anhydrite and salt with interbeds of shale, sandstone, dolomite, and limestone. In all, 1,460 feet of salt was passed through below a depth of 920 feet, and occurred at the following depths:

Depth from the surface Feet	Thickness Feet
920– 940	20
970–1,030	60
1,040–1,080	40
1,190–1,200	10
1,210–1,220	10
1,240–1,270	30
1,420–1,430	10
1,460–1,470	10
1,560–1,570	10
1,600–1,610	10
1,730–1,820	90
1,850–1,980	30
2,180–2,350	170
2,410–2,490	80
2,550–2,850	300
2,990–3,490	500
3,970–4,050	80
	1,460

The salt in many of these beds is pure white, coarsely crystalline, and is of considerable purity. Flame tests for potash were made, by Mr. Fraser of the Borings Division, Geological Survey, and indicate a low but consistent content of potash in the salt. The samples were examined for potash minerals, but, as these are probably microscopic in size and intimately associated with the salt, they were not detected.

The unexpected thickness of saline strata in this well suggests that the structure is not a simple anticlinal flexure but rather a complex of folds. Sections of the gypsiferous strata of the Windsor series (upper Mississippian) in Nova Scotia show clearly that such strata yield much more readily than the other sedimentary rocks of the Carboniferous formations. During the folding of the rocks they behave very much like a plastic mass and are drawn out like fluids, and thus not only exhibit flowage structures but also a much more complicated system of folds than the strata of the formations that enclose them on either side. Gypsum showing well-marked flowage structures is well exposed at Pink rock, toward the centre of the Minudie anticline on the west side of cape Maringouin. Here the character of the flowage is brought out by the behaviour of a 3-foot bed of limestone in the gypsum. The limestone has been broken and torn apart and now forms isolated, irregular lenses surrounded by gypsum, which has flowed evenly without any indications of breaking.

The salt structures and anticlines in Germany are exceedingly complex, and considerable detailed data regarding their character, obtained from the mines and bore-holes, have been published by Seidl.[1] His sections across these structures depict masses of highly contorted salt strata that have been forced upwards through overlying, younger strata. The stratigraphic and tectonic conditions in Nova Scotia are similar in some respects to those in Germany, so that it may well be expected that similar complex salt structures exist in Nova Scotia.

The real thickness of the salt in the Nappan well is undoubtedly less than the thickness listed above. This is due to the fact that the strata probably have a steep dip and may be repeated by folds which cannot be distinguished. It is clear, however, that a considerable thickness of salt does occur in this part of the basin, although it is difficult at present to formulate an idea of its extent. The numerous salt springs that occur in Cumberland county suggest that salt deposition occurred uniformly between Malagash and Nappan, a distance of about 50 miles in a northeast direction. The possible width of the basin in a northwesterly direction cannot be estimated because the salt-bearing strata are so largely concealed beneath younger rocks, and only appear in long, narrow belts extending northeastwards.

The known association of some potash with the salt and the probable great extent of the basin suggest that local concentrations of potash in beds of sufficient richness to be worked economically may occur. The lack of discovery of potash deposits up to the present has little significance other than that no systematic search has yet been undertaken. Considerable time elapsed before the salt was actually discovered, although the indications were correctly interpreted by Gesner[2] nearly a hundred years ago. The lack of detailed information regarding the character and structure of the Mississippian rocks of the basin would hamper an attempt to locate potash rich zones. These rocks are so largely concealed by surface deposits of boulder clay and gravel that little can be learned about them without the use of the diamond drill. The expense entailed by the use of such an aid would demand the most intelligent supervision.

MONCTON-SUSSEX BASIN

Little has yet been ascertained regarding the salt deposits of this basin. Salt springs were discovered early in the settlement of the country and those at Sussex were at one time utilized for the manufacture of salt by evaporation.[3]

[1] Seidl, Erich: "Schurfen Belegen und Schachtabteufen auf deutschen Zechstein-Salzhorsten"; Preussischen Geologischen Landesanstalt, Heft 26 (1921).
[2] Gesner, Abraham: "Remarks on the Geology and Mineralogy of Nova Scotia," 1836, p. 144.
[3] Bailey, L. W.: Geol. Surv., Canada, Ann. Rept., vol. X, pt. M, p. 121.

At Gautreau, on the east side of Petitcodiac river about 20 miles south of Moncton, exploratory wells put down by the D'Arcy Exploration Company and the New Brunswick Gas and Oil Company encountered salt. The presence of salt in this part of the basin had been entirely unexpected since no brine springs occur.

The relation of the salt deposit at Gautreau to those of the Cumberland basin in Nova Scotia cannot at present be clearly envisaged. The salt strata of Cumberland basin are associated with gypsum and anhydrite, which are known to occur in the Windsor series (upper Mississippian), but their relation to any definite horizon in the Windsor series has not yet been determined. They evidently do not occur in the upper strata of the Windsor series. This is shown by the various sections across the Malagash anticline in which the salt, although it does not actually appear, must lie well below upper Windsor strata. However, as considerable anhydrite and gypsum are known to occur in the Windsor series, and since the salt in Cumberland basin is associated with gypsum and anyhdrite, it is thought that the salt also occurs in the Windsor series.

At Gautreau the salt lies in a synclinal structure, which plunges to the west. The general synclinal structure of the basin is brought out by a band of volcanic ash rocks which outcrop at various points around the rim of the basin.

From the boring records the salt is known to underlie the ash rock. In the western extremity of the structure in the vicinity of overlapping Pennsylvanian strata on Cat creek, a tributary of Weldon brook which flows into Petitcodiac river north of Hillsborough, a small thickness of lower Windsor limestone occurs that must lie many hundred feet above the salt, owing to the westerly dip of the structure as a whole which brings in higher beds in a westerly direction. This lower Windsor limestone lies above the ash rock, a fact established by its field relations to this horizon.

The available information, therefore, certainly suggests that the Gautreau deposit was laid down at an earlier period than the Cumberland deposit, from which it is separated by the Caledonia Mountain ridge on the southwest. To the northeast, at the Nova Scotia-New Brunswick border, the relation of the two basins is concealed by a covering of flat-lying Pennsylvanian rocks.

Details regarding the cores of the two wells put down at Gautreau are furnished by Cole.[1]

The two wells on Boyd creek near the main highway from Pré d'en haut to Moncton encountered, respectively, 485 and 890 feet of salt, the top of which in each case was about 1,200 feet from the surface. Another hole a little more than half a mile to the northwest was sunk beyond the northern limit of the salt. The salt here, unlike the deposits in Cumberland basin, lies along the centre of a synclinal structure. The salt strata as obtained from the core suggest that for the most part the beds lie nearly flat. At intervals, however, the core shows that they have a vertical atti-

[1] Mines Branch, Dept. of Mines, Canada, "The Salt Industry of Canada," No. 716, pp. 21-25 (1930).

tude. Two alternative explanations seem to offer themselves: either that the vertical dips of the salt represent the upcurled edges of the salt along desiccation cracks, as suggested by Mr. L. H. Cole, or that the salt is locally buckled into small folds along certain horizons much like those exhibited by the gypsum strata at Hillsborough. In the gypsum at Hillsborough locally folded and contorted zones lie between undeformed, flat beds. In the mine at Malagash local contortions of the salt strata are present, which die out both upwards and downwards. Such local contortions if present at Gautreau would appreciably increase the thickness of the salt group as inferred from the drill records. In view of the fact that the Mississippian strata which enclose the salt have undergone considerable folding, it is difficult to imagine conditions whereby the salt has not also suffered considerable compression, and since salt strata are much more sensitive to deforming pressures it is quite probable that they have been thickened along the axis of the syncline by flowage from the limbs of the fold.

The only definite information regarding the salt in Gautreau basin has been obtained from two drill records which indicate its thickness and character. The method of determining the area underlain by the salt must be based on the structure and distribution of the rocks lying directly above and below the salt. There are, however, so many unknown quantities with regard to the origin and subsequent history of these salt beds that for the present it seems profitless to attempt the making of an estimate of the extent of the salt basin. It may be pointed out, however, that a block of salt 500 feet thick underlying 1 square mile would contain approximately 1,000,000,000 tons of salt. The structure of the rocks associated with the salt suggests that it underlies several square miles on either side of Petitcodiac river, although the thicknesses as discovered in the drilled wells may not persist. The westerly dip of the structure would imply that on the west side of Petitcodiac river, the salt would lie at greater depths in the centre of the basin. The effect of this westerly dip may, however, be offset locally, near the mouth of Weldon brook, by what appears to be a subsidiary anticlinal fold. To the east of the river the structure tapers out rather rapidly, so that the salt strata probably do not extend more than 1½ miles in this direction.

There is little doubt that eventually other deposits of salt will be discovered in the Moncton-Sussex basin, particularly in the district between Sussex and Salt Springs, since brine springs are known to occur in this region. But owing to the lack of detailed information regarding the stratigraphy of this part of the basin it is at present impossible to make a definite statement.

It is abundantly clear that the salt resources of Nova Scotia and New Brunswick are very large. The proximity of the salt, on the one hand, to adequate supplies of coal as a source of energy for the initiation and development of a chemical industry, and on the other to a seaboard that will ensure low transportation costs to the markets of the world, greatly enhances their ultimate value. There is, also, a prospect that local concentrations of potash may eventually be discovered, which would be a very important national asset.

MINERAL DEPOSITS AT NEW ROSS, INDIAN PATH, MIDDLE RIVER, AND MEAT COVE, N.S.

By E. A. Goranson

CONTENTS

INTRODUCTION

Brief visits were paid to three mineral deposits and one prospect in Nova Scotia during the course of field work, in 1931, in the Sydney, Glace Bay, and Bras d'Or map sheets, Cape Breton. The mineral deposits examined were the manganese deposits at New Ross, the scheelite deposit at Indian Path, the Middle River gold veins, and a reported copper deposit at Meat cove. Both the New Ross and the Middle River deposits were producers some years ago. The scheelite deposit at Indian Path is now being actively developed and recent diamond drilling indicates several zones showing scheelite mineralization.

The writer here wishes to acknowledge the courtesies extended to him by Mr. E. S. Romilly Smith, of Halifax, and Mr. N. M. McRae of Nyanza and his associates, during the visits to their respective properties; and to Mr. J. P. Messervey, Deputy Inspector of Mines for the Province of Nova Scotia, for information and statistical data on the deposits.

MIDDLE RIVER AURIFEROUS VEINS, VICTORIA COUNTY

Auriferous quartz veins occur in Middle River or Wagamatkook gold district, which is situated in the southwestern part of Victoria county, Cape Breton island. The district is drained by four tributaries of Middle River: First, Second, Third, and Fourth Gold brooks, named in order from south to north; these tributaries flow in a general westerly direction and are separated from one another by distances varying from one-half to one mile. The main showings and underground workings are situated on Second Gold brook, and similar auriferous veins are reported to outcrop in Third Gold brook. Second Gold brook flows through a narrow, V-shaped valley with steep walls rising several hundreds of feet above the stream bed in the vicinity of the workings. At the workings, the brook flows almost due north. The workings are accessible by road; the trunk road from Baddeck to Margaree passes within 6 miles of them and a branch road leads to them.

Placer gold was found in the district in 1863 and in 1868 the sources of the placer gold, the auriferous quartz veins, were discovered in the Gold brooks. From then on, to 1906, both placer and lode mining were carried on intermittently on a very small scale. In 1906 the Great Bras d'Or Mining Company acquired control of some of the properties on Second Gold brook, installed a ten stamp mill and steam compressor there, and began to mine the Lizard vein, which had been opened by previous operators. Three levels were driven and a shaft was sunk to a depth of 140 feet on the vein. In the course of underground work the Lizard vein was found to be faulted off on the west side of the brook and a considerable amount of unsystematic exploration work was done in the attempt to pick up the vein again, but the efforts proved fruitless. Insufficient capital finally forced the company to stop operations in 1916 and the property, as a gold producer, has been idle ever since. In 1929, Messrs. N. M. McRae and P. H. Fraser of Nyanza, Cape Breton, secured the property; they rebuilt the road to the workings and up to the present have confined their activities to surface stripping on Second and Third Gold brooks.

Lode mining returns[1] are available from 1906 to 1916; during 1906 and 1907 the property was operated by W. C. Scranton.

Year	Tons of ore crushed	Gold recovered		
		Ozs.	Dwts.	Grs.
1906	8	3	17	12
1907	69	20	17	9
1908	2,800	590	9	19
1909	1,783	708	....	....
1910	336	38	5	....
1911	125	23	4	....
1914	775	262	17	13
1915	274	41	14	19
1916	....	5	10	....
Totals	6,170	1,694	16	0

No crushing was done in 1912 and 1913.

The auriferous quartz veins occur in metamorphosed, arenaceous and argillaceous sedimentary rocks which are probably Precambrian in age; some are highly chloritic, others sericitic, and some slightly garnetiferous. The rocks are schistose and the schistosity appears to coincide with the original bedding of the sediments, which strikes in general east and dips about 40 degrees north; minor undulations in the strata are responsible for local changes in the strike and dip. The sediments are intruded by bodies of granitic rock, in the form of dykes and sills, in the vicinity of the workings.

Three quartz veins are exposed in Second Gold brook and are known as the Little Micmac, Lizard, and Big Micmac. The veins are coincident in strike with the schistosity of the country rock and are composed

[1] Rept. Dept. of Mines, Nova Scotia, pt. II, 1928, pp. 229 and 231.

for the most part of milky white, somewhat fractured quartz with a minor amount of sulphide. Small residuals of the country rock are in some places present in the veins and preserve the orientation of the wall-rock. Small pods and lenses of quartz occur between and above and below the veins.

The Little Micmac vein is the most northerly of the three and is exposed for a short distance in the bed of the brook. A sample from the cropping taken by J. P. Messervey, Deputy Inspector of Mines for the Province of Nova Scotia, gave $2.60 a ton in gold.

The Lizard vein, which lies about 200 feet south of the Little Micmac, was worked by three levels and a shaft. The lowest level, the No. 1 or track level, is entered by a crosscut driven on the west side of the brook. The level extends about 210 feet to the east, and about 390 feet to the west, of the brook. About 45 feet west of the intersection of the drift and the crosscut the vein is faulted off and a considerable amount of exploratory tunnelling was done west of the fault before the search for the vein was abandoned. About 400 feet of the No. 1 level is along the Lizard vein. The No. 2 or intermediate level and the No. 3 or Scranton level were driven into the west side of the valley and each extends about 250 feet along the vein. Stopes extend above all three levels. A shaft was sunk to a depth of 140 feet near the creek bed and short drifts were driven at depths of 60 to 80 feet below the surface. The Lizard vein averages about 2 feet in width and is highly irregular along both its strike and dip; the vein in some places splits into a number of small, contorted veinlets and may pinch out entirely to begin again a short distance farther on. A minor amount of sulphide is present in the quartz and includes arsenopyrite, chalcopyrite, galena, pyrite, and dark sphalerite; a little carbonate is present. Gold is mainly in the free state and is usually very fine grained; small values in silver are present. Platinum and native bismuth nuggets are said to have been found in the alluvium near the veins. Close to the fault in the No. 1 level, a small stringer composed mainly of massive pyrrhotite is exposed. Microscopically, a small amount of chalcopyrite, sphalerite, magnetite, and pyrite are associated with the pyrrhotite and through the latter minute specks of pentlandite are distributed (a confirmatory test with dimethyl glyoxene gave a good nickel reaction). The Lizard vein in the No. 1 level was sampled by Messervey, and the values in gold are as follows:

No.	—	—
1	Sample of slash from east end of drift	Trace
2	Composite sample from east end and extending over 100 feet in length	$8 00
3	Composite sample from west end of drift	1 00
4	The bottom of the drift 20 feet east of tunnel	38 00
5	The bottom of the drift 150 feet east of tunnel	3 40
6	The bottom of the drift 20 feet west of tunnel	20 00
9	Surface cropping of Lizard vein	3 00

No analysis of the pyrrhotite ore is available.

The Big Micmac vein lies about 300 feet south of the Lizard and averages about 3 feet in width for the short distance it is exposed on the surface. Between the Big Micmac and Lizard veins is a red, rather fine-grained, granitic dyke or sill whose boundaries and relation to the sediments could not be determined on the surface. Underground, in an exploratory crosscut on the No. 1 level west of the fault, a sill similar in texture and in mineral composition is exposed, having a width of about 30 feet. Careful underground and surface mapping should show whether the two bodies are parts of a single faulted sill and if so the horizontal displacement of the vein could be determined and the lead could be picked up again on the west side of the fault with a minimum amount of exploratory work. A few feet to the north of the Big Micmac a number of small kidneys of quartz occur in the country rock. A sample taken by Messervey from the Big Micmac gave $10.80 in gold a ton.

Similar quartz veins are reported by the present owners on Third Gold brook with a similar space distribution to a granitic dyke or sill, and are believed by them to be continuations of the leads outcropping on Second Gold brook. This locality was not visited by the writer. The strike of the rocks is in general agreement with the courses of the Gold brooks (east and west), which indicates that the veins do not cross from one brook to another. However, very little is known of the rock structure of the area, so predictions are probably unwarranted. A number of samples were taken by the owners from the veins on Third Gold brook and were submitted to Messervey for assays and the results varied from nil to $1 in gold a ton. The assays obtained from parts of the Lizard vein and from the Big Micmac vein are very encouraging and warrant further detailed examination. The variation in the assays from the Lizard vein suggests that the high gold values may be localized in pockets or shoots. The production of the Big Bras d'Or Mining Company for the years 1908 and 1909 averages approximately 0·28 ounce of gold recovered a ton of ore crushed and may or may not be the general run of the ore depending on the percentage gold recovery; a private investigator assayed the tailings from the old stamp mill and reported values up to $2 in gold from them.

REFERENCES

How, H.: "The Mineralogy of Nova Scotia, a Report to the Provincial Government," Halifax, 1868.
Rept. Dept. of Mines, Nova Scotia, 1898. "Ore Bearing Schists."
Geol. Surv., Canada, Rept. of Prog. 1882-84, pt. H, p. 97.
"Gold Fields of Nova Scotia," Geol. Surv., Canada, Mem. 156, pp. 230-232 (1929).
Rept. Dept. of Mines, Nova Scotia, pt. 2, 1928, pp. 225-231.

COPPER PROSPECT AT MEAT COVE, CAPE BRETON

Copper mineralization was reported to have been found near Meat cove on the northwestern tip of Cape Breton island, and a brief visit was made to the prospect. The mineralization consists only of a small amount of pyrite associated with carbonate veins; no copper is present.

The prospect occurs in Inverness county on the shore of Fraser beach about one mile east of cape St. Lawrence. The showing is exposed in a sea cliff rising from 25 to 200 feet above sea-level and consists of a number of carbonate veins from one-sixteenth of an inch to one foot or more in width carrying a small amount of pyrite. The veins follow fractures and shears in bedded, gritty and slaty sedimentary rocks of Carboniferous age. Pyrite is present either in small stringers or lining vugs within the carbonate veinlets. The prospect has no apparent commercial value.

NEW ROSS MANGANESE DEPOSITS, LUNENBURG COUNTY

The New Ross manganese deposits are located about 8 miles north of the village of New Ross, in the northwest corner of Lunenburg county. They may be reached by road either from Windsor, about 20 miles to the northeast, or from Chester basin, about 26 miles to the south. At present only the Windsor road is passable by motor car. The elevation of the deposits is around 600 feet above sea-level.

Manganese was discovered at this locality some years ago and mining operations began about 1903. From then on until 1921, when operations stopped, several companies worked the deposits with varying degrees of success. Recently E. S. Romilly Smith of Halifax acquired control of the workings and a lease of a large tract of land in the immediate vicinity of the deposits, and expects to resume mining operations shortly.

The geology of New Ross area and of the manganese deposits has been thoroughly described by Wright[1] and Hayes[2]. Manganese mineralization occurs along steeply dipping fissures in a porphyritic biotite granite. These mineralized fissures are usually characterized on the surface by a small depression with an intermittent wall of granite on the north. The main vein is said to be highly lenticular both vertically and laterally, averaging about 2 feet in width, and consists essentially of manganese oxides and hydroxides. The chief manganese mineral is pyrolusite, but towards the west manganite becomes important; other accompanying minerals include psilomelane, braunite, hematite, and carbonate. The manganese ore is believed to have originated by the action of meteoric waters on an original manganiferous carbonate vein filling.

Lately, under the direction of E. S. Romilly Smith, a considerable amount of surface work has been done on the property. The road from Falmouth to the mine has been repaired so it is passable by car. A shallow shaft about 800 feet east of the former Nova Scotia Manganese Company's mill was unwatered and examined by a private investigator; this shaft was inaccessible at the time of the visit, as were the other underground workings. Near the site of the old mill a small jigging and tabling plant has been installed to rework the mill tailings. The plant is now producing approximately 15 tons of concentrates a day, which are reported[3] to analyse: 96 per cent MnO_2, 0·33 per cent SiO_2, 0·037 per cent Cu, 0·047 per cent S. 0·038 per cent P, and less than 0·75 per cent Fe. A number of prospect shafts are reported to have been recently cleaned out and samples taken for analysis.

1 Wright, W. J.: "Geology of the Neighbourhood of New Ross, Lunenburg County, Nova Scotia"; Geol. Surv., Canada, Sum. Rept. 1912, pp. 384-389.

2 Hayes, A. O.: "Investigations in Nova Scotia and New Brunswick"; Geol Surv., Canada, Sum. Rept. 1918, pt. F, pp. 23-28.

3 Personal communication from E. S. Romilly Smith.

INDIAN PATH SCHEELITE DEPOSIT, LUNENBURG COUNTY

The Indian Path scheelite deposit lies about 4 miles slightly east of south from the town of Lunenburg, in Lunenburg county, Nova Scotia. The distance by road from Lunenburg is about 6 miles.

The rocks in the vicinity of the deposit are slates and argillites of the Halifax formation, the upper division of the Gold-bearing series[1]; some of the sediments are highly pyritic. A thickness of several feet of superficial material obscures most of the bedrock at the deposits. The deposits occur near the crest of the Indian Path anticline, and the sediments in general strike northeastward and dip about vertical. The scheelite is associated with a number of quartz veins which range up to 2 feet or more in width and generally parallel the strike of the country rock. The individual veins do not appear to be continuous for any great distance along the strike. The vein quartz is greasy looking, milky in colour, and somewhat fractured; vugs in some places occur within the veins and are lined with small, milky white, terminated quartz crystals. The scheelite is honey yellow and usually occurs within the quartz in clots and irregular patches; at or near the surface the scheelite may be slightly stained by iron oxide. Pyrite and arsenopyrite may occur in or near the veins. Free gold has been reported from one locality, associated with scheelite. An average of eighteen analyses of scheelite from various localities in Dana's System[2] gives approximately 77·6 per cent tungsten trioxide or roughly 61·5 per cent metallic tungsten.

The underground workings consist of three shafts sunk to depths, respectively, of 30 feet, 35 feet, and 75 feet on the ore zone; short cross-cuts and drifts were driven from the 30-foot shaft. Two of the shafts are close together and the third is about 900 feet to the southwest. These workings were inaccessible at the time of the visit on account of water. A large number of trenches were dug across and along the strike of the country rock within a belt about 1,800 feet long and 300 feet wide and exposed a number of quartz veins showing varying amounts of scheelite. In addition, an intensive diamond-drilling campaign was carried on during 1931 and seven holes were put down within a distance of 1,300 feet along the strike. The holes varied from 60 to 230 feet in depth and are reported to show several zones of scheelite ore.

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[1] *See* Bridgewater sheet No. 89, Lunenburg county, Nova Scotia, Geol. Surv., Canada, 1929.
[2] Dana, E. S.: "The System of Mineralogy," John Wiley and Sons, sixth edition, 1914, p. 987.

BORINGS IN ONTARIO, QUEBEC, AND THE MARITIME PROVINCES

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Collection of samples and records from wells drilled for oil, gas, and water was continued in 1931. Acknowledgments are made to Col. R. B. Harkness, Gas Commissioner of Ontario, for forwarding logs of wells drilled for oil and gas in Ontario in 1930. These records furnish information regarding the character of the ground water in the areas drilled for oil and gas. As a rule in these areas fresh water is found in the surface deposits near their contact with the bedrock and saline water is found in the bedrock.

By the courtesy of Mr. John Ness of the Imperial Oil Company and of Mr. W. A. Roliff, engineer in charge, samples were received from the Amherst well, Nova Scotia, put down by that company. This well showed a considerable thickness of salt. Samples from the well were examined by F. J. Fraser and the results are given in this report. The samples were also examined by G. W. H. Norman, whose assistance in a study of the samples is acknowledged.

Drilling for natural gas in the province of Quebec was carried on by several companies in Richelieu and Nicolet Rivers areas on the south side of the St. Lawrence and at a few places on the north shore. A number of well samples were received, chiefly through the courtesy of John DeMille and R. B. Anderson. Through an arrangement with the Quebec Bureau of Mines sample bags are being supplied by this division to the well drilling companies, and reports on samples are sent to the companies and to the Bureau of Mines.

Drilling to depths of several hundred feet, for water, was carried on at a number of places in Ontario and there was considerable demand for information as to the possibilities of obtaining usable water at depth, owing to the fact that many shallow wells went dry during the summer. In many cases information was available from records of wells collected by this division over a long period of years, but information regarding the results of drilling in many areas is not available. Co-operation of drillers, therefore, in securing records of wells and samples of the strata passed through is sought. As an illustration of the value of records it may be stated that deep wells at most of the towns along the north shore of lake Ontario between Belleville and Toronto have found saline water at depth in the bedrock, though there is an abundance of fresh water in the surface deposits of the hills to the north of these towns. As the area is underlain by limestones and shales, with some basal sandstone resting on the Precambrian and having a uniform slight dip to the southwest towards a closed basin, it is reasonable to suppose that conditions are uniform throughout the area and if saline water is found in a number of wells it is likely to occur throughout the area, or at least that potable fresh water is not likely to be found except possibly in the upper part of the bedrock near the contact with the surface deposits. At least one deep well was put down in this area during the year, but only salt water was found.

Ontario: Water Wells

RECORDS RECEIVED, 1931

Owner	Lot	Con-cession	Township	County	Province	At or near	Depth in feet covered by records	Depth in feet to bedrock	Depth from surface to water	Driller	Remarks
									Feet		
Hicks, A. E.	7	17	Fitzroy	Carleton	Ontario	Kinburn	118	56	—	A. Arbuckle	
Whitehead, L.	—	—	Artemesia	Grey	"	Markdale	154	56	75	W. R. McMaster	Water hard
Goderich Salt Co.	—	—	Goderich	Huron	"	Goderich	328	128	128	F. L. Davidson	"
McBurney, Sam	—	10	Wawanosh	"	"	Wingham	204	175	70	" "	"
McEwen, J.	11	10	Drummond	Lanark	"	Lanark	78	30	26	A. Arbuckle	
Stewart, A.	7	11	Ramsay	"	"	Almonte	60	—	—	"	
Mather, John	22	9	Bathurst	"	"	Balderson	90	23	30	"	
Watson, A.	—	3	Drummond	"	"	Perth	70	—	20	"	
McCullough, W. E.	18	7	"	"	"	"	52	6	20	"	Water in sand-stone
Campbell, L.	4	6	"	"	"	"	46	19	19	"	" "
Land O'Lanark Creameries	—	—	"	"	"	"	120	10	10	T. Scott	Temperature 48° F.
Layne Can. Water Supply	—	—	Ramsay	"	"	Almonte	110	8	33	Layne Can. Water Supply Co.	200-275 G.P.M.
" "	—	—	"	"	"	"	110	2	—	" "	70-80 G.P.M.
Hunter, P.	8	2	S. Elmsley	Leeds	"	Smiths Falls	46	9	8	A. Arbuckle	Water in sand-stone
Sheridan, T.	13	1	"	"	"	"	61	35	25	"	
Can. General Electric Co.	—	—	Monaghan	Peterborough	"	Peterborough	162	53	2¾	F. Hinds	
" "	—	—	"	"	"	"	53	—	—	"	
Bradford Corp.	—	—	Bradford	Seneca	"	Bradford	132	—	—	Layne Can. Water Supply Co.	Water hard
Agnew, C.	—	Guelph line	—	Wellington	"	Campbellville	80	26	20	J. A. Pegg	
Ancaster tp.	—	—	Ancaster	Wentworth	"	Ancaster	71	61	39	Jordan-Roberts Sales, Ltd.	Temperature 42° F.

Quebec: Water Wells

RECORDS RECEIVED, 1931

Owner	Lot	Con-cession	Township	County	Province	At or near	Depth in feet covered by records	Depth in feet to bedrock	Depth from surface to water	Driller	Remarks
Campbell, John	—	—	Chatham	Argenteuil	Quebec	Brownsburg	107	All rock	—	A. Arbuckle	Small supply
Chartrand, M.	754	—	"	"	"	"	104	23	35	"	
Guaranteed Pure Milk No. 1	—	—	—	Hochelaga	"	Montreal	1,386	48	26	Wallace Bell and Co.	Main supply at 815 feet
Guaranteed Pure Milk No. 2	—	—	—	"	"	"	840	51	30	" "	Main supply at 740 feet

Ontario: Wells Drilled for Oil and Gas

RECORDS RECEIVED, 1931

Lot	Concession	Township	County	Year drilled	Depth in feet covered by records	Yield	Depth in feet to bedrock	Depth from surface to water Feet	Drilling company, well name, etc.
30	2	Onondaga........	Brant........	1930	564	Gas....	90	91, 110	Dominion Natural Gas Co., Ltd.
54	River range ..	"	"	1930	540	"	49	49, 330	Petrol Oil and Gas Co., Ltd.
53	" " ..	"	"	1930	550	"	50	50, 331	" " "
53	" " ..	"	"	1930	543	"	47	—	" " "
49	" " ..	"	"	1930	543	"	40	—	" " "
48	" " ..	Tuscarora........	"	1929	615	"	74	—	" " "
48	" " ..	"	"	1929	675	"	139	—	" " "
48	" " ..	"	"	1930	640	"	119	—	" " "
46	" " ..	"	"	1929	623	"	72	—	" " "
48	" " ..	"	"	1929	662	"	88	—	" " "
45	" " ..	"	"	1930	616	"	64	64	" " "
40	" " ..	"	"	1930	573	"	69	—	" " "
48	" " ..	"	"	1930	573	"	90	—	" " "
38	" " ..	"	"	1930	559	"	63	—	" " "
48	" " ..	"	"	1930	535	"	64	—	" " "
37	" " ..	"	"	1930	610	Dry....	101	—	" " "
24	5	"	"	1930	639	Gas....	86	—	" " "
24	5	"	"	1930	560	"	75	—	" " "
(4 and 5)	7	Williamsburgh....	Dundas......	1930	130	"	130	—	Mrs. Sarah Armstrong
6	7	"	"	1930	120	"	100	—	Walter Carr
5	1	Malahide.........	Elgin.........	1930	306	Dry....	175	—	Western Peninsula Oil and Gas Co.
5	1	"	"	1930	305	"	197	—	" " " "
5	1	"	"	1930	300	"	146	145	" " " "
29	1	Anderdon	Essex.........	1930	1,388	"	48	1,360	Canadian Steel Corporation, Ltd.
7	1	"	"	1930	2,566	"	11	Salt water at 1,291, 1,325, 1,350, 2,445, 2,530, and 2,566	" " "
32	1	Gosfield..........	"	1930	2,603	"	90	—	Olga Gas and Oil Company, Ltd.
10	1	Sandwich West...	"	1930	760	"	58	—	Canadian Steel Corporation, Ltd.
	City of Sandwich	"	"	1930	1,600	"	90	—	Canadian Salt Company, Ltd.
8	1	Canborough.......	Haldimand...	1930	575	Gas....	73	75, 275	Dominion Natural Gas Co., Ltd.
4	1	Dunn............	" ..	1929	861	Dry....	35	—	W. C. Patterson
4	1	"	" ..	1929	850	"	35	—	"
3 and 4	2 and 3	"	" ..	1929	738	"	51	—	"
3	1	"	" ..	1929	859	"	34	—	"
6	1	"	" ..	1930	781	Gas....	86	—	"
8	Second range from Grand river	Moulton..........	" ..	1930	782	"	98	100, 160, 400	Dom. Natural Gas Co., Ltd.
10	1	North Cayuga....	" ..	1930	642	Dry....	48	—	" " "
37	1 N.T.R......	"	" ..	1930	767	Gas....	5	125, 425	" " "
10	1	"	" ..	1930	637	Dry....	58	—	" " "
40	1 N.T.R......	"	" ..	1930	783	Gas....	21	440	" " "

40	1 N.T.R.	"	"	1930	747	"	23	60, 400		" " "
41	1 N.T.R.	"	"	1930	766	"	18	68, 90, 425		" " "
11	1 S.T.R.	"	"	1930	690	"	58	80, 311		" " "
41	1 N.T.R.	"	"	1930	742	"	15	30, 425		" " "
38	1 N.T.R.	"	"	1930	759	Dry	23	80, 450		" " "
11	1 S.T.R.	"	"	1930	704	Gas	50	66, 308		" " "
36	1 N.T.R.	"	"	1930	752	Dry	12	95, 180, 425		" " "
12	1 S.T.R.	"	"	1930	722	Gas	51	60, 295		" " "
40	1 N.T.R.	"	"	1930	724	"	60	40, 410		" " "
40	1	"	"	1930	706	"	42	55, 400		" " "
42	1	"	"	1930	751	Dry	80	42, 422		" " "
11	1 S.T.R.	"	"	1930	697	Gas	62	65, 260		" " "
42	1	"	"	1930	726	"	49	55, 400		" " "
10	1	"	"	1930	688	"	54	57		" " "
8	1 S.T.R.	"	"	1930	681	Dry	43	48, 260		" " "
3	Jones tract	"	"	1930	813	"	15	104, 400		" " "
28	1 S.T.R.	"	"	1930	720	"	56	60, 335		" " "
24	1	"	"	1930	708	Gas	41	80, 350		" " "
24	1	"	"	1929	736	"	41		—	W. C. Patterson
25	1	"	"	1929	743	"	40		—	"
25	1	"	"	1929	719	"	47		—	"
13	1	"	"	1929	777	"	53		—	"
15	1	"	"	1929	801	"	60		—	"
19	1	"	"	1929	785	"	45		—	"
18	1	"	"	1929	795	"	54		—	"
18	1	"	"	1929	716	"	66		—	"
20	1	"	"	1929	705	Dry	73		—	"
13	1	"	"	1929	671	"	46		—	"
16	1	"	"	1929	690	"	63		—	"
12	1	"	"	1929	668	"	40		—	"
19	1	"	"	1929	774	Gas	50		—	"
28	Jones tract	"	"	1930	869	Dry	26	Sulphur 65	....	Union Natural Gas Co. of Canada, Lt d.
42	1	Oneida	"	1930	740	Gas	61	65, 410		Dom. Natural Gas Co., Ltd.
42	1	"	"	1930	715	Dry	42	90, 400		" " "
37	Broken Front.	"	"	1930	594	Gas	41	43		" " "
36	Andross Estate and River range	"	"	1930	611	Dry	49	295		" " "
47	1	"	"	1930	795	"	—	150		" " "
26	3	"	"	1930	750	"	30		—	" " "
2	2	Rainham	"	1929	940	"	19	45		Rainham Gas and Oil Syndicate
5	3	"	"	1929	905	"	23	60		" " "
4	2	"	"	1929	928	Gas	32	80		" " "
12	4	"	"	1930	899	Dry	10	54, 525		Dom. Natural Gas Co., Ltd.
11	3	"	"	1930	903	"	27	30, 115, 472		" " "
12	4	"	"	1930	897	Gas	10	25, 525		" " "
10	3	"	"	1930	902	"	28	556		" " "
12	3	"	"	1930	900	"	19	35, 555		" " "
8	3	"	"	1930	903	"	37	42, 473		" " "
11	3	"	"	1930	905	"	21	25, 552		" " "
13	2	"	"	1930	891	"	14	21, 98, 500		" " "
7	2	"	"	1930	933	"	17	98, 520		" " "
8	2	"	"	1930	929	"	10	96, 510		" " "
13	2	"	"	1930	938	"	13	19, 500		" " "
9 and 10	2	"	"	1930	917	Dry	24	140, 535		" " "
14	2	"	"	1930	902	Gas	16	30, 480		" " "

Ontario: Wells Drilled for Oil and Gas—Continued

RECORDS RECEIVED, 1931

Lot	Concession	Township	County	Year drilled	Depth in feet covered by records	Yield	Depth in feet to bedrock	Depth from surface to water Feet	Drilling company, well name, etc.
8	2	Rainham	Haldimand	1930	924	Gas	10	510	Dom. Natural Gas Co., Ltd.
5	2	"	"	1930	938	Dry	22	—	" " "
9	2	"	"	1930	917	Gas	13	460	" " "
13	2	"	"	1930	945	"	15	500	" " "
2	1 E. of Plank road	Seneca	"	1930	543	Gas	97	85, 100, 125	" " "
1	1 Third range	"	"	1930	502	Dry	100	80, 115	" " "
14	1 W. Stoney Creek road	"	"	1930	528	"	80	70, 138	" " "
14	1 W. Stoney Creek road	"	"	1930	585	Gas	82	76, 140	" " "
12	5 E. Stoney Creek road	"	"	1930	523	"	42	42, 45	" " "
11	5	"	"	1930	461	Dry	40	40, 50	" " "
8	2 W. Stoney Creek road	"	"	1930	515	"	73	76, 140	" " "
10	3	"	"	1930	611	"	80	76, 95	" " "
13	1	"	"	1930	589	Gas	84	190	" " "
15	1	"	"	1930	650	Dry	44	43, 60	" " "
8	1	"	"	1930	625	Gas	48	48, 55	" " "
13	2 W. Stoney Creek road	"	"	1930	559	"	77	81, 135	" " "
13	1 W. Stoney Creek road	"	"	1930	596	"	85	90, 130	" " "
6	2	"	"	1930	610	"	41	40, 90	" " "
	Nelles tract, W. Stoney Creek road	"	"	1930	620	"	64	82, 165	" " "
7	1	"	"	1930	590	"	54	53, 58	" " "
3 and 11	Portion of Nelles tract south of and fronting Stoney Creek road	"	"	1930	598	Dry	89	—	" " "
9	1	"	"	1930	640	"	32	—	" " "
9	2	Sherbrooke	"	1930	872	"	71	71, 80	" " "
6	1	"	"	1930	934	Gas	39	38, 80, 670	" " "
8	3	"	"	1930	850	Dry	167	165, 175	" " "
6	1	"	"	1930	939	Gas	44	43	" " "
1	1	Walpole	"	1930	1,039	"	22	570	" " "
21	3	"	"	1930	1,006	"	26	560	" " "
19	8	"	"	1930	889	Dry	25	—	" " "

20	3	"	"	1930	952	Gas	30	525	" " "
19	9	"	"	1930	880	Dry	3	50, 480	" " "
21	2	"	"	1930	983	Gas	11	65, 540	" " "
2	1	"	"	1930	1,047	"	25	40, 60, 560	" " "
22	1	"	"	1930	964	"	8	60, 530	" " "
23	3	"	"	1930	965	"	22	65, 518	" " "
2	1	"	"	1930	1,044	"	28	69, 100, 580	" " "
22	8	"	"	1930	957	"	18	50, 490	" " "
23	3	"	"	1930	966	"	13	65, 510	" " "
17	3	"	"	1930	1,040	"	18	52, 528	" " "
3	2	"	"	1930	1,025	"	22	62, 110, 580	" " "
22	7	"	"	1930	908	Dry	15	80, 500	" " "
23	3	"	"	1930	949	Gas	23	60, 510	" " "
5	12	"	"	1930	871	Dry	17	Fresh 40	Union Natural Gas Co. of Canada, Ltd.
24	3	"	"	1930	961	Gas	8	Fresh 78	Rainham Gas and Oil Co.
4	2	"	"	1930	1,015	Dry	22	—	Dom. Natural Gas Co., Ltd.
9	4	"	"	1930	972	"	43	83, 542	" " "
8	2	"	"	1930	1,071	Gas	26	102, 585	" " "
10	4	"	"	1930	975	"	28	73, 568	" " "
13	3	"	"	1930	1,004	Dry	22	55, 78, 560	" " "
3	1	"	"	1930	1,043	"	26	90, 550	" " "
23	8	"	"	1930	906	"	25	50, 510	" " "
3	1	"	"	1930	1,099	Gas	24	93, 600	" " "
16	3	"	"	1930	1,037	"	19	86, 530	" " "
15	1	"	"	1930	999	Dry	47	65, 565	" " "
22	2	"	"	1930	990	"	14	48, 542	" " "
3	2	"	"	1930	1,028	"	31	50, 115, 548	" " "
17	3	"	"	1930	985	Gas	18	43, 540	" " "
22	8	"	"	1930	908	Dry	11	60, 486	" " "
2	3	Dover East	Kent	1930	3,200	Gas	60	Salt 60	Olga Gas and Oil Company, Ltd.
3	3	" "	"	1929	3,365	Dry	390	710, 1,660, Salt 1,815	" " "
5	3	" West	"	1929	3,315	"	240	—	" " "
2	4	" East	"	1930	3,195	Gas	73	1,840	Acme Oil and Gas Co., Ltd.
2	4	"	"	1930	3,180	Dry	74	445, 1,780	" " "
2	Moravian Indian reserve	Orford	"	1930	362	"	45	—	Basic Resources, Ltd.
3	" "	"	"	1930	426	"	118	—	" "
3	" "	"	"	1930	303	Oil	55	—	" "
4	" "	"	"	1930	403	Dry	31	—	" "
12	River range	Zone	"	1930	3,998	"	148	250, 560, 1,910	Olga Gas and Oil Co., Ltd.
19	1	Dawn	Lambton	1930	1,718	Gas	66	66, 505, 530	Union Natural Gas Co., Ltd.
23	10	"	"	1930	2,201	Dry	40	425, 1,772	" " "
18	1	"	"	1930	2,031	Gas	60	60, 545, 1,815	" " "
20	1	"	"	1930	2,047	Dry	62	62, 545	" " "
19	1	"	"	1930	1,712	Gas	67	67, 605, 650	" " "
23	11	"	"	1930	1,822	Dry	45	380, 1,745	" " "
18	1	"	"	1930	2,046	Gas	53	573	" " "
19	1	"	"	1930	2,025	"	68	68, 520, 1,745	" " "
68	Front con.	Moore	"	1930	803	Dry	133	128, 735	Millar, Hess Syndicate
19	10	Plympton	"	1930	567	"	81	—	British Petroleum Co., Ltd.
25	9	"	"	1930	569	"	113	63, 113, 569	" " "
30	9	Sombra	"	1930	2,105	"	65	610, 645, 760, 1,815	Union Natural Gas Co., Ltd.
23	2	Caistor	Lincoln	1930	461	"	72	118	Dom. Natural Gas Co., Ltd.
9	1	"	"	1930	521	Gas	58	150, 290	" " "
1 and 2	1	"	"	1930	590	"	89	—	Grimsby Natural Gas Co., Ltd.
9	1	"	"	1930	526	"	79	68, 250	Dom. Natural Gas Co., Ltd.

Ontario: Wells Drilled for Oil and Gas—Concluded

RECORDS RECEIVED, 1931

Lot	Concession	Township	County	Year drilled	Depth in feet covered by records	Yield	Depth in feet to bedrock	Depth from surface to water Feet	Drilling company, well name, etc.
1 and 2	1	Caistor	Lincoln	1930	555	Dry	78	—	Grimsby Natural Gas Co., Ltd.
1	4	"	"	1930	548	Gas	54	—	" " "
6	1	"	"	1930	549	"	67	—	" " "
4	2	"	"	1930	548	"	78	—	" " "
8	2	"	"	1930	542	"	59	—	" " "
5	1	"	"	1930	545	"	70	—	" " "
1 and 2	1	"	"	1930	604	"	73	—	" " "
6	2	"	"	1930	541	"	58	—	" " "
6	1	"	"	1930	551½	"	67½	—	" " "
4	3	"	"	1930	537	"	76	—	" " "
6	1	"	"	1930	538¾	"	72¾	—	" " "
4	3	"	"	1930	535	"	66	—	" " "
6	2 and 3	"	"	1929	539	"	63	—	" " "
7	3	"	"	1929	548	"	53	—	" " "
8	2	"	"	1929	502	Dry	50	—	" " "
5	3	"	"	1929	543	Gas	56	—	" " "
8	3	"	"	1929	523	"	57	—	" " "
6	1	"	"	1930	552	"	67	—	" " "
5	2	"	"	1930	534	"	70	—	" " "
6	3	"	"	1930	493	"	57	—	" " "
5	3	"	"	1930	539	"	56	—	" " "
131	Talbot road	Raleigh	Kent	1930	1,913	Dry	160	—	Southern Ontario Gas Co., Ltd.
147	S. "	"	"	1930	1,560	Gas	195	195, 615, 695	American Engineering Co., Ltd.
144	Talbot road	"	"	1930	1,669	Dry	182	200, 310, 1,600, 1,630	Union Natural Gas Co., Ltd.
16	15	"	"	1930	1,441	Gas	185	185, 425, 790	" " "
144	Talbot road	"	"	1930	1,595	Dry	181	320, 730, 815, 1,595	" " "
144	"	"	"	1930	1,745	Gas	195	305, 1,740-1,745	" " "
146	"	"	"	1930	1,565	"	195	305, 720	" " "
15	14	"	"	1930	2,065	Dry	175	425, 1,740, 1,775, 1,790	" " "
145	Talbot road	"	"	1930	1,558	Gas	198	198, 410, 675, 1,573	" " "
16	14	"	"	1930	1,875	Oil	177	295, 305, 420, 490, 720, 770, 1,630, 1,795, 1,810, 1,825	" " "
14	15	"	"	1930	1,755	Dry	180	650, 1,730, 1,755	" " "
15	15	"	"	1930	1,786	"	190	306, 425, 820, 1,640, 1,760, 1,786	" " "
147	Talbot road	"	"	1930	1,574	Gas	190	314, 675, 690	" " "
147	"	"	"	1930	1,580	"	223	570, 770	" " "
142	"	"	"	1930	1,560	"	180	180, 425, 525	" " "
146	"	"	"	1930	1,570	"	207	290, 700, 760	" " "
187	"	Romney	"	1930	1,379	"	167	240, 690	" " "
SE. part Gore "A"	2	"	"	1929	1,310	"	148	150, 695, 760	Smith's Oil and Gas Syndicate

178	Talbot road	"	"	1930	1,349	Dry	170	180, 580, 675, 1,310, 1,330, 1,349	Southern Ontario Gas Co., Ltd.
SE. part Gore "A"	2	"	"	1930	1,311	Gas	150	158, 260, 624, 685, 1,311	Smith's Oil and Gas Syndicate
185	Talbot road	"	"	1930	1,295	"	152	310, 500, 1,295	Southern Ontario Gas Co., Ltd.
177	"	Tilbury East	"	1930	1,366	"	179	560, 715	" " "
173	"	"	"	1930	1,332	"	187	675	" " "
6 and 7	River range	Zone	"	1930	296	Oil	160	—	Acme Gas and Oil Co., Ltd.
6-A	South of Long-woods road	"	"	1930	345	"	30	—	" " "
44	2	Assiginack	Manitoulin	1930	450	—	10	—	Manitowaning Oil Co.
4	14	"	"	1930	210	—		—	" "
16	12	Metcalfe	Middlesex	1929	500	Dry	88	—	A. Trevlean
15	3	Mosa	"	1930	1,986	"	74	75, 425, 512	Southern Ontario Gas Co., Ltd.
15	3	"	"	1930	1,995	"	80	430, 1,620	" " "
14	3	"	"	1930	1,967	"	130	435, 1,624, 1,655, 1,860	" " "
15	3	"	"	1930	1,984	Gas	80	429, 650, 1,630	" " "
14	3	"	"	1930	2,006	Dry	122	435, 451, 1,660, 1,810	" " "
5	S. Talbot st.	Middleton	Norfolk	1930	1,434	"	190	245, 425, 1,030, Salt 1,315	Tillsonburg Oil and Gas Co.
16	10	Bertie	Welland	1930	738	Gas	29	32	Welland County Gas Syndicate
16	11	"	"	1930	750	"	28	47	" " "
16	11	"	"	1930	732	"	26	38	" " "
16	12	"	"	1930	733	"	38	61	" " "
14	13	"	"	1930	693	"	55	58	" " "
13	13	"	"	1930	755	"	47	69	" " "
13	11	"	"	1930	737	"	25	33	" " "
16	4	Crowland	"	1929	621	Dry	123	—	W. C. Patterson
15	5	"	"	1929	626	"	117	—	" "
9	7	"	"	1930	715	Gas	127	—	Industrial Natural Gas Co., Ltd.
64	1	Whitchurch	York	1930	1,292	Dry	570	80, 112, 1,145	John H. C. Durham

Log of Amherst No. 1 Well, Amherst, Cumberland County, Nova Scotia

Lithology	Depth (in feet)	Lithology—*Con.*	Depth (in feet)
Gypsum	90 to 270	Anhydrite	1,480 to 1,490
Dolomite	270 " 280	Sandstone	1,490 " 1,510
Anhydrite	280 " 300	Anhydrite	1,510 " 1,520
Dolomite	300 " 310	Sandstone	1,520 " 1,530
Anhydrite	310 " 320	Anhydrite	1,530 " 1,560
Gypsum	320 " 400	Salt	1,560 " 1,570
Conglomerate	400 " 430	Anhydrite	1,570 " 1,590
Gypsum	430 " 440	Sandstone	1,590 " 1,600
Sandstone	440 " 460	Salt	1,600 " 1,610
Conglomerate	460 " 470	Limestone	1,610 " 1,620
Sandstone	470 " 500	Dolomite	1,620 " 1,630
Shale	500 " 510	Anhydrite	1,630 " 1,730
Conglomerate	510 " 520	Salt	1,730 " 1,820
Sandstone	520 " 530	Anhydrite	1,820 " 1,950
Conglomerate	530 " 540	Salt	1,950 " 1,980
Sandstone	540 " 550	Limestone	1,980 " 2,000
Anhydrite	550 " 580	Anhydrite	2,000 " 2,110
Gypsum	580 " 600	Dolomite	2,110 " 2,120
Dolomite	600 " 610	Anhydrite	2,120 " 2,140
Gypsum	610 " 640	Dolomite	2,140 " 2,160
Conglomerate	640 " 660	Shale	2,160 " 2,180
Anhydrite	660 " 750	Salt	2,180 " 2,350
Sandstone	750 " 760	Anhydrite	2,350 " 2,410
Anhydrite	760 " 890	Salt	2,410 " 2,490
Sandstone	890 " 920	Anhydrite	2,490 " 2,530
Salt	920 " 940	Dolomite	2,530 " 2,550
Sandstone	940 " 970	Salt	2,550 " 2,850
Salt	970 " 1,030	Shale	2,850 " 2,860
Anhydrite	1,030 " 1,040	Limestone	2,860 " 2,880
Salt	1,040 " 1,080	Anhydrite	2,880 " 2,950
Anhydrite	1,080 " 1,230	Shale	2,950 " 2,960
Dolomite	1,230 " 1,240	Anhydrite	2,960 " 2,990
Salt	1,240 " 1,260	Salt	2,990 " 3,490
Anhydrite	1,260 " 1,420	Anhydrite	3,490 " 3,910
Salt	1,420 " 1,430	Dolomite	3,910 " 3,920
Sandstone	1,430 " 1,460	Anhydrite	3,920 " 3,970
Salt	1,460 " 1,470	Salt	3,970 " 4,050
Sandstone	1,470 " 1,480	Anhydrite	4,050 " 4,132

Notes on the Samples. Many of the samples from the upper part of the well are mixtures, and are reported on with reference to the dominant content only. When the salt content was not easily determined by inspection, the approximate amount of material insoluble in hot water was determined. Samples in which over 50 per cent is soluble in hot water are recorded as salt. Samples that are mixtures of gypsum, anhydrite, and sand are recorded in the name of the dominant constituent, the relative proportions having been determined by floating the materials in bromoform mixtures of specific gravity 2·58 and 2·8.

The samples fall into two main groups, an upper brownish series to 1,600 feet, and a lower, lighter-coloured series consisting mainly of salt and anhydrite. The upper brownish series may be divided into six divisions as follows:

—	Colour	Depth in feet
Gypsum	Cream	90 to 250
Anhydrite and dolomite	Grey	250 " 320
Gypsum	Light	320 " 400
Mainly anhydrite, conglomerate, and sandstone	Brownish	400 " 770
Mainly anhydrite with some salt and a little sandstone	Light	770 " 1,430
Mainly anhydrite, sandstone, and salt	Brownish	1,430 " 1,600

The lower, lighter-coloured series are broken at the following depths by grey beds of dolomite, limestone, or shale:

Lithology	Depth (in feet)	Lithology—*Con.*	Depth (in feet)
Limestone	1,980 to 2,000	Green-grey shale	2,850 to 2,860
Dolomite and anhydrite	2,110 " 2,160	Grey limestone	2,860 " 2,880
Greenish shale	2,160 " 2,170	A little dolomite in anhydrite.	2,880 " 2,910
Grey shale	2,170 " 2,180	Green-grey shale	2,950 " 2,960
A little dolomite in anhydrite.	2,350 " 2,380	Dolomite	3,910 " 3,920
Dolomite	2,530 " 2,550	A little dolomite	4,090 " 4,110

To 1,630 feet the beds are anhydrite, gypsum, dolomite, shale, sandstone, and salt. Below 1,630 feet the beds are massive anhydrite and salt with occasional dolomite and shaly bands.

The first sample is in gypsum at 90 feet, and this continues to 270 feet; below this the gypsum beds are thinner, the last being at 640 feet. The dolomite is always in thin seams and never pure. Three beds are recorded as limestone; the distinction between limestone and dolomite is ill-defined in these samples; carbonates are persistent in all samples except in the thicker salt beds.

Anhydrite is the most persistent constituent in the samples. Judging from the examination of many of the insoluble residues, both after hot water and acid, most of the anhydrite occurs as a well-compacted deposit of small, well-formed, stumpy, prismatic crystals.

Pebbles occur irregularly in the samples down to 1,280 feet. The sandstone beds are intimately associated with anhydrite; the sand grains are angular and splintery, and some show traces of secondary, fine- to medium-grained silicification.

There are four definite beds of shale, none more than 20 feet thick. Their texture and colour compared with the associated rocks are distinctive. The first bed at 500 to 510 feet is brown; the second at 2,160 to 2,180 feet is green in the upper part, grey in the lower part; the third and fourth at 2,850 to 2,860, and 2,950 to 2,960, feet, respectively, are green-grey.

The thicknesses of the salt beds, like those of the anhydrite, increase with depth. The greatest thickness of salt is between 2,990 and 3,490 feet. The first definite salt bed is at 920 to 940 feet, between two sandstone beds. The samples of salt from the thicker beds below 1,700 feet are a good colour and leave little insoluble residue in water. The residues from such samples are anhydrite with occasional secondary quartz. Tests for magnesium were carried out on samples from the following depths (feet): 930, 1,000, 1,080, 1,200, 1,250, 1,430, 1,570, 1,610, 1,770, 2,300, 2,450, 2,600, 2,800, 3,100, 3,200, 3,300, 3,400, and 4,000. The results were negative.

Flame tests show that all the salt samples contain traces of potassium, and careful chemical tests for small amounts of potassium were, accordingly, made on a number of the samples by the introduction of 2 c.c. of 60 per cent perchloric acid solution into 3 c.c. of a nearly saturated solution of salt sample, a method suggested by H. V. Ellsworth. A standard solution of potassium chloride (0·4 per cent) was used for control at a definite temperature. All tests gave negative results, and the samples tested do not, therefore, contain any appreciable amount of potash, certainly nothing approaching 1 per cent. These tests were carried out on samples from the following depths (feet): 930, 940, 980, 990, 1,000, 1,010, 1,020, 1,030, 1,050, 1,060, 1,070, 1,080, 1,250, 1,430, 1,470, 1,570, 1,610, 1,740, 1,750, 1,770, 1,780, 1,790, 1,800, 1,810, 1,820, 2,240, 2,450, 2,630, 2,740, 2,820, and 3,020.

OTHER FIELD WORK

Geological

T. L. TANTON. Mr. Tanton commenced a systematic investigation of iron ore deposits in Canada east of British Columbia and Yukon. He examined a number of occurrences in Ontario. Further field work is required before a report can be written. This report will form the second part of an Economic Geology Series report on "The Iron Ores of Canada," of which Part I, dealing with British Columbia and Yukon, is published.

A. F. MATHESON. Mr. Matheson concluded the geological mapping and investigation of Michipicoten 1-mile quadrangle (latitudes 47° 45′ to 48° 00′, longitudes 84° 30′ to 85° 00′), Ontario. A geological map and report are being prepared.

T. T. QUIRKE. Mr. Quirke concluded the geological investigation of the region about the northeast angle of Georgian bay, Ontario. A report dealing with problems of granitization and correlation of the sedimentary gneisses and with the mineral possibilities of the region is being prepared.

B. C. FREEMAN. Mr. Freeman, under the supervision of T. T. Quirke, geologically studied and re-mapped a part of Copper Cliff 1-mile quadrangle (latitudes 47° 45′ to 48° 00′, longitudes 81° 00′ to 81° 30′), Ontario. The results will be incorporated in the Copper Cliff sheet, undermentioned.

W. H. COLLINS. Mr. Collins and Mr. C. D. Kindle continued geological mapping and study of Sudbury nickel basin and vicinity. Further field work is required before a report can be written. A series of four 1-mile sheets are, however, in various stages of preparation for publication. The Espanola sheet (latitudes 46° 15′ to 46° 30′, longitudes 81° 30′ to 82° 00′), and the Copper Cliff sheet adjoining on the east are complete; field work on the Chelmsford sheet, north of the Copper Cliff, and on the Wanapitei sheet, east of the Chelmsford, is not yet complete.

A. E. WILSON. Miss Wilson spent a part of the season mapping the Ottawa 1-mile quadrangle (latitudes 45° 15′ to 45° 30′, longitudes 75° 30′ to 76°), Ontario and Quebec. Further field work is required.

H. V. ELLSWORTH. Mr. Ellsworth commenced a study of vanadium occurrences in Canada. In company with H. C. Cooke he visited four reported occurrences in southern Quebec. It is proposed to publish an Economic Geology Series report on the subject when enough information has been obtained.

M. E. WILSON. Mr. Wilson commenced a detailed investigation of a limited area that includes the principal mines around Noranda, Quebec.

Further field work is contemplated; the results of 1931 are being communicated, in advance of a final report and map, to the companies concerned.

O. L. Backman. Mr. Backman, under the supervision of A. H. Lang, commenced the geological study and mapping of Makamik 1-mile quadrangle (latitudes 48° 45′ to 49° 00′, longitudes 78° 30′ to 79° 00′), Quebec. Further field work is required before a map-sheet and report can be prepared.

A. H. Lang. Mr. Lang explored, geographically and geologically, much of the area between latitudes 49° and 50°, and longitudes 76° 15′ and 78° 00′, Quebec. The results are being compiled for incorporation in a second edition of the Nottaway 8-mile geological map, No. 190A.

T. H. Clark. Mr. Clark nearly completed the geological study and mapping of the west part of the Memphremagog 1-mile quadrangle (latitudes 45° 00′ to 45° 15′, longitudes 72° 00′ to 72° 30′), Quebec. A series of three 1-mile map-sheets (Lacolle, Sutton, and Memphremagog) and a series of reports are in course of preparation.

F. J. Alcock. Mr. Alcock concluded the geological study and mapping of the country bordering Chaleur bay, both in Quebec and New Brunswick. A memoir on the region and a series of 1-mile geological sheets are being prepared.

G. W. H. Norman. Mr. Norman concluded the geological study and mapping of the Hillsborough 1-mile quadrangle (latitudes 45° 45′ to 46° 00′, longitudes 64° 30′ to 65° 00′), the Moncton 1-mile quadrangle (latitudes 46° 00′ to 46° 15′, longitudes 64° 30′ to 65° 00′), and the Chignecto 1-mile quadrangle (latitudes 45° 30′ to 45° 45′, longitudes 64° 30′ to 65° 00′), New Brunswick. Mr. Norman also commenced the geological study and mapping of the Oxford 1-mile quadrangle (latitudes 45° 30′ to 45° 45′, longitudes 63° 30′ to 64° 00′), Nova Scotia. A report and three 1-mile geological map-sheets are being prepared.

W. A. Bell. Mr. Bell completed the geological study and mapping of the Sydney 1-mile quadrangle (latitudes 46° 00′ to 46° 15′, longitudes 60° 00′ to 60° 30′), Glace Bay 1-mile quadrangle (latitudes 46° 00′ to 46° 15′, longitudes 59° 30′ to 60° 00′), and Bras d'Or 1-mile quadrangle (latitudes 46° 15′ to 46° 30′, longitudes 60° 00′ to 60° 30′), Nova Scotia. A report and three 1-mile geological map-sheets (Sydney, between latitudes 46° 00′ and 46° 15′, and longitudes 60° 00′ and 60° 30′; Glace Bay, east of the Sydney; and Bras d'Or, north of the Sydney) are being prepared.

Topographical

H. N. Spence. Mr. Spence made control surveys in the Gargantua 1-mile quadrangle (latitudes 47° 30′ to 47° 45′, longitudes 84° 30′ to 85° 00′) and Harmony quadrangle (latitudes 46° 45′ to 47° 00′, longitudes 84° 00′ to 84° 30′). The geographical detail for these sheets will be obtained later from aerial photographs taken by the Ontario Government and from information obtained in the course of geological work.

A. G. HAULTAIN. Mr. Haultain continued topographical mapping of Sudbury nickel basin and vicinity. Control surveys were made for the use of aerial photographs in compiling a contoured map. Work in 1931 was in the Chelmsford quadrangle (latitudes 46° 30′ to 46° 45′, longitudes 81° to 81° 30′), the Wanapitei quadrangle, east of the Chelmsford, and extensions into two adjacent quadrangles. Field work in the Chelmsford quadrangle is complete, but some further work is required in Wanapitei quadrangle.

J. W. SPENCE. Mr. Spence made control surveys near Noranda for the production of a map on a field scale of 1 inch to 800 feet, of an area about 9 miles by 4 miles within which are located most of the producing mines of Rouyn mineral area. The map is being compiled, but further field work may be undertaken in order to contour the area. Mr. Spence also completed a similar survey of the asbestos mining area at Thetford Mines and Black Lake, begun in 1930. The map is being prepared.

S. C. MCLEAN, J. V. BUTTERWORTH, and K. G. CHIPMAN continued, from 1930, detailed mapping, on a field scale of 1 inch to 800 feet, of the coal mining area at Sydney, Cape Breton. The control surveys by Mr. McLean were compiled and information was obtained for compilation of five map units, each five minutes of latitude by five minutes of longitude. These units are being compiled.

INDEX

The annual Summary Report of the Geological Survey is issued in parts, referring to particular subjects or districts. This year there are four parts, A, B, C, and D. A review of the work of the Geological Survey for the year forms part of the Annual Report of the Department of Mines.