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## CANADA

## DEPARTMENT OF MINES

hon. W. A. Gordon, Minister; Charles Camsell, Deputy Minister

## GEOLOGICAL SURVEY

W. H. Collins, Director

## Summary Report, 1930, Part D

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OTTAWA
F. A. ACLAND

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.

# THETFORD MAP-AREA, QUEBEC 

By H. C. Cooke

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## INTRODUCTION

In the spring of 1930 the writer was instructed to commence the geological examination of Thetford map-area, in the Eastern Townships of Quebec, for the purpose of determining, if possible, the origin of the asbestos deposits and the causes that determined their localization. The maparea is a quadrangle extending from $71^{\circ}$ to $71^{\circ} 30^{\prime}$ west longitude, and $46^{\circ}$ to $46^{\circ} 15^{\prime}$ north latitude. A topographic map of the area on a scale of 1 mile to 1 inch, with a contour interval of 25 feet, was published in 1927 by the Department of National Defence, under the name of the Thetford sheet. This was used as a base.

The district is well provided with roads, running northwest and northeast parallel to the general trend of the valleys, and spaced from $\frac{3}{4}$ mile to 2 miles apart. Provincial Highway No. 1, which runs from Montreal to Quebec via Sherbrooke, passes through the middle of the map-area. Thetford Mines, with a population of about 10,000 persons, is the largest centre, and there are a number of small towns and villages.

The district lies within the highland area known as Notre Dame hills, a continuation of Green mountains of Vermont and White mountains of New Hampshire. A part of what is known as the Sutton range of hills occupies the northwestern half of the map-area. The ridges trend northeasterly, and the intervening valleys are rather broad. The general level of the larger valley bottoms is from 1,000 to 1,200 feet above sea-level, and the highest ridges rise above 2,200 feet, so that the maximum relief is about 1,000 feet. In addition to the main valleys with their northeast trend, there are a number of rather narrow valleys that trend northwest and have been eroded to the same general depth as the main valleys.

The greater part of the map-area drains northwest, through the transverse valleys mentioned, to Bécancour river, which enters the St. Lawrence opposite Three Rivers. In the southern part, however, the creeks from Clapham, Bolduc, and Trout lakes flow to St. Francis river which continues southwest to Sherbrooke before turning northwest to the St. Lawrence. The eastern side of the map-area drains to Chaudière river, which enters the St. Lawrence a few miles above Levis. The maparea thus lies on the divide between the waters of these three large rivers, and, accordingly, all the streams are small creeks, unnavigable even by canoes. For the most part, the creeks flow over beds of glacial drift.

The first descriptions of this district were by Sir William Logan, in several of the early reports of the Geological Survey, and were later embodied in the "Geology of Canada", published in 1863. Later, in the years 1886, 1887, 1888, and 1894, R. W. Ells revised the areal geology of the entire Eastern Townships, and published reports accompanied by maps on a seale of 4 miles to 1 inch. The area under discussion falls within two of these maps. In 1907 and 1909 J. A. Dresser made a more detailed examination of the belt of asbestos-bearing rocks from St. Francis river, near Richmond, as far as East Broughton, a distance of nearly 70 miles, and mapped the distribution of the various intrusive rocks. His results are embodied in Memoir 22. From 1915 to 1921 Robert Harvie was at work in the southwestern quarter of the map-area and adjacent territory to the south, as far as Disraeli village. A manuscript copy of his report is on file; and his earlier results were published in a paper by J. K. Knox in the Summary Report for 1916. In 1918, B. R. MacKay made a map of a portion of the Chaudière basin, only a few miles northeast of the maparea under discussion, and published his results in Memoir 127.

## GENERAL GEOLOGY

The Sutton range of hills, which occupies the northwestern half of the map-area, is the axis of a major anticline. The rocks of the range, within the small areas studied last summer, are mainly highly contorted sericite schists, and have been considered by Ells and those following him to be probably of Precambrian age. Harvie and Knox have termed them the Bennett schists, a local name that will be used in this report. Southeast of these is a series of quartzites, grey and green slates, red slates, and basaltic lavas supposed to be of Cambrian age. They are much less deformed than the Bennett schists, and for that reason are presumed to overlie the Bennett with unconformity, although other evidence of unconformity has not yet been obtained. In Chaudière valley, 5 miles to the northeast, MacKay termed a petrographically similar series, with the same stratigraphic position, the Caldwell series; and to avoid multiplication of local names this term will be tentatively applied in Thetford map-area until field correlations can be made. The Caldwell series was, probably, folded slightly before the next series of sediments was deposited. These, consisting of black slates and impure quartzites, outcrop southeast of the Caldwell series and extend to the southeast limit of the map-area. MacKay has named the corresponding series of sediments in Chaudière valley, the Beauceville series, and the same name will be tentatively used here, although the Beauceville of Chaudière valley differs from that of Thetford area in containing considerable amounts of rhyolite and rhyolite tuff. No rhyolite was found in Thetford map-area, but it is possible that some of the so-called impure quartzites may prove to be tuffs. The Beauceville series overlies the Caldwell series with unconformity; at its base there is a conglomerate perhaps 100 feet thick made up of fragments of the Caldwell slates and quartzites. It is supposed to be of Ordovician age, although, as in the case of the Caldwell, no fossils have yet been found by which its age can be fixed with certainty. Both the Caldwell and Beauceville have been strongly folded along northeast axes, so that the strata now dip, for the most part, at angles ranging 45 degrees to vertical.

No further information as to the geological history is obtainable in Thetford map-area, but in Chaudière valley MacKay found Devonian (Onondaga) strata, with abundant fossils, overlying the Beauceville beds with an angular unconformity of about 40 degrees. The Devonian strata are themselves severely folded and faulted, so that they now dip at angles up to 40 degrees. Evidently, therefore, the region was strongly folded between Beauceville and Onondaga times, and again, almost equally strongly, after deposition of the Devonian strata.

At some time after the principal folding movements were completed, intrusion took place of the basic igneous rocks that gave rise to the asbestos deposits of the district. The intrusives were injected along anticlines in the older rocks, illustrating very beautifully the control exercised by structure over intrusion.

## Table of Formations

| Post-Ordovician. |  | Serpentinized dunite and peridotite, pyroxenite, granite |
| :---: | :---: | :---: |
| Ordovician(? ) | Beauceville series. | Black slates, impure quartzites |
| Cambrian(?). | Caldwell series. | Quartzite, basaltic lavas, grey, green, and red slate |
| Precambrian(?). | Bennett schists. | Sericite and chlorite schists |

## BENNETT SCHISTS

Very little study was given to the Bennett schists during the past summer, hence little information concerning them can be given. In the main they are silvery sericitic schists, probably formed by the shearing of quartzites, but only in rare instances can any remnant of original bedding be seen. Here and there darker chlorite schists occur, and in one place, range $V$, lot 1c, Thetford township, what appears to be a much altered basic lava is interbanded with the schists. The rocks are distinguished by their extreme schistosity and crumpling. It appears as if the original beds had been sheared to a very perfect schist, and then, by a later movement, the schist had been refolded and much crumpled. A single linear foot, along the strike, will commonly exhibit from five to thirty small plications; these plications, in turn, form parts of larger folds a few yards across, and these, again, are parts of still larger folds. At the crests of anticlines, however, the schists in some cases do not exhibit the smaller plications.

## CALDWELL SERIES

The Caldwell series overlies the Bennett schists on the southeast side of the Sutton range. Actual contact between the two was observed only in one place, in range IX, lot 13, Broughton township; although in range V , lot 1c, Thetford township, the contact is hidden only by a 3 or 4 -foot width of drift. There is no conglomerate developed at the contact in either place. The Caldwell, at the base, is a white, fairly pure quartzite, which where sheared forms a sericite schist very difficult to distinguish
from the Bennett; and as shearing has been pronounced at the contact of the two series, it is not easy to determine the contact with accuracy. These facts at first suggested that the Bennett might be merely the schistose equivalent of the Caldwell, but further study made this seem improbable. Where the Caldwell quartzite has been rendered schistose, the schist always cleaves along flat planes, whereas the Bennett schist, as already explained, is intricately crumpled. In addition, the Caldwell quartzites are sheared only locally, whereas the Bennett is quite uniformly schistose. These differences, it is believed, indicate that the Bennett is much older than the Caldwell, and has been subjected to at least one more period of metamorphism. If this is correct, the Caldwell series must lie unconformably on the Bennett schists.

From the base upward, the Caldwell series consists of quartzite, basaltic lavas, grey and green slate, red slate, and a second grey and green slate. The full succession does not, however, appear along every line of crosssection. The lavas are of local distribution, and are absent from certain areas. The red slates, also, seem to thin and possibly even disappear toward the eastern side of the area.

The Caldwell quartzites were termed the L'Islet formation by Dresser, but as this term implies a correlation with rocks on the St. Lawrence northeast of Levis, the writer does not feel justified in using it. The quartzites are white or light grey rocks, commonly quite massive, and made up principally of quartz with a few grains of feldspar, biotite or chlorite, zircon, and tourmaline. Here and there, however, beds containing considerable amounts of feldspar, biotite, etc., may be found. The grain is commonly rather fine, particularly in the northwestern band that flanks the Bennett schists; but in places, as in range X, lot 21, Thetford township, beds contain quartz pebbles up to the size of beans. The beds vary from a few inches in thickness to 6 feet or more. Throughout the quartzite formation occur many beds of grey slate, varying in thickness from a fraction of an inch to 6 inches. These, by the relationship of their slaty cleavage to the bedding, afford valuable information as to the structure.

The total thickness of the quartzite formation has not yet been measured with accuracy, but is estimated, from known dips and widths of outcrop, to be between 2,000 and 2,500 feet.

For the most part the quartzites are massive rocks, jointed to a moderate extent by the strains of folding, but otherwise only slightly changed from their original condition. Near their contact with the Bennett schists, however, they are notably sheared in places, and converted into a fissile, sericite schist. Such shearing is especially pronounced in the synclinal area of quartzite in range XI, lots $9-11$, Broughton township. Also, for distances up to a mile from the contact, the quartzite is much more fractured than elsewhere, and the cracks filled with quartz, forming narrow, crooked veins. In places the rock is so cut up with these veins, that it is difficult or impossible to determine the bedding planes.

In other places, where the strata have been sharply bent by severe drag-folding, the brittle quartzites have been shattered to a breccia. The best examples of this are seen just west of Clapham lake, in ranges VIII, IX, and X, Thetford township. In range VIII, lots 17 to 19, there are four knobs in an east-west line three-quarters of a mile long, composed
entirely of this breccia. At this locality the strata have been bent sharply through a right angle. The breccia formed by the crushing of the beds within the angle is of very striking appearance. It consists mainly of boulders of somewhat schistose quartzite of all sizes up to 3 feet, or even more, in diameter, embedded in a matrix of sand and grit which is clearly only crushed quartzite. Some of the boulders are slate and some are of quartz, and many boulders both of quartzite and slate contain quartz veins that end at the margin of the boulder. As might be expected, all the boulders are sharp angled or sub-angular.

Further outcrops of the breccia are found in range IX, lot 17a, and in range $\mathrm{X}, \operatorname{lot} 17 \mathrm{a}$. In the latter locality the origin of the breccia is clearly evident. The strata, striking north 60 degrees west on the whole, and dipping vertically, are sharply bent by a series of drag-folds up to 15 feet across. Certain, presumably the more brittle, of the beds within the dragfolds are crushed, yielding bodies of breccia identical with those described in the last paragraph; in one place, the fragments formed by crushing of a bed of distinctive grain and colour could be traced through the body of breccia. All stages of the brecciation were observed, from the initial fragmentation with but little matrix to the final stage in which 30 per cent or even more of the rock is crushed to sand and grit. Bodies of breccia 10 or 15 feet wide and up to 100 feet or more in length are thus formed here.

Lavas. The lavas, in the area studied last summer, are all altered basalts, in which pillow structure is almost universally present. They are fine-grained, dark green rocks for the most part, but in places dark red varieties occur. The best example of the latter occurs on the hill northwest of Clapham lake, in range VIII, lots 15 and 16, Thetford township. Associated with the lavas in places are small amounts of reddish cherts and tuffs, the latter converted into slates.

Certain writers, misled by the close field association of the lavas and the asbestos-bearing intrusives in areas farther to the southwest, have supposed that both probably originated from the same magma basin. In the area studied last summer the lavas and intrusives are not closely associated, and accordingly it could be definitely determined that they are not related in origin to each other. The lavas can be seen in the field to be conformably interbedded with the sediments of the Caldwell series, so that they are necessarily of Caldwell age; but the 'intrusives, as will be shown, are very much later.

The basalts lie for the most part near the top of the Caldwell quartzites, and in some places at the top, between the quartzite and the overlying shale. They exhibit their best development in the southeastern end of Thetford township, ranges X and XI, and in the adjoining parts of Broughton township, where there are two thick masses of lava separated by more than a half mile width of quartzites, and two thin flows of local extent lying between the thicker masses at about the same horizon. The more southerly lava forms a body roughly $4 \frac{1}{2}$ miles long and 0.37 mile wide. The more northerly can be traced for more than 15 miles, within which distance the outcrop varies in width from 400 feet to nearly a mile.

On Clapham lake, also, there are two lava masses, the northeasternmost of which is a continuation of the large flow just described, and the second lies below it and separated from it by a considerable width of quartzite. It seems probable that this lower flow was extruded at or
about the same time as the lowest flow farther east, but there is no connexion between the two. On Clapham lake the quartzites between the lavas have an average width of about 2,000 feet, but northwest of the lake both the lavas and the intervening quartzite narrow rapidly, until the latter is only about 200 feet thick in range VII, lot 19, Thetford township. Beyond this point only one flow can be found, but it is not known whether this is due to the complete disappearance of the intervening quartzite and consequent coalescence of the two flows, or to the disappearance of one of the flows.

No lavas were found in the eastern 4 miles of the map-area. MacKay, however, reports similar lavas in the Caldwell series on the east side of Chaudière river.

The lava masses are probably of considerable thickness, but there is no way of determining the thickness because changes of dip cannot be observed within them.

Actual contacts between the lavas and the sediments are rather uncommon, although in many places they are hidden by only a few feet of drift. An excellent contact is observable, however, in range VII, lot 12c, on a cliff facing west toward a small creek. Two flows are visible, separated by about 15 feet of quartzite. The succession from south to north is: quartzite, pillowed lava about 12 feet thick, massive quartzite about 15 feet thick, followed by lava. No break of any kind is visible at the contacts of the lava and sediments, and the planes of contact are parallel to the bedding of the sediments.

A second excellent contact is visible in lot 25, range XI, Broughton township, close to the Broughton-Thetford boundary. Its character is similar to that of the contacts described in last paragraph.

Lower Green Slate. A rather thick series of grey and green slates conformably overlies the lavas and quartzites. For the most part it is in contact with quartzites, but in Thetford township, ranges VI and VII, lot 12 and westward, is in direct contact with the lavas. The slates are well-bedded rocks, the beds rarely more than 2 inches thick, with a perfectly developed slaty cleavage. The metamorphism has not, however, obliterated the bedding, which is usually readily visible on glaciated or other smooth surfaces. Beds of quartzite, some of them 25 feet or more in thickness, are here and there interbanded with the slates. The slates, which flowed readily under pressure, have been intricately folded in many places, particularly near the crests of the major folds, and undoubtedly by these processes have been much thinned in some places and thickened in others. They have been further disturbed by a multitude of small faults, with displacements of a few inches.

The slates, on account of their softness, are commonly rather poorly exposed, even where they form fairly high ridges. In many places there are large areas of slate so uniformly covered with soil 2 to 4 inches in depth that it is difficult to obtain sufficient outcrop for determination. Almost all the larger areas mapped as slate are of this character.

Because of the poor exposures, and the intricately folded and faulted nature, it is impossible to make accurate determinations of the thickness. The general dip, combined with the width of outcrop, in range VII, lot 12, Thetford township, suggests that it may be in the neighbourhood of 1,200 feet.

Red Slate. Red slate was found only in ranges VII and VIII of Thetford township, from lot $14 e$ to the Thetford-Broughton boundary, and northeastward into Broughton township for about $1 \frac{1}{2}$ miles. Its outcrops are thus confined to a band about 7 miles long and $1 \frac{1}{4}$ miles wide. It, and the slates above and below, are supposed by Dresser to be correlative with the Sillery slates in the neighbourhood of Levis. Except for its colour, the origin of which is not yet determined, it is in every way similar to the grey and green slates described. Its thickness, toward the western end of the band, is of the order of 600 feet. Toward the eastern end the band thins, so that the easternmost outcrop is only about 75 feet thick. The fact that the slate is not found farther east, coupled with the known thinning, suggests that it may pinch out entirely in that direction.

Upper Green Slate. Other beds of grey and green slate overlie the red slates. They are identical in every way with the lower grey and green slates, so that they can be distinguished as a separate formation only in ranges VII and VIII, lots 2-10, where the red slates intervene. In the eastern part of the area, where the red slates seem to disappear by thinning, the upper green slates, if present, can not be distinguished from the lower green slates.

Structure of the Caldwell Series. The Caldwell series has been folded fairly closely along northeast-southwest axes, so that the strata now dip for the most part at high angles to the northwest or southeast. The folding has been rarely extreme enough, however, to cause overturning. In addition to the main folding, there is also a cross-folding along north-west-southeast axes, causing the folds to plunge at small angles seldom exceeding 25 degrees. In places, however, as in the area between Clapham lake and Bécancour hills, the cross-folding is more pronounced, so that the strata have northwest instead of northeast strikes.

In Figure 1 a preliminary attempt has been made to depict the structure by a cross-section along a northwest line that passes half a mile west of Sacre-Cœur-de-Marie village. The positions of the axes of the folds indicated in this diagram have been definitely determined between the northwest end of the section and the point marked "A"; and the position of the main anticline, marked " C ", is also definite. The folding indicated between A and C , however, is hypothetical, and is shown as it is because the better-exposed quartzites about 6 miles to the northeast, along the strike, are thrown into folds of about the same magnitude. Similarly, the stracture indicated for the lava flow is purely hypothetical. It is known that the axis of a small syncline passes through the point "B", and for this reason the possibility is noted that the narrow outcrop of lava at B may be merely a downfolded remnant of the main flow; but this possibility is not to be considered a proved fact.

A longitudinal section along the anticlinal axis about $1 \frac{1}{4}$ miles south of Robertsonville, shown in Figure 2, illustrates the character of the crossfolding.

The Caldwell series, as indicated in Figure 1, forms a synclinorium about $5 \frac{1}{2}$ miles wide, lying between two anticlinal axes. The northern of these axes lies just north of the Bennett-Caldwell contact, the southern passes through Trout lake. The red shales and upper green shales occur only in the axial part of the synclinorium.

8D


[^0]The Beauceville series occupies the southeastern part of the map-area. The rocks consist of a basal conglomerate, overlain by a rather monotonous succession of dark grey to black slates and impure quartzites. The series is supposed by Dresser and others to be of Ordovician age, but as no fossils have been found in them, probably because they have been destroyed by metamorphism, this correlation can be regarded as only tentative.

The basal conglomerate is a very constant feature of the series, within the area examined. Dresser, in his report dealing with the whole asbestosbearing belt, states that in places the conglomerate has a thickness of 100 feet or more; and it is probable that this figure is approximately correct for the part within Thetford map-area. It was found impossible, unfortunately, to make direct determinations of the thjekness, partly because the conglomerate is well exposed only in three places, partly because bedding within the conglomerate can rarely be determined, and partly because the basal bed is folded into a small syncline, followed, of course, by an anticline, before it plunges beneath the slates. In such circumstances the beds must be repeated, or partly repeated, three times, in the band exposed, the width of which is approximately 2,000 feet, at the widest known place.

In most localities the conglomerate has been badly sheared, so that it now consists of pebbles of quartzite and slate in a slaty or schistose matrix. The pebbles are commonly rounded by the shearing movements, and the whole rock is indistinguishable from an autoclastic rock formed by the brecciation and shearing of thin, alternating bands of quartzite and slate. Fortunately, however, two or three localities were found, where shearing is less intense, and where, in consequence, it can be clearly established that the rock is a true conglomerate rather than an autoclastic breccia.

The best place for study of the conglomerate is toward the northeast ends of lots 34 and 35, range XIV, Adstock township. The conglomerate here lies directly on the Caldwell quartzite, and at the contact is of the character described in the last paragraph. The conglomerate dips to the south in what appears to be a short syncline, near the centre of which, about 1,200 feet southeast of the contact, the rock is not at all schistose. At this point it is made up of pebbles of quartzite and slate embedded in a matrix of grit or small slate fragments. The pebbles are numerous, of all sizes up to 2 inches in diameter, and subangular to moderately rounded. Black slate, grey and whitish slate, dark quartzite, light grey quartzite, coarse quartzite, and fine quartzite, were identified among the pebbles, all of which can be matched with the underlying Caldwell rocks. Some parts of the conglomerate are made up so largely of slate fragments that the rock resembles coquina, or shell rock.

At another locality, lot 34, range V, Adstock township, the conglomerate is but slightly sheared. Some of the beds consist of the usual mixture of quartzite and slate fragments, but others are of a type previously unobserved, namely, a quartzite conglomerate, made up of pebbles and boulders of quartzite in a matrix of grit and small quartzite pebbles. A very few pebbles of slate are present. Approximately 90 per cent of the rock, in places, consists of pebbles an inch or more in diameter. The
pebbles are of all sizes up to 2 feet in diameter, and have rounded edges and corners, but are not otherwise very rounded, so that they have evidently not undergone long-continued abrasion. The quartzites are of the various types found in the underlying Caldwell series.

Overlying the basal conglomerates there is a rather monotonous succession of dark grey slates, commonly called black slates, with which is interbedded in places somewhat dark, dirty-looking quartzite. In Chaudière area, MacKay found similar quartzites to be, in some cases, of tuffaceous origin; and it is possible that some of these may likewise be tuffs. The question has not yet been investigated. The slates and quartzites are folded into short folds with steep dips. In a few places it was determined that the distance from an anticlinal axis to the axis of the next succeeding anticline is about 2,100 feet. On account of the very poor exposure of the slates, however, the axes cannot be traced far, and only a few of them were located. In these circumstances, measurements of the thickness of the series are not possible.

The slates are characterized by an excellent secondary cleavage crossing the bedding at various angles, depending on whether the place of observation is on the flank or near the crest of a fold. The metamorphism has nowhere obliterated the bedding, but it has destroyed any fossil remains the shales may have contained, so that it has been impossible, in this area, to secure definite evidence of their age. The quartzites have not been rendered schistose as a rule, pres imably because the soft shales around them took up the strains of folding, so that, if fossils ever occurred in them, they may not have been destroyed. None bas yet been found, however.

## Relations of the Beauceville Series to the Caldwell Series

The base of the Beauceville series, as indicated, is a fairly thick conglomerate made up of fragments of the Caldwell series, so that the latter must have undergone considerable erosion before Beauceville deposition began. The Beauceville series is in contact, not with the upper slate horizons of the Caldwell, but with the lower horizons, the quartzites or the lower grey and green slates. At no place in the area is the band of Caldwell slate below the Beauceville contact more than 500 feet wide, and in most places the Beauceville, where the contact was seen, is in direct contact with the quartzites. Therefore, either the upper slates were never laid down in the localities where the contact is now seen, or else the Caldwell series must have been folded and then eroded down to the quartzites before the time of Beauceville deposition. The second conclusion seems the more likely, because of the great abundance of slate fragments in the Beauceville conglomerate and because the conglomerate rests in some places on the Caldwell quartzites, in others on the lower grey and green slates.

Further evidence to this effect is obtained from the examination of pebbles in the undeformed conglomerate of lot 34a, range XIV, Adstock township. Great numbers of argillitic pebbles are present. A few of these are rather dull and earthy in appearance, and might be classed as varying from well lithified shale to fissile shale. The great bulk of them,
however, have a well-developed cleavage, and the cleavage faces are smooth and shining. Such a cleavage can have been formed only by metamorphism during folding. The cleavage must, likewise, have been present in the rocks before they were broken up to form the conglomerate, because they now lie at various angles to one another in the conglomerate. The metamorphism causing the cleavage could not, however, have been extreme, because the pebbles are not hard and dense, like roofing slate, but comparatively soft and friable.

It may, therefore, be concluded that the Caldwell series was moderately folded, and then subjected to erosion for a time sufficiently long to permit of the almost complete removal of the various Caldwell slates, before the deposition of the Beauceville series began.

## Folding of the Caldwell and Beauceville Series

After the close of Beauceville deposition, both series were intensively folded. This folding undoubtedly took place in at least two stages. MacKay has found, a few miles to the northeast, Devonian (Onondaga) strata overlying the Beauceville beds with great structural unconformity; and the Devonian beds are themselves folded so that in places they dip at angles of 30 to 40 degrees. It may, therefore, be concluded that a fairly strong folding of the Caldwell and Beauceville beds occurred between the end of Beauceville and the beginning of Onondaga time; and that a second folding, probably less strong, took place after Onondaga time. It is probable that the latter folding was effected by the late Devonian movements that mountain-built Gaspe peninsula.

## THE INTRUSIVES AND THEIR STRUCTURAL RELATIONS

The latest rocks of the district, the intrusives, consist chiefly of dunites and peridotites, now largely altered to serpentine, together with some associated gabbro and pyroxenite, and small amounts of granite and allied rocks. No great amount of study was given to these rocks during the past summer, hence no description of the rocks or their alteration will be attempted. The structural relations of the intrusives, however, are of interest. The serpentines and associated rocks commonly have somewhat ribbon-like outcrops that parallel the bedding of the sediments into which they are injected. For this reason previous writers have commonly considered them as sills, and, logically, have then supposed that the sills must have been folded with the sediments. Drilling done in the neighbourhood of Thetford first threw doubt on the correctness of this interpretation, as the peridotite masses were not found to occupy the positions the theory would indicate; and the structural work of the past summer, coupled with the relations of the intrusives to the folds, indicates pretty conclusively that the masses are dykes rather than sills, and injected after the folding was largely completed.

In Figure 2 are shown the principal anticlinal axes determined during the past summer, together with the positions of the igneous masses as mapped by Harvie, Knox, and the writer. It will be noted that the long, narrow body marked (1) follows closely the axis of the northernmost anticline, lying just soutb of it. The larger igneous masses on the southwest, marked (2) and (3) respectively, likewise lie directly on the projected strike of the determined positions of anticlines; and it will be observed


Figure 2. Relationship between the anticlinal axes and positions of the basic intrusives. Intrusives indicated in solid black, known anticlinal axes by solid lines, projections of anticlinal axes by pecked lines.
again that the bulk of the igneous rocks also lies on the south sides of the projected axes. These structural relationships indicate either: (1) that the igneous masses are true sills rather low down in the Caldwell series, and hence outcrop only in the anticlines; or else, (2), that they are intrusive masses other than sills, which were injected after the folding. In that case the folding so controlled the injection that the intrusives were localized in the anticlines. Such localization is of very common occurrence.

Evidence as to which of these possibilities is correct was obtained from examination of the body numbered (1) in the figure. This body, as previously noted, follows closely the axis of an anticline, so closely that in Thetford township, range V, lots 2 and 5, and in Broughton township, range XI, lot 12, the bedding of the sediments immediately north of the intrusive is almost flat. The intrusive, however, shows no signs of flattening, but dips steeply south at angles of 60 degrees or steeper. Further, in the first two localities mentioned, the intrusive lies at or close to the Bennett-Caldwell contact, and Caldwell quartzites outcrop again on the north side of the anticline less than one-quarter mile away. If the intrusive were a folded sill, it would likewise appear again between the Caldwell and the Bennett series on the north side of the anticline, but it does not. It must be concluded, therefore, that the igneous masses are not sills injected before the folding, but that they were intruded after the folding, and localized along the already established anticlines.

Further evidence to the same effect is obtained from a study of the masses themselves. If the bodies were sills injected prior to the folding, then the strains of folding must have caused drag effects. On the south side of an anticline the beds on the south move upwards, toward the anticlinal crest, while the strata are being bent. In the sedimentary beds, drag-folds, cleavage, and in places schistosity, are induced by these movements, and the nature of the movement can be inferred from these features. A sill, on account of its thickness, might not be rendered schistose or bent into drag-folds, but it might be to some extent fractured, and in that case the direction of the movement along the fracture planes should show an upward movement of the south side relative to the north side. The serpentines, as a matter of fact, are very highly fractured, but the fracture planes show none of the movement that might be expected had the intrusives been folded with the sediments. On the contrary, all the movements are of the opposite character, i.e., they indicate an upward movement of the north side. It is concluded, therefore, that the serpentines were not sills folded with the sediments, but were injected after the folding was pretty well completed; the movements fracturing the serpentines must, therefore, have been of still later date.

The bedding of the Bennett and Caldwell series did, however, exercise a pronounced control over the intrusion. The igneous rocks in general parallel fairly closely the bedding of the sediments, although they do cut it in places at small angles; and the writer is informed by Mr. Dresser that where the bedding is nearly flat, at the summit of the anticline near Blais post office, some almost flat sheets of the intrusive are also found. These occurrences do not, however, contradict the conclusion that intrusion occurred after the main folding; they merely illustrate the tendency of intrusives in general to follow bedding planes rather than to cut across them.

A rather interesting coincidence was observed, suggesting a possible connexion between structure and the occurrence of asbestos. It has been shown that the various peridotite masses outcrop at or near the summits of the major anticlines in the Caldwell series. The position of the axis of the principal anticlinal cross-fold of the area examined passes through Bécancour hills, approximately through lot 25 , range VII, Thetford township. This axis strikes northwest, and its projection, therefore, passes
through the town of Thetford. The Thetford asbestos deposits, therefore, are found at a point where an anticlinal cross-fold intersects a major anticline. Whether this is mere coincidence, or whether there is a true genetic connexion between the asbestos deposits and such structure combinations, only further investigation can show.

## SUMMARY

The work of 1930 has fairly well established the following points:
The rocks of the district include the Bennett, Caldwell, and Beauceville series of sediments, and various intrusives, chiefly of a basic nature.

The Bennett series, supposedly of Precambrian age, consists of schists which-after their shearing-have been intensely crampled by some later folding.

The Caldwell series, supposedly of Cambrian age, consists, from the base upward, of quartzite, basalt, lower grey and green slate, red slate, upper grey and green slate. It is presumably unconformable on the Bennett series. The Caldwell series was somewhat folded and eroded before the deposition of the Beauceville series.

The Beauceville series, supposedly of Ordovician age, has a moderately thick conglomerate at the base made up of fragments of the Caldwell series, on which it lies with unconformity. The remainder of the formation consists of black slates with some beds of dark, impure quartzite.

The Caldwell and Beauceville series were strongly folded after deposition of the Beauceville was complete. A second, probably less intense, folding appears to have occurred late in the Devonian.

The basic intrusives are not sills as formerly supposed, but dyke-like or irregularly shaped masses injected into the anticlines after folding was fairly complete.

The major folding is along northeast axes, the minor folding along northwest axes. The minor folding, for the most part, causes the major folds to plunge at angles of 20 degrees or less, but in places, as between Clapham lake and Bécancour hills, it is so pronounced that the strata have northwest rather than the usual northeast strikes.

# CHEMICAL AND MINERALOGICAL STUDIES OF SOME QUEBEC CHROMITES 

By E. Poitevin

The writer was instructed in 1930 to collaborate with Prof. L. Gilchrist of Toronto University and Mr. A. H. Miller of the Dominion Observatory, who were conducting geophysical investigations of chromite ore deposits in Coleraine and Ireland townships, Megantic county, Quebec. Chromite ore from some forty localities was collected in order to assist in this work. A preliminary examination of the ores made it apparent that metallographic microscopic studies alone would not reveal their characteristics. Accordingly, eight samples from various localities miles apart were selected and prepared for chemical and microscopic study, the results of which follow. In the Eastern Townships of Quebec, especially near Coleraine, Black Lake, and Thetford Mines, chromite is found in very basic rocks. These are quite close in chemical composition, but differ in mineralogical composition. They include: dunite is 95 to 100 per cent olivine and in many cases has picotite and magnetite as accessory minerals; harzburgite, or saxonite, is about 90 per cent olivine and 10 per cent orthorhombic pyroxene; wehrlite is 90 per cent olivine and about 10 per cent monoclinic pyroxene; lherzolite is 90 per cent olivine and about equal amounts of monoclinic and orthorhombic pyroxene; and pyroxenite (diallagite) composed almost entirely of pyroxene but with a little dunite.

It is very difficult in the field to distinguish between harzburgite, wehrlite, and lherzolite, but when fresh, and sometimes even when altered, they are easily distinguished from dunite owing to the large cleavage faces of pyroxene which can be seen in them. However, the four rock types are very rarely found in a fresh state. Generally they have been transformed into serpentine which makes their identification more difficult. The serpentine is generally olive-green on fresh surfaces and weathers either green or brown. The pyroxene is dark green and is easily recognized by the numerous pyroxene cleavage faces which are quite visible to the naked eye. These rock types are differentiation products of one magma and in the field one may find masses of different rock types within a few feet of one another.

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

The chromite ore-bodies are roughly lenticular, and vary in size from small pockets up to masses containing thousands of tons. As a rule the bodies merge into the country rock, through the adjacent parts of which chromite occurs in scattered nodules and grains the size of a pea or smaller. For instance, on the Martin Bennett property (lot 28, range I, Ireland township) the chromite occurs in nodules enclosed in the serpentine adjacent to the massive chromite ore-bodies. These nodules are of all sizes, from mere grains up to bodies several centimetres in diameter; one of the largest collected had dimensions 3.5 by 2.5 by 1.5 cm . The nodules at first sight appear to be entirely massive chromite, but when broken open they are found to hold a fair amount of interstitial serpentine, in part altered to brucite.

Although several hundred deposits of chromite have been found in the Coleraine-Black Lake-Thetford district, it is notable that more than 95 per cent of them were discovered by surface work. Very few were located by diamond drilling.

Most of the chromite ore-bodies are cut by dykes or lenticular masses of aplite and pegmatite and by dyke-like bodies composed of vesuvianite, grossularite, and diopside. Mining for chromite has shown that these bodies do not always outcrop. In many instances they were located 20 to 50 feet from the surface.

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

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

Eight of the chromite specimens were studied in more detail. Chemical analyses of them are presented on a following page. The localities from which the specimens were obtained are listed below.
Specimen No. 2. Chromite pit (Bennett Martin chrome) on the road to Vimy, Ireland tp., lot 28, range I, Megantic county, Que.
Specimen No. 462. Chromite pit on south slope, near summit of Caribou mountain, Ireland tp., Megantic county, Que.
Specimen No. 432. Chromite pit on north slope of Kerr hill at 1,300 feet elevation in bottom of a draw, Coleraine tp., Megantic county, Que.
Specimen No. 501. Woolsey's pit on west slope, 1,540 feet elevation, Quarry hill, Coleraine tp., Megantic county, Que.
Specimen No. 1. Chromite pit (Caribou chrome) on southeast slope of Quarry hill, 1,200 feet elevation, near lake Caribou, Coleraine tp., Megantic county, Que.
Specimen No. 518. Ross chromite pit on south slope, 1,550 feet elevation, Murphy hill, Coleraine tp., Megantic county, Que.
Specimen No. 494. Old Greenshields chrome pit on west slope, 1,000 feet elevation, Provençal hill, Coleraine tp., Megantic county, Que.
Specimen No. 487. Chromite pit (American chrome) east of Morin hill, at 1,300 feet elevation on trail to Peach lake, Coleraine tp., Megantic county, Que.

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

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

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

## Specimen No. 462

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

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

Specimen No. 432
The chromite in thin section is reddish brown and translucent. The gangue is antigorite serpentine. Inclusions of fresh and altered olivine are common. No picotite nor magnetite is visible.

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

## Specimen No. 501

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

The country rock of the chromite deposit was a dunite. The olivine has low indices of refraction and, therefore, belongs to the variety low in iron. The rock is now 60 per cent mesh antigorite serpentine with probably 1 to 2 per cent chromite. A little brucite was identified.

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

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

## Specimen No. 518

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

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

## Specimen No. 494

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

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

## Specimen No. 487

The chromite in thin section is brownish red. The edges of partings are oxidized to black ore. Olivine inclusions are absent, but idiomorphic crystals of picotite are present. The matrix is largely a low, birefringent chlorite derived from diallage. Chromiferous pennite is also present. It is interesting to note that when much black chromite is observed chromiferous pennite is an associated mineral. Many occurrences studied, but not described, here show this phenomenon.

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

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

The results of the analyses are as follows.
Analyses of Quebec Chromites

| Specimen No. | 2 | 462 | 432 | 501 | 1 | 518 | 494 | 487 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathrm{SiO}_{2}$ |  | 0.53 | 0.47 | 0.50 |  | 1.00 | 0.40 | 0.30 |
| $\mathrm{TiO}_{2}$ |  | trace | 0.08 | $0 \cdot 15$ | 0.22 | trace | $0 \cdot 15$ | $0 \cdot 17$ |
| $\mathrm{Al}_{3} \mathrm{O}_{3}$. | $12 \cdot 30$ | 14.32 | 14.23 | 14.36 | $15 \cdot 63$ | 23.63 | $12 \cdot 61$ | 20.29 |
| $\mathrm{Cr}_{2} \mathrm{O}_{8}$ | $57 \cdot 31$ | 56.30 | 53.94 | 56.00 | 52.21 | 45.00 | 56.81 | $45 \cdot 16$ |
| MgO . | $16 \cdot 13$ | 12.27 | $12 \cdot 80$ | 10.45 | 17.62 | $12 \cdot 18$ | 13.66 | 11.78 |
| CaO |  | $0 \cdot 70$ | $0 \cdot 50$ | $0 \cdot 60$ | trace | $0 \cdot 40$ | $0 \cdot 40$ | $0 \cdot 70$ |
| $\mathrm{Fe}_{2} \mathrm{O}_{8}$. | 6.99 | $0 \cdot 44$ | $4 \cdot 16$ | $0 \cdot 59$ | 6.56 | 1.12 | $3 \cdot 68$ | $5 \cdot 07$ |
| FeO | 8.80 | 14.95 | 14.51 | 17.51 | $8 \cdot 70$ | $16 \cdot 69$ | 12.92 | 16.92 |
| MnO . | trace | 0.12 | 0.20 | $0 \cdot 20$ | Nil | $0 \cdot 20$ | $0 \cdot 16$ | 0.18 |
| NiO . | $0 \cdot 06$ | $0 \cdot 20$ | $0 \cdot 20$ | $0 \cdot 14$ | $0 \cdot 13$ | $0 \cdot 20$ | $0 \cdot 15$ | $0 \cdot 50$ |
|  | 101.59 | 99.83 | 101.09 | $100 \cdot 50$ | $101 \cdot 07$ | $100 \cdot 42$ | $100 \cdot 94$ | 101.07 |

Chromites may be considered as being constituted of a series of salts wherein aluminium, chromium, and iron functioning as acids are in chemical combination with magnesium and iron as bases. Thus, the iron may exist in them as an acid as well as a base; but it is to be remembered that aluminium and chromium may exhibit basic as well as acidic properties depending entirely upon the conditions involved in any given chemical reaction. It is to be noted that the order of acidity of the acids is Al, Cr, Fe, and that magnesium has stronger basic properties than iron. (These properties are also indicated by the position of the elements in the Periodic Table.) In other words chromites are mixtures in various proportions of several terms of an isomorphous series of spinels $\mathrm{R}_{2} \mathrm{O}_{3}$ RO. To establish these proportions the above analyses were reduced to total $100, \mathrm{CaO}$ was added to MgO and $\mathrm{TiO}_{2}$ to $\mathrm{SiO}_{2}$. To simplify calculations, enough $\mathrm{SiO}_{2}$ and MgO to combine to form olivine $\mathrm{Mg}_{2} \mathrm{SiO}_{4}$ was subtracted and the remainder recalculated to total 100. Then all the alumina was combined with MgO to form $\mathrm{Al}_{2} \mathrm{O}_{3} \mathrm{MgO}$; the remaining MgO was combined with $\mathrm{Cr}_{2} \mathrm{O}_{3}$ to form $\mathrm{Cr}_{2} \mathrm{O}_{3} \mathrm{MgO}$; the rest of $\mathrm{Cr}_{2} \mathrm{O}_{3}$ was united with FeO to form $\mathrm{Cr}_{2} \mathrm{O}_{3} \mathrm{FeO}$; and what was left of FeO was combined with $\mathrm{Fe}_{2} \mathrm{O}_{3}$ as $\mathrm{Fe}_{2} \mathrm{O}_{3} \mathrm{FeO}$.

The results obtained are given in the following table.
Recalculated Compositions of Quebec Chromites

| Specimen No. | 2 | 462 | 432 | 501 | 1 | 518 | 494 | 487 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathrm{Al}_{2} \mathrm{O}_{8} \mathrm{MgO}$. | 22.81 | $27 \cdot 44$ | 26.87 | $27 \cdot 62$ | 22.00 | $42 \cdot 30$ | 23.80 | 37.57 |
| $\mathrm{Cr}_{2} \mathrm{O}_{3} \mathrm{MgO}$ | 54.00 | $32 \cdot 05$ | 34.55 | $23 \cdot 15$ | $50 \cdot 33$ | $15 \cdot 20$ | 42.03 | 17.83 |
| $\mathrm{Cr}_{2} \mathrm{O}_{3} \mathrm{FeO}$. | 14.88 | 39.73 | $33 \cdot 40$ | $48 \cdot 63$ | $18 \cdot 30$ | 39.02 | $29 \cdot 37$ | 38.52 |
| $\mathrm{Fe}_{2} \mathrm{O}_{3} \mathrm{FeO} . . . . . . . . . . .$. | $8 \cdot 31$ | $0 \cdot 78$ | $5 \cdot 18$ | 0-60 | 9.37 | $3 \cdot 48$ | $4 \cdot 80$ | 6.08 |
|  | $100 \cdot 00$ | 100.00 | $100 \cdot 00$ | $100 \cdot 00$ | $100 \cdot 00$ | $100 \cdot 00$ | $100 \cdot 00$ | $100 \cdot 00$ |

All these chromites are characterized by their high proportions of magnesia spinels and by their relatively low content of $\mathrm{Fe}_{2} \mathrm{O}_{3} \mathrm{FeO}$.

The country rocks of Nos. 2, 462, 501, and 494 are true dunites, whereas those of Nos. 432 and 1 are dunites with a little orthorhombic pyroxene (enstatite), that is, the country rocks in all these cases did not contain aluminium-bearing minerals. Moreover, the olivine of all these rocks is relatively low in iron. Because of the essential similarity existing between the country rocks one would expect that the associated chromites would be nearly the same in composition, yet no two are alike, although their $\mathrm{Cr}_{2} \mathrm{O}_{3}$ contents and in a lesser degree their $\mathrm{Al}_{2} \mathrm{O}_{3}$ contents are about the same. As shown in the above analyses the value $\mathrm{Cr}_{2} \mathrm{O}_{3}$ of pure chromite from dunite is always above 50 per cent.

The country rock of No. 487 is a lherzolite-a rock containing appreciable quantities of aluminium-bearing diallage pyroxene and in this case the associated chromite is relatively high in $\mathrm{Al}_{2} \mathrm{O}_{3}$, the $\mathrm{Al}_{2} \mathrm{O}_{3} \mathrm{MgO}$ salt forming, as seen by the table, at least 10 per cent more of the chromite than in the case of any chromite directly associated with dunite. Moreover, the $\mathrm{Cr}_{2} \mathrm{O}_{3}$ content is several per cent below 50 and the $\mathrm{Cr}_{2} \mathrm{O}_{3} \mathrm{MgO}$ content is comparatively low.

Chromite No. 518 came from a lherzolite carrying about 10 per cent diallage, that is from a rock much richer in $\mathrm{Al}_{2} \mathrm{O}_{3}$ than the dunites and, accordingly, the $\mathrm{Al}_{2} \mathrm{O}_{3} \mathrm{MgO}$ content of the chromite is high, higher even than in chromite No. 487, although the chromium spinels in the two are about the same in amount.

Thus the analyses seem to indicate a direct relationship between the composition of the chromites and that of their enclosing rocks. The chromites from the dunites are comparatively high in $\mathrm{Cr}_{2} \mathrm{O}_{3}$ and comparatively low in $\mathrm{Al}_{2} \mathrm{O}_{3}$, whereas the chromites from the lherzolites (rocks richer in $\mathrm{Al}_{2} \mathrm{O}_{3}$ ) are comparatively low in $\mathrm{Cr}_{2} \mathrm{O}_{3}$ and high in $\mathrm{Al}_{2} \mathrm{O}_{3}$. On the other hand, the chromites from the dunites, from rocks presumably very nearly alike in composition, exhibit a considerable variation in composition.

The peridotites and pyroxenites of the Black Lake-Thetford district are poor in iron as shown by their mineral constituents; this condition is reflected in the chromites which also are comparatively low in iron. The direct relations of the iron content of chromites with that of the country rock are strikingly shown in the case of the chromites of the ultrabasic rocks
of the northern Urals. These ultrabasic rocks are much richer in iron than those described above. The olivine of the Ural dunite contains more iron; koswite, one of the rock varieties associated with the dunite, is an olivine rock with diallage and much magnetite; diallagite and tilaite also contain much magnetite, indicating a magma rich in iron. Below are given the analyses and calculated compositions of the Ural chromites. ${ }^{1}$

## Analyses of Ural Chromites

|  | I | II | III | IV | V |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathrm{SiO}_{2}$ | $0 \cdot 82$ | $0 \cdot 90$ | $0 \cdot 82$ | 1.83 | 0.98 |
| $\mathrm{TiO}_{2}$ | 0.24 | $0 \cdot 24$ | $0 \cdot 40$ |  | $1 \cdot 14$ |
| $\mathrm{Cr}_{2} \mathrm{O}_{2}$ | $53 \cdot 60$ | $53 \cdot 19$ | $52 \cdot 67$ | $35 \cdot 88$ | $33 \cdot 10$ |
| $\mathrm{Al}_{2} \mathrm{O}_{3}$. | 9 -68 | 9.63 | $10 \cdot 56$ | $8 \cdot 57$ | 14.78 |
| FeO. | $23 \cdot 20$ | $21 \cdot 16$ | $23 \cdot 37$ | 42-61 | 37.99 |
| MgO | 12.26 | $14 \cdot 33$ | $12 \cdot 23$ | 10.04 | $8 \cdot 73$ |
| CaO | $0 \cdot 34$ | $0 \cdot 27$ | 0.24 |  | $0 \cdot 23$ |
|  | $100 \cdot 14$ | 99.72 | $100 \cdot 29$ | 98.93 | 96.95 |

I. d'Alexandrowsky-log, Taguil; II. Kroutoi-log, Taguil; III. Rivière Kaménouchka, Kaménouchky; IV. Centre du Iow, Tilai-Kanjakowsky; V. Rivière Omoutnaia, Syssertskaïadatcha.

The above analyses recalculated in the manner previously outlined, give the following results.

Recalculated Compositions of Ural Chromites

|  | I | II | III | IV | V |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathrm{Al}_{2} \mathrm{O}_{3} \mathrm{MgO}$. | $13 \cdot 82$ | $13 \cdot 83$ | $15 \cdot 12$ | $12 \cdot 62$ | $22 \cdot 40$ |
| $\mathrm{Cr}_{2} \mathrm{O}_{3} \mathrm{MgO}$. | $35 \cdot 95$ | $45 \cdot 69$ | $32 \cdot 66$ | 21.25 | 1.48 |
| $\mathrm{Cr}_{2} \mathrm{O}_{8} \mathrm{FeO}$. | 38.95 | $27 \cdot 50$ | 41.57 | 31.09 | 51.24 |
| $\mathrm{Fe}_{2} \mathrm{O}_{8} \mathrm{FeO}$. | $12 \cdot 12$ | 13.94 | 11.44 | $37 \cdot 64$ | 26.73 |
|  | $100 \cdot 84$ | $100 \cdot 96$ | $100 \cdot 79$ | $102 \cdot 60$ | $101 \cdot 85$ |

It is apparent that in the Ural chromites the iron spinels dominate, whereas in the Quebec chromites the magnesian spinels are the more abundant. Although the chromites from Quebec show great divergences of composition, and the same is true of those of the Urals, yet the chromites from each of these two distant countries have characteristic chemical compositions which are related to their respective ultrabasic mother rocks.

[^1]
## SOUTHERN PART OF OPEMISKA MAP-AREA, QUEBEC

By C. Tolman

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## INTRODUCTION

Opemiska quadrangle, Abitibi territory, Quebec, is bounded by latitudes $49^{\circ} 45^{\prime}$ and $50^{\circ} 00^{\prime}$ north and longitudes $74^{\circ} 30^{\prime}$ and $75^{\circ} 00^{\prime}$ west and lies about 150 miles north of the Canadian National railways. It is situated just west of Chibougamau district, has in places been prospected to some extent for a number of years, but first came into prominence in the autumn of 1929 when Leo Springer, prospecting for Prospectors Airways, Limited, made a promising discovery midway between lakes Presqu'ile and Opemiska. By spring the surrounding country was solidly staked. It was in consequence of this activity that the writer was instructed to enter and survey geologically the field in the 1930 field season. Time did not permit examining the whole quadrangle, and, therefore, mapping was confined to the southern part, which contained all the discoveries and was the most promising from the prospecting point of view.

The Opemiska quadrangle can be reached from points on the Canadian National railways by a number of canoe routes, each about 160 miles in length. The most used is that from Oskelaneo which for most of the distance follows the route into lake Chibougamau. The latter route is shown on a special route map on the scale of 3 miles to 1 inch, issued by the Quebec Department of Lands and Forests. For 12 miles from Oskelaneo the only obstacles are a lock over a cascade and a half-mile, wagonroad portage around rapids at the head of lake Bureau. From there the route crosses 60 miles of continuous lakes to lake Verreau. These lakes constitute part of the reservoir created by the Gouin dam on St. Maurice river. In the next 60 miles from lake Verreau to lake Obatogamau there are twenty portages, the longest of which is $1 \frac{1}{4}$ miles. In general they are in fairly good shape. From lake Obatogamau the route leaves the Chibougamau route and passes through lakes Eau Jaune, and Muskosho with intervening short stretches of Obatogamau river, to lake Presqu'ile at the southern boundary of the quadrangle. There are two portages in this distance, a short one around a fall at the outlet of lake Obatogamau and one over a mile long to avoid rapids at the outlet of lake Eau Jaune.


Figure 3. Southern part of Opemiska quadrangle, Abitibi territory, Quebec.

A second, well-travelled and fairly easy route begins at the Canadian National railways about 4 miles west of Monet station and follows Susie river and Cedar lake to Megiskan river and down that stream to the mouth of St. Cyr river. The latter river, which has no rapids, is ascended for 30 miles to lake Bailly in Bailly township nearly 80 miles by water from the railway. From lake Bailly a portage leads to the headwaters of Eagle river which empties into the northeastern part of Father lake. ${ }^{1}$ From Father lake, Opawika river is ascended through lake Bras-Coupé to Windy lake. Just beyond the head of Windy lake, a portage leads into lake Irene, from which by a number of small streams and lakes with intervening portages the southern tip of lake Eau Jaune is reached. The quadrangle is then reached by the mile portage at the lower end of lake Eau Jaune and thence by way of Obatogamau river to lake Presqu'sle. There is a variant of this route used principally by the Indians; instead of going to the head of Windy lake and thence by way of lake Irene to lake Eau Jaune, lake Presqu'ille is reached directly from the south from the Opawika drainage system by a number of small streams, lakes, and intervening portages.

For a number of years a winter road has been maintained from St.Félicien to lake Doré, Chibougamau district. During the winter of 19291930, it was extended westward from Dore lake into the Opemiska quadrangle, a total distance of about 180 miles from lake St.-Félicien. Some freighting was done into the area, the cost of which is said to have exceeded 25 cents a pound.

During 1930, transportation of freight and passengers into the area from points on the railway was done largely by airplanes. The usual freight charges ranged from 25 to 30 cents a pound. At these prices there was no competition from summer freighting by canoe. The most regular airplane service was maintained from Amos on the Canadian National railway. Airplane transportation companies with bases at Senneterre and Oskelaneo, on the Canadian National railways, and St.-Félecien on lake St. John, also brought freight and passengers into the area. The main Opemiska terminus is at lake Presqu'ile, but freight or passengers can be landed in the area on any lake of sufficient size.

The first geological observations in the area of Opemiska quadrangle are those of R. W. Brock ${ }^{2}$ who crossed the quadrangle by way of lake Opemiska and Chibougamau river. Henry O'Sullivan, Inspector of Surveys, Province of Quebec, surveyed the route through lakes David, Simon, and Asinitchibastat and down the river to Waswanipi. A general description of the country is included in his reports, published in 1898 and $1901^{3}$. A. P. Low ${ }^{4}$, in 1905, made a geological reconnaissance along Chibougamau river through lakes David, Simon, Asinitchibastat, and Opemiska to the junction of Obatogamau river. He continued up Obatogamau river through lakes Presqu'1le and Eau Jaune and the other lakes at the headwaters of the Obatogamau. In 1908 E. Dulieux ${ }^{5}$ visited lakes David, Simon, and Asinitchibastat.

[^2]The territory covered by the Quebec Mining Commission ${ }^{1}$ included a small part of the eastern margin of the Opemiska quadrangle. H. C. Cooke ${ }^{2}$ carried on geological reconnaissance in the general region, but makes no specific reference in his reports to the area embraced by the Opemiska quadrangle. In 1927, J. B. Mawdsley ${ }^{3}$ mapped Lake David area, the western part of which extends into the Opemiska quadrangle. J. M. Roi in 1928 and 1929, and Mr. Fafard in 1930, carried on topographic work for the Quebec Department of Surveys in the general area which includes the Opemiska quadrangle.

The writer in 1930, in connexion with the exploratory geological mapping of a large area, examined and mapped the geology of the waterways in the region of lakes David, Simon, and Asinitchibastat. ${ }^{4}$

Frank C. Foley and John R. Bridger rendered able assistance in the field. The field work was much facilitated through courtesies extended by engineers and prospectors of the district and the writer takes this opportunity of expressing bis appreciation of their assistance and cooperation. The major lakes and streams and several lines in the area had been surveyed by J. M. Roi, 1928-1929, and Mr. Fafard, 1930, both of the Quebec Department of Surveys. It is a pleasure to acknowledge the many courtesies received from different officers of the Department of Surveys at various times. The surveys of the Quebec department, supplemented by further surveys by the writer, served as control for geological mapping. Some of the laboratory work involved in this report was aided by an allotment from the grant made in 1930 by the Rockefeller Foundation to Washington University, St. Louis, for the support of research in science.

## GENERAL CHARACTER OF THE DISTRICT

The southern third of the quadrangle has very low relief. Its eastern part is particularly flat, swampy, and almost devoid of rock outcrop. Farther west, areas of rock outcrops are present and commonly form low elevations separated by stretches of sand-plain, morainal material, swamp, or water-filled depressions. There are two especially prominent areas of rock outcrop in this part of the region, one northeast of Presqu'ile lake and the other in the southwest corner of the quadrangle. Between them and stretching northward from lake Presqu'ille is a large area of drift and sand-plain, which has been swept clean by forest fires. Especially prominent in this locality is a stretch of morainal material extending northwest from lake Presqu'ile. The moraine is present largely as irregular accumulations not more than a few tens of feet in height, broken at intervals by sand-plain. They are composed of a wide assortment of rock material with diameters ranging up to several feet. Granite boulders are the most common. Some esker-like forms, traceable as far as 200

[^3]yards, were noted. North of the morainal accumulations are broad areas of sand-plain, probably representing outwash material. Just south of lake Opemiska, the sand-plain rises into an area of rougher topography with appreciable relief constituting the middle topographic zone of the quadrangle.

The middle topographic zone consists of a series of hills and ridges trending east-west through the quadrangle. They are most pronounced in the east and attain their greatest prominence farther east along the north shore of lakes Doré and Chibougamau. Near the west side of the Opemiska quadrangle, this topographical feature, as contrasted with its development farther east, tends to fray out. The hills and ridges are not as long and many of them are detached elevations rising abruptly above the general level. Some, especially those largely surrounded by sand-plain, are very conspicuous features. A good example of this type is Springer mountain situated just west of Springer lake and southeast of lake Opemiska. Its south side rises abruptly above the sand-plain. The northern slope is more gradual to the level of lake Opemiska. Aneroid readings indicate the hill to be about 600 feet above the level of lake Opemiska.

The northern topographic subdivision of the quadrangle is flat over wide areas. Here and there a few isolated hills rise conspicuously above the general level.

The character of the underlying rock is in some measure expressed in the topography of the quadrangle. Many of the prominent elevations are composed largely or wholly of dioritic or gabbroic rock bodies intrusive into the lavas and sediments. However, a few, such as Springer mountain, are composed predominately of lavas. Areas of volcanics and sediments tend to be relatively flat. Areas of granitic rocks typically present a more rolling type of topography.

The greater part of the quadrangle drains to Chibougamau river. A small area in the southern part drains to Obatogamau river which joins Chibougamau river about 25 miles west of the quadrangle. These waters, by way of Waswanipi river, reach Nottaway river and eventually James bay. Within the quadrangle, Chibougamau river consists of a series of lakes united by stretches of river. Opemiska lake is the largest and has an area of about 30 square miles. It is crossed by the west boundary of the quadrangle and its elevation above sea is approximately 1,032 feet; the elevation of lake Merrill in the southeast corner of the quadrangle is 1,215 feet. ${ }^{1}$

The southwestern part of the area has been swept clean by forest fires. Most of the remainder is fairly well forested with timber of pulpwood quality. Black spruce constitutes the best timber and also is the most common. Some very good stands occur south of lakes Simon and David and north of lake Opemiska. Jackpine is common in the sandy areas and many of the hills and ridges show a considerable number of white birch.

[^4]There appear to be no agricultural possibilities in the area. It is deficient in arable soil. Killing frosts also may be expected every month of the year. During the summer of 1929 a small vegetable garden was especially prepared by an employee of a mining company. Radishes were produced, but potatoes were not successful as the plants could not progress far before being frozen to the ground.

Game is not plentiful. There are a few moose and black bear. The Indians in the winter do some trapping of the small fur-bearing animals. Small game is practically absent. Rabbits are almost never seen. In some of the more open localities a few partridges can be found. Pike and pickerel are found generally throughout the lakes and larger streams. Some of the streams and lakes contain a few trout. Sturgeon are said to be quite prevalent in lake Presqu'fle.

## GENERAL GEOLOGY

## OUTLINE

All the consolidated rocks of the area are Precambrian. The oldest consist of altered volcanics and a thick, sedimentary series which separates the volcanics into an upper and a lower division. The sediments are conformable with the overlying and underlying volcanics.

The volcanics and sediments are intruded by much basic igneous material usually considerably altered, but originally of rock types ranging from diorites through diabases and gabbros to peridotites. They occur as dykes, sills, and bodies of more equidimensional cross-section, and range in width from a fraction of a foot to half a mile or more.

The volcanics, sediments, and the basic intrusives are intruded by large masses of granitic rock possibly not all of the same age. Some masses consist of two or more phases which in some cases at least probably represent separate but closely related intrusions. The rock types range from anorthosite and associated rock types to biotite granite, hornblende granite, and syenite.

Dioritic and diabasic dykes, commonly less than 50 feet wide, cut some of the granite bodies.

Table of Formations

| Quaternary | Peat, clay, silt, sand, gravel, and unsorted morainic material. <br> PrecambrianDranitic intrusives. <br> Intermediate and basic intrusives. <br> Upper volcanics: metamorphosed acid to basic flows and pyroclastics. <br> Sedimentary series: arkose, grit, conglomerate and minor amounts of grey- <br> wacke, slate, and limestones. <br> Lower volcanics: metamorphosed acid to basic flows and pyroclastics. |
| :--- | :--- |

## vOLCANICS

The volcanics are separated into a lower and an upper division by a sedimentary series which occurs conformably between them. The volcanics of the two divisions have the same general characters. Their manner of distribution in the southern part of the quadrangle is indicated on Figure 3. The northern part of the quadrangle was not mapped in detail, but so far as could be determined from reconnaissance along the main waterways, the volcanics appear to extend throughout without major interruptions.

The volcanics are greatly altered. Their original textures have been, with very few exceptions, entirely obliterated. Rock types of intermediate basicity appear to predominate greatly. More acidic types appear to be next in abundance. Basic and fragmental types appear to be mucb subordinate in amount.

At least 10,000 feet of volcanics are exposed beneath the sedimentary series with no trace of the basement over which they were extruded. Above the sediments is another great sequence of volcanics, but no evidence was obtained on which to base an estimate of its thickness. The general picture obtained was that of a great series of flows predominately of intermediate basicity, but with which in places are associated more acidic and more basic flows, and also bands of fragmental volcanic material.

Probably the most striking feature in the volcanic assemblage is a great succession of pillow lavas of intermediate basicity occurring in the upper volcanic group. They are best exposed north of Cavan lake where they are several thousand feet thick and where many of the flows show well-developed pillows. A similar succession is exposed less clearly just northwest of the southern tip of lake Asinitchibastat. Lower in the section, beds of tuff and breccia become prevalent. Also, there are some beds of arkosic material which, still lower in the section, increase in number until they predominate and with other sedimentary rock types constitute the sedimentary series. These relations are very well shown north of lake Cavan.

At the base of the sedimentary series the gradational relation between the sediments and volcanics is much more gradual than at the top. Beds of arkose interbedded with the volcanics are encountered for several thousand feet below the base. This part of the volcanic section, in the region south of West bay, lake Opemiska, where outcrops are best, is considerably obscured by a great number of gabbroic and dioritic intrusions. About a mile south of West bay and stratigraphically not far below the base of the sedimentary series, an especially fine series of flows was encountered of which many have extremely well pillowed tops. The same section is well exposed along the strike just southwest of Trenholme lake.

Small areas of acidic flows were found in a considerable number of places. Recognizable fragmental rocks, particularly finely laminated varieties, are widely distributed. No area in which there was a marked development of very basic flows was noted. A number of such flows were encountered here and there, interbedded with the other volcanic types.

The alteration to which the volcanic rocks were subjected has most commonly taken the form of the production of hornblende from the original ferromagnesian mineral and the breaking down of the plagioclase to a more sodic feldspar accompanied chiefly by epidote and zoisite. In places a variable amount of chlorite has been produced. An appreciable degree of schistosity has been produced only locally. In places, carbonatization and silicification are important.

Among a considerable number of thin sections of the least metamorphosed volcanics only one contained even a trace of the original plagioclase (about $\mathrm{Ab} 60-\mathrm{An} 40$ ). This slide also exhibited the only augite noted; in a few other slides the hornblende gives indications of being secondary after augite.

The bulk of the volcanics are some shade of green. Some exhibit some degree of schistosity, but the others show no schistosity, although they are thoroughly metamorphosed. The "greenstones" and "greenstone schist" are seen under the microscope to be composed of varying proportions of several or all the following minerals: hornblende, sodic plagioclase, zoisite, epidote, talc, chlorite, sericite, quartz, magnetite, leucoxene, pyrite, calcite, and biotite. Some of the main rock types are: amphibolite; hornblende schist; biotite-hornblende schist; chlorite schist; and tale schist.

The amphibolites are dense, almost black, rocks with, commonly, a slight greenish cast. In most examples minute, brightly reflecting cleavage faces of hornblende can be distinguished. The microscope shows that hornblende, the predominant mineral, is a green, brilliantly pleochroic variety. It occurs typically in particles about 0.15 mm . in diameter with a short, stubby habit. The next most prevalent minerals are sodic plagioclase, epidote, and zoisite in different relative amounts in the various examples. A few particles of magnetite, pyrite, talc, and carbonate are commonly present. In a few amphibolites the hornblende occurs as elongated particles, which tend to fray out at their ends and are oriented at random.

The hornblende schists differ chiefly from the amphibolites in the presence of schistosity, but many also contain much less hornblende. Some were formed from quite acidic rocks, are largely composed of feldspar and quartz, and in them the hornblende lies in more or less definite bands. Chlorite, on the whole, is rare. Epidote may be sparse or the rock may be essentially a horablende-epidote schist. Zoisite was noted in a few instances, but does not appear to be as prevalent as in the amphibolites. Sodic plagioclase, quartz, pyrite, magnetite, chlorite, biotite, talc, and sericite were noted in variable amounts. A few flows represent variants of the amphibolites and more rarely of the hornblende schists. They appear to have been, originally, andesitic types with large phenocrysts of feldspar now represented by pale green blotehes of saussurite.

Chlorite schists are subordinate in amount. Talc occurs in some of the amphibolites and hornblende schists and a few typical tale schists were encountered which were composed chiefly of talc and sodic feldspar with a little quartz.

Some of the volcanics contain practically no ferromagnesian minerals and appear to represent rhyolitic or trachytic types. They are, essentially, fine-grained aggregates of varying amounts of quartz and alkalic feldspar with scattered particles of zoisite and epidote. Sericite is commonly present and in most specimens examined there is considerable carbonate. Most of these rocks could be classified either as sericite schists or quartz schist.

The recognizable volcanic fragmental rocks can be divided into three types: coarse breccia; "pebble tuff"; and finely laminated tuff. These rocks are much subordinate in amount to the other volcanic types.

Coarse breccia representing brecciated or fragmental tops characterizes many flows. In such flows there is commonly a gradation upward from massive bottoms into a pillowed zone and from this into a blocky or fragmental top. Other examples of coarse, brecciated material probably are agglomerates. They consist of angular blocks up to several feet in diameter with, usually, very little matrix. Blocks and matrix now appear to be composed of the same material-although the matrix in places appears somewhat finer in grain-and are, in most cases, some variety of amphibolite or hornblende schist.

The so-called "pebble tuff" consists of fragments of material resembling rhyolite and ranging in average diameter from a fraction of an inch to 2 or 3 inches. In places they are flat, lens-like, and oriented parallel to the plane of the schistosity. The matrix where examined in detail is a fine-grained amphibolite.

The laminated tuff has usually a fine-grained, cherty appearance and occurs interbedded with the flows, in bands rarely more than 10 feet wide. The lamination of most is fine and regular. Some of the flows with which they are interbedded show pillow structure. Under the microscope many of the tuffs are structureless, aphanitic aggregates of quartz and feldspar no doubt representing a recrystallization of the original material. Some could quite well be devitrified, glassy tuff in which traces of chards had been obliterated. Some of the materials saggest that it may have been a crystal tuff, and in them angiular fragments of quartz, plagioclase, and orthoclase are scattered at random throughout a microcrystalline groundmass.

South and southeast of West bay, lake Opemiska, some narrow bands of laminated, cherty material contain magnetite and some hematite and resemble iron formation.

## SEDIMENTARY SERIES

The sedimentary series is conformable with the underlying and overlying volcanics. It occurs in two nearly parallel bands about $3 \frac{1}{2}$ miles apart, each about 2 miles wide and striking south 70 degrees east. The bands represent the same formation on the two sides of an eroded anticline. The beds are essentially vertical and over 10,000 feet of sediments appear to be represented. The southern band is best exposed between West bay, Opemiska lake, and Cavan lake. It stretches an unknown distance westward beyond the quadrangle. To the southeast the outcrops become fewer, are separated by large areas of morainal material and sand-plains and at the southeastern border of the quadrangle the band is cut off by
a body of granite. The northern band is best exposed just northeast of Trenholme lake. Its extension southeast is indicated by good exposures to beyond the southern border of the quadrangle. To the northwest this band is well exposed to the vicinity of Laura lake, but beyond there a large area of swamp lies along the strike of the sediments, outcrops are very few and those encountered were small and of rocks of rather indeterminate character. Some were no doubt metamorphosed dioritic or andesitic material, others may have been metamorphosed sediments. It is assumed, however, that the sediments persist in the direction of their strike and are cut off by the granite body bordering Opemiska lake.

Sediments were encountered on the shores of lake Deux Orignaux about 15 miles to the west of Opemiska quadrangle. ${ }^{1}$ Prospectors report the occurrence of similar sediments yet farther west on the shores of a large, unmapped lake west of Chibougamau river. Little is known regarding their distribution southeastward beyond the Opemiska quadrangle. A metamorphosed rock suggesting derivation from sediments occurs on the south shore of lake Presqu'ile and may represent the southeastern extension of the southern band beyond the granite mass of Presqu'ile lake. Metamorphosed sediments, probably belonging to the northern band, were noted near a granite contact just east of lake Muskosho.

No structural discordance whatever was noted between the sedimentary series and the underlying and overlying volcanics. At the base there is a transition zone from the lavas into the sediments at least 2,000 feet wide. The lower part of this zone consists of lavas, predominately andesitic, with minor amounts of interbedded sediments. Higher up, the sediments occur in increasing amounts until they constitute the predominant rock with few interbedded andesitic flows. The major portion of the sedimentary series contains little if any interbedded volcanic material. However, small bodies paralleling the sediments and consisting of altered igneous material occur in small numbers throughout the sedimentary bands. They may represent lava flows or sills of dioritic and gabbroic intrusives. The concordant relationship between the sediments and lavas is also shown at the upper contact. Just above the sediments is considerable volcanic fragmental material, much of which was waterlaid. This passes upward into andesitic lava, much of which is characterized by splendidly developed pillow structure.

The sediments consist predominately of coarse clastic material. Arkose, grit, and conglomerate are the most common rock types. Minor amounts of greywacke were noted. Very little argillaceous material appears to be present and only two narrow bands of limestone were encountered. The most prominent characteristic of the rocks as a whole is their highly feldspathic nature. The grain varies from very fine, like that of silts, to that of grits and conglomerate. A striking characteristic is a general lack of sizing of the constituent particles of the individual beds. A welldeveloped stratification is not general, although in most places there is at least a certain amount of broad bedding, which in the case of the arkoses is commonly indicated by lenses of grit or conglomerate. In the fine-grained types, the stratification tends to be thin and some very fine-grained types exhibit delicate lamination.

[^5]A highly feldspathic, fine to coarse-grained arkose is by far the most dominant rock type; much of it could be called a grit. This rock type is estimated to form over 70 per cent of the total sediments. Its weathered surface is markedly white and is of bleached, kaolin-like material resulting from the weathering of the feldspar. Freshly broken surfaces vary from a light to a very dark grey and some have a slightly greenish cast. Glistening feldspar cleavage faces are conspicuous on the fresh surfaces of most specimens, and the rock in some instances resembles markedly a syenite poor in dark mineral. Under the microscope poor sizing of the constituents is particularly marked and in typical examples 90 to 95 per cent of the rock is feldspar, of which one-sixth to one-half is in the form of subangular particles from 1 to 2 millimetres in longest dimension and distributed at random in a feldspathic ground of particles 0.01 to 0.05 millimetre in diameter. From 10 to 50 per cent of the larger feldspar particles show albite twinning. No microcline twinning was observed. No feldspar indices of refraction appreciably above that of balsam were noted. Quartz rarely exceeds 5 per cent of the rock and may be present in both large and small particles. Dark minerals are practically absent. Some fine, silt-like varieties are also composed of feldspar particles. In the feldspar grits, common variants of the feldspathic arkose, random particles up to 5 millimetres in longest dimension are present. Most of them are feldspar, but in some examples, some are quartz. They lie in a matrix composed essentially of feldspar particles less than one millimetre in diameter. No typical quartzite was noted.

Conglomerates are next in abundance to the arkose and are widely distributed. Outcrops of conglomerate practically continuous for as much as 400 feet across the strike were noted. The content of pebbles, cobbles, and boulders varies from place to place. There may be square yards with only one such fragment, very rarely do they exceed the matrix in amount, and typically they are only sparsely distributed through an arkose or grit matrix. Their diameters range from a fraction of an inch to as much as 2 feet. Probably those with diameters in the neighbourhood of 5 inches are the most common. Those of granitic rocks are rather well rounded, whereas the few noted of greenstone and slaty material tend to be of irregular form. The characters of the fragments were carefully noted and specimens of the different types were collected and studied in thin section. Most are syenites, flesh to grey in colour, fine to coarse in grain, and equigranular, or, as in some cases, porphyritic. In the syenites no feldspar with an index appreciably above that of balsam was noted. Some specimens are predominantly of potassium feldspar, others are predominantly of albite (Ab $93+$ An 7 ), but the majority show varying proportions of albite and potassium feldspar. About 5 per cent of quartz is present in most slides and apatite and zircon were noted as accessories. In some slides very small amounts of chlorite apparently derived from some original ferromagnesian mineral, are present. Other pebbles noted in very small numbers comprise chlorite schist, slate, metargillite, diorite, quartzfeldspar porphyry, and hornfels.

A few narrow beds of slate were noted, some of which showed fine lamination. A small amount of sheared greywacke was encountered. A little graphitic schist was found in one locality. Two bands of limestone

[^6]were noted. Two exposures of one of these bands occur about $2 \frac{1}{2}$ miles northeast of lake Presqu'lle. At one outcrop the exposed thickness is about 50 feet; one contact lies in a swamp and the other is with banded argillaceous material and feldspathic quartzite. The other occurrence is about one-half mile east of Laura lake and consists of a band of limestone about 20 feet thick with slate and feldspathic quartzite adjoining. From its reaction with dilute acid, the limestone appeared to be dolomitic.

All the sediments exhibit some schistosity, but, except locally, it is only marked in the fine-grained varieties. In general, the conglomerate pebbles have not been elongated, although locally the appearance of some of the greenstone and slaty pebbles suggests that they may have been so affected. The matrix, especially when fine grained, and locally where coarse grained, shows schistosity which, when intensely developed, appears to wrap around the pebbles.

## Structure of Volcanic and Sedimentary Assemblage

The major structure in the southern half of the quadrangle is a closely compressed anticline trending about south 70 degrees east. The structure appears to persist at least as far west as lake Deux Orignaux about 15 miles beyond the western boundary of the map-area. In the map-area, the anticline plunges to the southeast. Beyond the map-area, to the southeast, particularly in the neighbourhood of lake Obatogamau, prominent north-south cross-folding, probably accompanied by some faulting, is indicated. Dips are everywhere very steep if not vertical.

The general structure of the volcanics and associated sediments is confirmed by the relationship of the primary flow structures, bedding and lamination of the volcanics or sediments to the schistosity produced in them. In the western part of the area, the schistosity is for the most part approximately parallel to the primary flow structures, bedding, and stratification. In the southeastern part the schistosity continues to trend easterly, but primary flow lines, bedding, and stratification deviate to the south. This relationship becomes more marked beyond the southern limits of the area. Accordingly, the lavas and sediments in this locality would appear to form the north limb of an anticline plunging southeast.

## INTERMEDIATE AND BASIC INTRUSIVES

A large number of intermediate and basic intrusive masses occur in the area. They are of different relative ages, but all are younger than the volcanics and sediments and older than the granite intrusives. They occur as dykes, sills, and larger irregular bodies with minor dimensions of several thousand feet.

The following petrographic types were distinguished: diorite, gabbro, diabase, pyroxenite, and peridotite.

Diorite, commonly greatly altered, is the most prevalent rock type. It varies wideiy in the kind, relative amounts, and textural relations of the original minerals and in the degree of alteration and the kind, relative amounts, and textural relations of the resultant alteration products. The rocks range from fine to coarse. Porphyritic types are relatively rare. The colour on freshly broken surfaces varies from light grey to almost black. A greenish cast is common. The feldspar of some, especially in
acidic segregations, is slightly pinkish. The weathered surface of finegrained varieties is typically greyish brown, whereas that of coarse varieties is typically mottled. Feldspar may predominate in amount and have the appearance of a base throughout which are scattered elongated particles of hornblende oriented at random. Microscopically the diorites show variable proportions of sodic plagioclase, hornblende, epidote, zoisite, magnetite, leucoxene, apatite, pyrite, sericite, chlorite, and quartz. In every specimen examined, the original plagioclase has been completely changed to a mixture of albite, zoisite, epidote, and in places particles of either, or both, sericite and hornblende. The material secondary after feldspar ranges in amount between 30 and 55 per cent. The hornblende is greenish and occurs mainly in elongated particles bounded by cleavage faces. The hornblende content ranges from 30 to 50 per cent. Magnetite is the commonest accessory. In a few slides it is surrounded by leucoxenelike material. Apatite is not nearly so common. Some disseminated pyrite is usually present. A few particles of quartz were noted in some specimens. Chlorite was noted in only one section, in very small amounts.

Most of the rocks classified as gabbros contain augite, or there is a suggestion that some of the mineral constituents are secondary after this mineral.

Megascopically they can be distinguished from the diorites only by their greater percentage of dark mineral and common tendency to be coarse grained. In the larger masses, coarse-grained, acidic segregations and basic phases are common. The colour of the gabbros on freshly broken surfaces ranges from dark grey to black with a greenish cast. On the weathered surface they are typically mottled, and the white-weathering feldspar and the greenish ferromagnesian minerals contrast sharply. The plagioclase is albite with which epidote, zoisite, and occasionally sericite and hornblende are intimately associated. Determinations of the plagioclase of the "Ventures" gabbro from a number of points gave Ab $88+\mathrm{An} 12$. The augite is considerably altered, in most cases to hornblende, and only the merest remnants may remain. Magnetite is the commonest accessory and is in some cases surrounded by leucoxene. In one slide some well-crystallized titanite was noted. Apatite may be present. Pyrite is common. A little carbonate is present in many of the rocks.

Diabasic texture is not commonly present in the dioritic and gabbroic rocks. Traces of it can be seen in a number of occurrences and it may have orginally been quite prevalent.

Pyroxenites make up some small intrusions, but generally occur as phases of large, gabbroic masses as in the case of the "Ventures" gabbro and large intrusions to the northwest. They are the least altered rocks of this group. The primary minerals noted were augite, hornblende, and magnetite. Augite appears to be the ordinary non-pleochroic variety. Primary brown hornblende is present in many of the occurrences. As alteration products the following were noted: aggregates of zoisite, epidote, chlorite, green hornblende, serpentine, and tale with magnetite.

The rocks classed as peridotites are highly altered and were found only as dykes. They are, in every case, largely of serpentine, talc, and magnetite with, commonly, some remnants of pyroxene. Asbestos veinlets a fraction of an inch in width are common in such bodies.

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Three, large, isolated areas of granitic rocks occur within the area. Each is composed of rock types differing from those of the other two areas.

One of these areas lies in the region of lakes David, Buckell, Dulieux, Simon, and Asinitchibastat. It is about 5 miles wide and 10 miles long and is the western and greater part of a band-like area continuing a few miles east of the east edge of the quadrangle. Mawdsley ${ }^{1}$ has given an account of the rocks of a part of this area. He distinguished three main types which he named oligoclase granite and syenite, oligoclase anorthosite, and albite-oligoclase granite. He found that...."end phases of each type resemble end phases of the other types"... and because "all three types show certain petrographic peculiarities".... he suspected...."that all originated from a common magma and are of about the same age." The results of the present writer's more extended observation indicate that the oligoclase granite and syenite type could be better referred to as diorite, quartz-diorite, and gabbro. All the types and phases are highly altered in that the plagioclase has been converted into a more sodic variety accompanied by such minerals as zoisite, epidote, sericite, and chlorite. An opalescent quartz characterizes all types.

Each of the three main types occupies large areas, but in each such area there are minor areas of the other rock types. The anorthosite commonly contains inclusions of the gabbro, diorite, and quartz diorite type. Both these types are cut in many places by the granite.

The diorite-gabbro type is commonly dark greenish grey on weathered surfaces and dark grey to black with a greenish tinge on fresh surface. In some varieties, most commonly the quartz diorite, the feldspar has a pinkish cast and the rocks are transition phases towards granite. The minerals recognizable megascopically are: hornblende, feldspar, opalescent quartz, epidote, and chlorite. Microscopically the feldspars are seen to be now represented by a sodic plagioclase, usually with much associated zoisite and epidote and smaller variable amounts of sericite and hornblende. Common green hornblende also occurs as large particles, possibly secondary after augite. The relative proportions of the hornblende and the saussuritized feldspar vary considerably, so that both dioritic and gabbroic phases occur. Quartz is a minor constituent in some of these rocks and in the quartz diorite is an essential constituent. It is opalescent, is strained, and is dusted with minute inclusions. Magnetite and apatite are generally present as accessory minerals.

The anorthosite weathers white or light grey. On fresh surfaces it is light grey with a slight greenish cast and rarely shows some brightly reflecting feldspar cleavage faces. Scattered through the rock are light green blotches apparently composed largely of epidote and chlorite. Typically the rock is coarse grained, but in many places the feldspar has been granulated. Microscopically the feldspar is seen to be now represented by an intimate mixture of sodic plagioclase (Ab 95 An 5 in the slides examined), zoisite, epidote, chlorite, and white mica. Commonly the sodic plagioclase is greatly obscured by the accompanying minerals.

[^7]Hornblende with associated chlorite, epidote, and zoisite appears in those phases of the anorthosite gradational into the diorite gabbro type. Opalescent quartz is present in phases gradational into the granitic type.

The granite is light grey with, in places, a pinkish cast. An opalescent variety of quartz may make up as much as 50 per cent of the rock. Very little dark mineral is present as a rule, but a little hornblende altered in various degrees to chlorite is present in places. The feldspar appears to have been plagioclase now represented by albite, zoisite, epidote, chlorite, and white mica. Apatite, magnetite, and zircon were noted as accessories. With increasing amounts of hornblende there are types gradational between the granite and the quartz diorite.

A second area of granitic rocks lies north and west of lake Presqu'ile. This area extends south beyond the quadrangle; granite outcrops on the southern shore of lake Presqu'sle, but how much farther it may extend is not known. The rocks of this area are granites, light grey to flesh coloured, of medium grain and composed essentially of feldspar, quartz with an opalescent tendency, and variable amounts of biotite and hornblende. They are massive and comparatively fresh appearing. Thin sections of typical granite contain 20 per cent quartz, 65 per cent feldspar (microcline and oligoclase), about 15 per cent hornblende and biotite, and the usual accessories apatite, magnetite, titanite, and zircon. The hornblende and biotite are relatively unaltered. Oligoclase preponderates over the microcline in most places. The microcline is comparatively fresh, but the oligoclase is masked by white mica and minor amounts of slightly pleochroic epidote. A considerable number of dykes related to the intrusion cut the bordering volcanics and sediments to the north. Quartz-feldspar porphyries are the most numerous, but quartz porphyries and feldspar porphyries are also present. Most of the dykes are very low in dark mineral.

The third granitic area is elongated east-west and extends for about 12 miles into the quadrangle from the west in the region of Opemiska lake where it averages about 7 miles in width. Three distinct phases are represented, namely, hornblende granite, hornblende syenite, and mica diorite. The granite occupies the greatest area; the syenite and the diorite are of the nature of border phases. The granite is pinkish to flesh coloured and of medium grain. Flesh-coloured to pinkish feldspar with highly reflecting cleavage faces is the predominant constituent. Quartz is the next most prominent constituent and commonly shows a reddish tint. It comprises as much as 35 per cent of the rock in places, but probably 25 per cent is the normal content. Hornblende is the only original femic mineral; a representative specimen would probably contain about 10 per cent of hornblende. Small blotches of epidote can be seen scattered throughout the rock. The microscope shows that both microcline and sodic plagioclase are present in varying relative amounts, but the sodic plagioclase always seems to predominate. The bornblende is the ordinary green pleochroic variety. The quartz is strained. Magnetite, titanite, apatite, and zircon are present as accessories.

The syenite occurs along the borders of the granitic body in a band ranging between 1 and 2 miles in width. There is a gradual transition from the granite into the syenite which, in places along the edge of the intrusion, grades into diorite. Megascopically and microscopically the
granite and the syenite are similar, except that in the case of the syenite quartz is lacking or is only an accessory constituent. Just west of the Opemiska landing, a striking porphyritic phase of the syenite occurs with phenocrysts up to $1 \frac{1}{2}$ inches in length. The phenocrysts tend to show a definite orientation striking about 112 degrees magnetic.

The diorite was noted at intervals along the southern contact of the intrusion. It grades into the syenite in a short distance. Its greatest width is about one-third of a mile. Outcrops were noted in particular northwest of Springer lake and at points about $1 \frac{1}{2}$ miles and 3 miles east of West bay, Opemiska lake. The rock is medium to coarse grained and equigranular. Megascopically it differs from the syenite in its larger percentage of dark minerals (biotite and hornblende) and in the feldspar being grey or as in a few places having only a slight pinkish cast. Biotite in well-formed flakes is a prominent constituent. Under the microscope the minerals noted are: plagioclase, microcline, biotite, hornblende, augite, epidote, zoisite, white mica, quartz, apatite, and magnetite. The original plagioclase is greatly altered; remnants vary considerably in percentage composition from place to place; Ab $70+$ An 30 was the most calcic of the determinations made. A few particles of microcline were noted in the more syenite-like varieties; it was absent in the more basic type. Dark minerals comprise about 35 per cent of the rock and in typical examples are represented by about equal amounts of augite, hornblende, and biotite. The hornblende is the common green variety and it is thought that some of it is primary. Dykes related to this granitic body intrude the bordering rocks a short distance from the main mass. They are particularly common along the eastern contact. Most are porphyritic and many of them are of syenitic types.

## DIORITIC AND DIABASIC DYKES

A few narrow dykes intrude the granitic intrusives. Some of them are probably genetically related to the igneous mass which they intrude. Others do not appear to be so related and most of these appear to be diabases. To what extent these later dykes occur within the pre-granitic rocks cannot be definitely told, for they cannot be distinguished from the pre-granite intermediate to basic intrusives. A number of narrow dioritic dykes intrude the western end of the "Ventures" gabbro in the region of the important sulphide mineralization.

## ECONOMIC GEOLOGY

## GENERAL FEATURES

Opemiska district received little attention from the prospector until the autumn of 1929. Some work had been done previously on lake Asinitchibastat, lake Simon, and that part of lake David which lies within the quadrangle, but very few claims were held in the quadrangle in the summer of 1929. However, with the discovery, in September 1929, by Leo Springer of the Prospectors Airways, Limited, of a promising prospect midway between lakes Opemiska and Presqu'ile, the whole southern half of the quadrangle was soon staked. In the following spring a number of individuals and companies began active prospecting and testing of mineral discoveries.

The most important mineral desposits so far discovered occur in comparatively narrow zones of shearing traversing the volcanics and sediments or the intermediate and basic rock bodies intruding them: Characteristically there is little gangue other than the country rock, but locally quartz is present in considerable amounts. The metallic minerals are mainly chalcopyrite, pyrite, pyrrhotite, and magnetite. Small amounts of sphalerite are usually present and a little arsenopyrite and molybdenite has been noted. Assays of some occurrences show appreciable amounts of gold. Some of the deposits have vein-like forms, others consist of a single, short lens or a succession of lenses. Their widths range from a fraction of a foot to 10 to 12 feet.

At two localities, sulphides occur in comparatively narrow bands of limestone belonging to the sedimentary series associated with the volcanic rocks. Quartz veins, most of them small, occur throughout the area. They are chiefly in the volcanics and sediments, but have been found cutting the granitic bodies. Their content of metallic minerals is, as a rule, very low.

## OPEMISKA MINES, LIMITED

The property of Opemiska Mines, Limited, is about $3 \frac{1}{2}$ miles north of lake Presqu'ile, from which a rough wagon road leads to it. The original discovery was made in the autumn of 1929 by Leo Springer of the Prospectors Airways. Shortly thereafter the property was bonded by Prospectors Airways, Limited, to Ventures, Limited. Ventures, Limited, carried on a program of prospecting, stripping, trenching, and diamond drilling until September 1930, when Opemiska Mines, Limited, was formed to take over the property.

The country rock in the locality of the original discovery is an altered gabbro generally known as the "Ventures gabbro" and which is one of the intrusions grouped under the heading of intermediate and basic intrusions. It is intruded by a number of narrow dykes all of which appear to be pre-mineralization in age. The important mineralization is confined to the southwest end of the Ventures gabbro. This body is elongated in a northeast direction at an angle to the general structure of the area and is about 2 miles long and about $\frac{1}{2}$ mile wide at its widest part near its middle. The outline of the body is somewhat irregular, but in general it appears to gradually taper at its ends. The southwest end is not well known, as the contact is there obscured by a sand-plain of wide extent. The gabbro body along its eastern side is bounded by an area of highly altered dioritic rock also belonging to the group of intermediate and basic intrusives. The relative ages of the gabbro and the altered diorite are not definitely indicated, but it is surmised that the diorite is the older because it is more altered and because it is intruded by some higbly altered basic dykes not found intruding the gabbro. Along the northern part of its western edge, the gabbro intrudes altered lavas of intermediate basicity. Along the southern part of the west edge, the bounding rocks are altered acidic rocks, probably approaching a trachyte in composition. The opinion has been expressed that the fine-grained acidic rock intrudes the gabbro, but the present writer, after a study of the contacts in exposures and drill cores, believes that the qabbro intrudes the acidic rock and that there is
no definite evidence suggesting that the latter is not a member of the volcanic series. The relations are complicated by the presence of dykes in the vicinity of the contact. The ages of the rocks are of considerable importance from the standpoint of the possible extension of the mineralized shear zones into the acidic rock.

The gabbro typically is a coarse, even-grained rock consisting essentially of hornblende and plagioclase. Hornblende is estimated to make up about 55 per cent of the rock in most places. Small segregations rich in feldspar or abnormally rich in hornblende and not more than a few square yards in area are sparsely present. Both types are usually present in the same locality. A particularly large basic segregation or phase of the gabbro occurs a short distance east of and along the strike of the mineral deposits. Opinions have been expressed that it is an intrusion distinct from the gabbro. However, to the writer there seems little doubt that it is a phase of the gabbro of the nature of a large segregation. Its contact with the normal gabbro, where exposed, is gradational, although the transition takes place in a few inches. This feature is also typical of the smaller segregations. A rough banding, striking 163 degrees magnetic, is discernible in the northern part of the intrusion. Elsewhere the rock is essentially structureless except for local shear zones. The rock in general gives the impression of freshness and its rather thoroughly metamorphosed nature is hardly apparent except under the microscope.

Minerals recognizable in the gabbro under the microscope are plagioclase, hornblende, remnants of augite, magnetite, titanite, apatite, chlorite, epidote, calcite, and pyrite. The composition of the feldspars as determined in specimens from various parts of the mass varies little from Ab 88+An 12. Most of the feldspar is considerably obscured by small particles of epidote and tiny shreds of hornblende. The hornblende is a green, pleochroic variety, and in addition to tiny shreds in the plagioclase it occurs in large crystals. In a few slides remnants of augite were noted forming cores in the large particles of hornblende and most if not all the particles of hornblende are presumably secondary after augite. In some slides a very small amount of the hornblende bas changed to chlorite. A very few clean-cut particles of titanite were observed, but in most cases it is represented by leucoxene associated with magnetite, assumed to be titaniferous. Very little apatite was observed. Calcite is not particularly prevalent. There are scattered particles of pyrite in most places.

Dykes intruding the gabbro appear to occur mainly or solely in the southwest part of the mass in the region of the important metallic mineralization. Most of them are dioritic or more basic. A few are more acidic and are either porphyritic or equigranular. All are considerably altered, particularly those tending to be basic in composition. None of the dykes can be traced far. They either pinch out or are faulted. A striking feature brought out by the dykes is the great amount of minor faulting to which the rocks have been subjected. In an exposure of 50 feet of one narrow dyke, there were nine faults striking in various directions, with displacements ranging from 2 inches to 2 feet. Some of the dykes certainly are older than the mineralization, because they are offset by shear zones or faults which are pre-mineralization. No evidence was obtained that would suggest that the dioritic dykes were not all of the same general age. The age relationship of the acidic dykes is not known.

All the dioritic and more basic dykes that were found lie in the gabbro, except one which intrudes the acidic volcanics near the contact of the gabbro. They vary in width from a fraction of a foot to 10 feet. Many pinch and swell markedly along their strike. A number contain small inclusions of gabbro and others split before pinching out. Most of them have an easterly trend along the same general direction followed by the mineralization and the general structure. A few, however, are at a considerable angle to this direction. Their dip where it could be observed ranges from 65 degrees to vertical. The dip of any one dyke may change markedly from place to place along the strike.

The dyke rocks are fine to medium grained, their weathered surfaces are yellowish brown and commonly are pitted. Freshly broken surfaces are dark grey to black, commonly with a greenish cast. Some show pink blotches of calcite scattered throughout or over considerable areas. Some show a porphyritic tendency in the hand specimen with phenocrysts of dark mineral.

The dioritic dykes have the petrographic character of lamprophyres. The ferromagnesian minerals occur both as phenocrysts and as constituents of the groundmass. Feldspar is confined solely to the groundmass and in most examples is subordinate in amount. The occurrence of the dykes in or near the gabbro suggests that they may be genetically related to it, but their mineral composition indicated that such is probably not the case. The percentages of dark mineral in them and in the gabbro are of the same order of magnitude, whereas lamprophyres of a gabbro typically should be much more basic. It would seem that these dykes are most probably related to a more acidic igneous mass than the gabbro, possibly the same igneous mass that gave rise to the solutions from which were deposited the vein minerals comprising this deposit.

A feldspar porphyry dyke was encountered in one drill hole and passed through for a distance of 2 feet. It is a light grey rock with a small amount of dark mineral scattered throughout. In thin section more than 60 per cent of the rock is seen to consist of phenocrysts of albite and of orthoclase with a few of hornblende. About half of the groundmass is quartz. The remainder is feldspar with random flakes of biotite and a little hornblende. The core of another drill hole shows 45 feet of fine to medium-grained, dark grey, syenitic rock. The microscope shows the rock to be composed almost wholly of sodic plagioclase considerably altered. About 5 per cent of quartz, but no dark mineral, was shown in the slide.

The metallic mineralization lies in shear zones and simple fractures or faults. The most important of these structures from the mineralization standpoint trend east. Others of subsidiary importance trend southeast and some at least of these, although pre-mineralization in age, are later than the east-west shear zones. Three important east-west mineralized shear zones have been distinguished. In these zones the widths of important sulphide mineralization as exposed in outcrop stripping and trenches varies considerably from place to place and reaches a maximum of 12 feet. The northernmost shear zone, known as zone No. 1, has been traced on the surface in outcrop and in trenches for about 500 feet and is mineralized throughout this distance. The dip is somewhat variable, but is in the neighbourhood of 65 degrees north. Three diamond drill holes indicate that the shear zone extends for about 250 feet east beyond the surface exposures, but with greatly diminished mineralization. Zone No. 2
roughly parallels zone No. 1, lies about 150 feet to the south, and has been traced on the surface, in outcrop and in trenches, for about 800 feet. Zone No. 3 is much less definite than the other two. It lies about 300 feet south of zone No. 2 well down the billside where rock exposures are poor. As exposed at the present time it appears to consist of a number of relatively short lenses. Between the three mineralized zones there are small shear zones or fractures trending in the same general direction and which are more sparingly mineralized.

Shear zones trending northwest and intersecting the main east-west zones exerted considerable influence on the deposition of the ore minerals. This is particularly well shown in two places along zone No. 1. At one such place the mineralization turns from the normal east-west diection to the southeast along an intersection shear zone which it follows for about 40 feet to where it again turns east. A fairly strong shear zone continues southeast and appears to intersect zone No. 2 and to cause a similar deviation in the strike of the mineralized zone. This cross shear, although pre-mineralization, appears to be later than the east-west shear zones, for it has offset them. Another cross shear zone parallel to the one just described intersects zone No. 1 farther east, offsets the east-west zone about 30 feet, and is also mineralized between the offset ends of the east-west shear zone. The second cross shear dies out southeast of mineralized zone No. 1 and does not affect zone No. 2. It continues northwest of zone No. 1 and about 50 feet from zone No. 1 intersects a lamprophyre dyke, displacing it about 30 feet.

The main shear zones weaken to the east and the mineralization dies away. The zones cannot be located in the outcrops a few hundred feet east. The gabbro there is more compact and structureless, and in general is finer grained and in part more basic. Little is known of the structural conditions to the west. A wide stretch of sand-plain devoid of outcrop stretches west from the hill on which the deposit is situated. In zones Nos. 1 and 2 shearing and metallic mineralization occur in the westernmost trenches, but neither the shearing nor the mineralization is as strong as farther east. These trenches are near the western edge of the gabbro. Neither the shearing nor the mineralization seem to extend far west beyondthem, for a diamond drill hole put down to intersect the mineralized zones a short distance west of these trenches did not encounter prominent shearing nor appreciable mineralization. This hole was in an aphanitic acidic rock for its whole length of 269 feet. Another drill hole which passed east of the westernmost trenches showing mineralization in both zones Nos. 1 and 2, showed very little metallic mineralization. This hole passed through the aphanitic acidic rock for 100 feet from the surface, then through over 70 feet of gabbro, and back into the acidic rock which continued to the bottom of the hole at 248 feet. The little metallic mineralization encountered was in the gabbro. The apparently rather abrupt termination of the mineralization and of conspicuous shearing in the region of the contact between the gabbro and the acidic rock on the west, suggests that the acidic rock may be younger than the mineralization. But the termination of the same features at the east end of the mineralized zones takes place in the gabbro and is no less abrupt. The acidic rocks exposed in the few outcrops and the drill cores could well be members of the volcanic assemblage and the writer prefers to consider them as such until definite evidence to the contrary is found.

The minerals noted in the deposit are as follows: magnetite, chalcopyrite, pyrite, pyrrhotite, sphalerite, arsenopyrite, molybdenite, covellite, azurite, malachite, marcasite, quartz, actinolite, biotite, and calcite. Two generations of quartz are recognizable in places. The early generation is the earliest of the minerals. It is extremely fractured and is veined by the other minerals as well as, in places, by the later generation of quartz which, however, occurs only in very small amounts. Actinolite and biotite appear to have formed next. They appear always to be accompanied by magnetite and chalcopyrite. Magnetite appears to have been the first metallic mineral deposited. It is followed by pyrite, pyrrhotite, and chalcopyrite. Chalcopyrite is the predominating sulphide; pyrite is next in amount followed by pyrrhotite. The other sulphides are present sparingly. Covellite was noted as a coating of fractures traversing chalcopyrite. Azurite and malachite were also noted as surface coatings. Marcasite in nodular forms and in places associated with pyrite, was noted in small amounts in two trenches. It is probably of late generation and possibly was produced by downward moving solutions. Calcite, which is very subordinate in amount, also came in late.

Some silver is reported in most assays and in some amounts to several ounces to the ton, but the silver-bearing minerals were not identified. Gold values are general and in places are high. Neither native gold nor tellurides have so far been found. In places the gold seems associated with arsenopyrite, for in one drill hole phenomenal gold values were obtained in mineralization where arsenopyrite was a prominent mineral accompanied by pyrite and a little chalcopyrite. However, the distribution of gold values throughout the property is much more general than the distribution of arsenopyrite. Some pyrite may be auriferous, but it does not seem generally so. There is considerable variation in the physical appearance of the pyrite from place to place in the deposit. In apparently massive chalcopyrite, gold values occur, but as far as the writer is aware they are never above the average.

The important mineralization, as previously stated, is confined to three shear zones, striking roughly east-west. Zone No. 2 is about 150 feet south of zone No. 1; zone No. 3 is about 300 feet south of zone No. 2.

Outcrops and trenches indicate that mineralization is essentially continuous in zone No. 1 for about 500 feet and in zone No. 2 for about 800 feet. Diamond drilling on zones Nos. 1 and 2 has not, so far, extended their lengths appreciably. The dip of these two zones varies somewhat, but in general is between 55 and 70 degrees north. The drill cores show that the mineralization at the depth of intersection is of about the same characters and carries about the same values as at the surface. The two zones carry, in general, appreciable values of copper and gold and in most places, silver, over widths ranging from a fraction of a foot to 12 or 14 feet. Some zinc also appears in places.

Numerous assays of samples from the surface and from drill cores have been made and from the results in the possession of the mining company indicate wide variations in the copper and gold contents from place to place both along and across the mineralized zones. In the cases of zones Nos. 1 and 2, for part breadths of a foot or more of the individual cross-sections, the copper content ranges from less than 1 per cent to nearly 30 per cent and the gold values from 20 cents to nearly $\$ 13$ a ton.

There is much heavy overburden in the locality of zone No. 3. Several lenses of mineralization are indicated which are difficult to line up. The mineralization is similar to that in zones Nos. 1 and 2, but the widths are narrower. This zone has been drilled by four holes. They showed small lenses of mineralization which in places appear closely spaced and may represent low-grade ore.


A detailed picture of the mineralization can best be given by summary descriptions of the trenches. The trenches are at right angle or nearly so to the mineralized zones and with few exceptions the mineralized material has been blasted out for a few feet.

The trenches crossing this zone are considered in order from west to east.
Trench No. 1 is in the sand-plain at the foot of Ventures hill and apparently did not reach bedrock.

Trench No. 2 was filled with water at the time of examination. There is said to have been a width of about 10 feet of heavy sulphide mineralization. Specimens on the dump show magnetite, pyrite, and chalcopyrite with a small amount of quartz.

Trench No. 3 is about 25 feet long. The middle 10 feet of the section exposed in the trench is mineralized with chalcopyrite ( 25 per cent), milky to clear quartz ( 25 to 50 per cent), and considerable magnetite. The quartz is veined by the metallic minerals. The remainder of the trench is in sheared gabbro with shears 6 to 8 inches apart and connected by cross fractures. The fractures and shears contain stringers of chalcopyrite, pyrite, and magnetite, up to one inch in width. The intervening rock is fresh looking and is sparsely impregnated with fine particles of pyrite.

Trench No. 4 and the stripping adjoining have exposed about 3 feet of heavy sulphide mineralization with about 6 feet of quartz containing blotches of magnetite with very little sulphide. The boundary between the rich sulphides and the quartz-bearing part is sharp, but stringers of the metallic minerals finger into the quartz. The band rich in metallic minerals continues to the eastern end of the stripping, but there nearly pinches to nothing, its place being taken by the quartz band. Blebs of watery quartz with much chalcopyrite, some pyrite, and magnetite are the predominant minerals of the zone rich in sulphide. The trench also exposes a few widely separated veinlets of various proportions of chalcopyrite and pyrite a fraction of an inch wide traversing the gabbro.

Trench No. $5 b$ reveals a width of about 6 feet fairly heavily mineralized with chalcopyrite, pyrite, and magnetite. The gabbro exposed in the trench south of the main mineralized zone is sheared and is impregnated with pyrite. The gabbro of the northern part of the trench is massive except for an irregular jointing. In the western part of the stripping at trench No. 5b about one foot of massive quartz is present and rather sparsely distributed veinlets of magnetite and a little chalcopyrite up to 2 inches wide cut the adjoining gabbro.

Trench No. 5 shows a strongly sheared zone 4 feet wide with about 9 inches on the south side heavily mineralized with magnetite, chalcopyrite, and pyrite which also occur sparsely distributed through the zone and, here and there, in blebs. The remainder of the trench is in coarse, blocky gabbro with sparse disseminations of pyrite. A very small amount of quartz, and some biotite and actinolite are intimately associated with the sulphides. A little calcite was also noted.

Trench No. 5a. Between trenches Nos. 5 and $5 a$ the mineralized zone follows a southeasterly trending cross fracture. This part of the sheared zone is about 6 feet wide and holds a lens of quartz about 2 feet wide by 12 feet and also quartz stringers, but very little metallic mineralization is visible. At trench No. 5a the shear zone resumes its easterly course and a width of about 5 feet consists largely of chalcopyrite with some magnetite and pyrite, and sparse blebs of quartz and some biotite.

Trench No. 6 displays a width of about 9 feet of good chalcopyritequartz mineralization. About 3 feet of this, in the southern part of the trench, is almost massive chalcopyrite, with particles of sphalerite and blebs and veinlets of pyrrhotite; this along its southern side grades into a 4 -inch band or lens of pyrite, which seems to pinch out in the eastern wall of the trench but extends to the west for about 3 feet.

## Zone No. 2

The trenches crossing the zone are described in order from west to east.
Trench No. 23 was partly filled with water. Bedrock does not appear to have been reached in the north part. In the southern part a breadth of about one foot strongly mineralized with chalcopyrite was exposed above the water. The rock exposed elsewhere in the trench is relatively fresh-appearing gabbro with joints dipping about 50 degrees north, parallel to the mineralized band, and with minor joints at right angles. Stringers of pyrite with chalcopyrite a fraction of an inch in width follow the joints and the rock is shot throughout with pyrite largely associated with the minor fracture planes. Much of the pyrite is coarse and of cubic habit; some cross-sections as much as one-half inch square were noted.

Trench No. 22 was filled with water. The ore on the dump consists of about 90 per cent magnetite with stringers of pyrite and chalcopyrite.

Trench No. 16 exposes rock relatively poor in metallic minerals. The dip of the shearing is essentially vertical. Two small shears are exposed. The southernmost is about 2 feet wide and contains scattered lenses up to 2 inches in width of chalcopyrite with some pyrite and magnetite. The northern is, also, about 2 feet wide and carries the same minerals, but not so abundantly. The gabbro between the two zones is jointed and in part shattered. Pyrite is disseminated throughout all the exposed rock. Twenty feet east of trench No. 16, 18 inches of massive chalcopyrite with blebs of quartz is exposed.

Trench No. 15 was partly filled with water. There is about $2 \frac{1}{2}$ feet of rich chalcopyrite-quartz mineralization in the middle, with about 5 feet of sheared gabbro on each side mineralized with a few sulphide lenses up to an inch in width and with sparsely disseminated pyrite. In the rich chalcopyrite zone, pyrite with some associated marcasite is present. Between trenches Nos. 15 and 25 the mineralized zone is exposed at intervals and in this stretch the metallic minerals are comparatively low in amount. There are some quartz lenses up to $2 \frac{1}{2}$ feet wide, magnetite stringers, and some chalcopyrite.

Trench No. 25 shows a 3 -foot zone strongly mineralized with chalcopyrite and quartz, bounded on the north by a strongly sheared zone about 5 feet wide and containing lenses of chalcopyrite and pyrite. The rock in the rest of the trench is fresh, blocky gabbro. The chalcopyrite contains a small amount of pyrrhotite, and sphalerite is visible in polished sections. The mineralized zone is exposed to the east, between trenches Nos. 25 and 24. Along this part it expands and contracts. In places it consists of quartz sparingly mineralized with magnetite and chalcopyrite; in some places there are lenses of almost solid chalcopyrite 3 or 4 feet wide.

Trench 24 on its west side displays a zone about 5 feet wide, fairly heavily mineralized with chalcopyrite, quartz, and magnetite. The east side of the trench is relatively barren of metallic mineralization, only about 2 feet of rather poor quartz-sulphide mineralization being shown there.

Trench No. $14 a$ reveals a sheared and shattered zone about 10 feet wide. It is almost devoid of quartz. Irregular veinlets of sulphide traverse it. On the western side of the trench some cross fractures trending southeast meet the main shear zone at an angle of about 45 degrees. These contain veinlets of iron sulphide and in the vicinity there is considerable arsenopyrite. This mineral and molybdenite are also quite plentifully disseminated in the south end of the trench.

Trench No. 14 was partly water-filled at the time of examination. A width of about $3 \frac{1}{2}$ feet is heavily mineralized with chalcopyrite and magnetite. The remainder of the trench shows fresh, blocky gabbro. A few lenses of fine-grained, pale pyrite are present with the other metallic minerals. Some biotite is intimately associated with the metallic minerals.

Trench No. 13 shows about 4 feet of heavy magnetite-chalcopyrite mineralization. The mineralized zone is shot through with calcite and on its north side there appears to have been a lens of calcite about 2 feet wide sparingly mineralized with metallic minerals. Very little pyrite is visible. Twenty feet east of trench No. 13, a stripping exposes the ore zone here about 2 feet wide. From a point 40 feet east of trench No. 13, a stripping extends to trench No. 12 and exposes a rusty zone which pinches and swells and branches about 45 feet west of trench No. 12, the two parts continuing to trench No. 12 where they are about 12 feet apart.

Trench No. 12 shows two zones about 12 feet apart, of almost solid chalcopyrite and each about 2 feet wide. The remaining material exposed is irregularly fractured gabbro with small stringers of chalcopyrite and pyrite in the fractures. Very little quartz is present.

Trench No. 11 had caved. Some chalcopyrite ore is present on the dump.

Trench No. 9 was partly caved and filled with water. Some mineralized material is on the dump consisting of chalcopyrite veins in relatively fresh gabbro.

## Zone No. 3

The trenches crossing this zone are described in order from west to east.
Trench No. 35 exposes a 5 -foot zone of chalcopyrite, magnetite, quartz, and pink calcite. The constituents show a rough tendency to be banded.

Trenches Nos. 28, 37, and 38 show narrow lenses of mineralization like that in No. 35.

Trench No. 18. The southern part of the trench is in sheared and shattered gabbro with a few, narrow, irregular lenses consisting essentially of chalcopyrite and pyrite. The rock exposed in the remainder of the trench is, in general, blocky, fresh-appearing gabbro with a small amount of shearing in places. Throughout there is a small amount of pyrite and a little chalcopyrite, both disseminated and in stringers following fractures. A lens about 1 foot wide composed essentially of calcite with considerable actinolite is exposed near the middle of the trench.

Trench No. 27. Only in the northern part is rock exposed. This shows a shear zone containing a lens about 18 inches wide and composed of magnetite, chalcopyrite, and calcite. About 6 inches of it is rich in chalcopyrite, the remainder is essentially magnetite and calcite.

Trench No. 19 shows a very clean-cut, vertical body 6 inches wide at the top and about 1 foot wide at the bottom 7 feet below the top. It is composed of magnetite, quartz, pyrite, and patchy amounts of chalcopyrite. There are a few parallel sulphide veinlets less than an inch wide. The wall-rock is sheared gabbro, containing disseminated, fine pyrite. This zone may be continuous with that exposed in trench No. 21 as it can be traced fairly well by intermediate exposures.

Trench No. 95 shows two narrow lenses of sulphide; one in the southern part of the trench and the other in the north.

Trench No. 21a shows two lenses each about 6 inches wide and composed essentially of fine-grained, pale pyrite and very little chalcopyrite. The remainder of the material exposed is fresh, blocky gabbro. There is no quartz.

Trench No. 21 exposes a zone 3 feet wide and also a lens about 6 inches wide, consisting essentially of chalcopyrite. A little pyrite occurs with the chalcopyrite, but there is practically no quartz and very little magnetite. The remainder of the trench shows fresh, blocky gabbro with veinlets of chalcopyrite, magnetite, and biotite.

## WRIGHT DISCOVERY

This showing is about a half mile northeast of the Springer discovery of the Opemiska Mines, Limited. The claim, Q7691, on which it is located, is controlled by Opemiska Mines, Limited. The showing occurs in the greatly altered dioritic rock that bounds the Ventures gabbro on the east and lies about 400 feet southeast of the contact. About 6 feet of mineralization has been exposed in a small outcrop isolated by drift. Any continuation could not be picked up by trenching the drift and effective trenching was impossible because the water table is practically at the surface in this locality. The metallic minerals are rather coarse pyrite threaded with chalcopyrite. A little magnetite was noted. Practically no quartz is present. Some actinolite occurs intimately associated with the chalcopyrite.

## REA OPTION

The Rea Option comprised fifteen claims originally staked by Prospectors Airways, Limited. The option was not taken up and the claims are now included in the property of the Opemiska Mines, Limited. The showings, two in number, are located in the southern part of the block. The westernmost lies about 1,500 feet east of the Wright Discovery. The other is about half a mile east. The country rock is the same highly altered dioritic rock in which the Wright showing was found. The Ventures gabbro lies about 1,200 feet north of the showings.

The mineralization of the eastern showing occurs in a shear zone, strike 130 degrees magnetic, dip 85 degrees north, and has been opened by six trenches at right angles to the strike. Considerable clear quartz is present in discontinuous lenses, otherwise sheared diorite constitutes the
gangue. Pyrite, chalcopyrite, pyrrhotite, and sphalerite are the metallic minerals noted. The strongest metallic mineralization occurs in the north end of a trench where about 10 feet of sheared diorite is fairly heavily mineralized with quartz, pyrite, chalcopyrite, and a little magnetite, sphalerite, and pyrrhotite. The mineralization in the other trenches consists largely of pyrite disseminated throughout sheared diorite.

In the eastern showing, a strong shear zone striking about 100 degrees magnetic is mineralized. It has been opened by a number of trenches. The country rock is the altered diorite. At the east end of the showing a zone about 3 feet wide is well mineralized with quartz, pyrite, chalcopyrite, and a little pyrrhotite, magnetite, and sphalerite. To the east this zone disappears under the drift. To the west, in the next trench, there is about 1 foot of heavy chalcopyrite mineralization and an equal width of sparsely mineralized material. In the next trench west the shear zone is about 2 feet wide and contains small lenses of massive chalcopyrite about 2 inches wide. Farther west the shearing and the mineralization gradually die out. About 55 feet to the south of this shear zone, a parallel shear zone has been opened in two places, but shows very little sulphide.

## SLADEN MALARTIC

The Sladen Malartic group of claims is located about $2 \frac{1}{2}$ miles northeast of lake Presqu'île. Rock exposures are not plentiful in this part of the region. Most of the outcrops are low, rounded hills commonly of altered diorite with, in some instances, exposures of sediments at the edge of the outcrops near the bases of the hills. There are two small showings.

One showing is on the east side of a low hill of altered diorite with a small outcrop of limestone at its eastern base in which the mineralization occurs. The diorite does not appear to have had noticeable metamorphic effect on the limestone at the contact. The limestone exposure is about 35 feet long and 7 feet wide. The limestone is indistinctly banded, strike 140 degrees magnetic, dip vertical, and is mineralized along fracture planes by pyrite, pyrrhotite, and chalcopyrite. Most of the fractures are vertical and roughly at right angles to the bedding. All are irregular. On the whole, the sulphide mineralization is sparse and of the sulphides, chalcopyrite is the least abundant. Some actinolite occurs in the limestone adjoining the sulphides.

At the base of a diorite hill about 530 feet southeast of the abovedescribed showing, the sediments outcrop again practically along the strike of the limestone. The exposed width of limestone is 50 feet. The limestone is exposed in outcrop and trench along its strike for 75 feet where it is cut off by the diorite. At the western edge of the limestone outcrop, a 9 -inch vein is exposed. It is composed largely of sphalerite, with some pyrite and very little chalcopyrite.

Le Roy Mines have done considerable trenching on claims west of Laura lake. Scattered lenses of mineralization have been exposed. Onehalf mile east of Laura lake a trench has exposed limestone for a width of about 20 feet. Outcrops on both sides are of slate and banded quartzitic material. The limestone is in part quite strongly mineralized with pyrite and traces of chalcopyrite.

On some claims southwest of Laura lake a milky to clear quartz vein is exposed, with widths ranging from $2 \frac{1}{2}$ feet to 10 feet and striking 135 degrees magnetic. It traverses volcanics and traces of it have been picked up for a length of 700 feet. It appears to be pure quartz except for disseminated spots of rust which probably represent altered pyrite. A little chalcopyrite was noted in a quartz veinlet 2 inches wide and a few feet from the main vein.

## DESLAURIERS EXPLORATION COMPANY, LIMITED

The Deslauriers Exploration Company, Limited, hold a considerable number of claims along the shores of lake Asinitchibastat. Considerable trenching has been done north of the entrance of Chibougamau river into lake Asinitchibastat near the contact of granite and the volcanics. Other trenching has been done on some islands in the southern part of lake Asinitchibastat and a quartz vein about 3 feet wide containing some disseminated chalcopyrite was picked up in one trench. It occurs in diorite (granitic intrusives group). The quartz tends to be milky. Small calcite veins and stringers were noted in other trenches in the diorite. Some contain a little chalcopyrite.

## THICKNESSES OF THE ORDOVICIAN FORMATIONS IN ONTARIO AND QUEBEC

By D. C. Maddox

As further drilling in search of oil, natural gas, and water is likely to be carried on in the province of Quebec between Montreal and Quebec city, and in Ontario, it seems advisable to assemble the available information on the thicknesses of the Ordovician formations in parts of southern and central Ontario and to draw attention to the variations in thickness of these formations from west to east. The area is largely drift covered, so that the data are necessarily largely derived from the logs of deep wells. As far as possible the records of well drillings examined by the Borings Division of the Geological Survey have been used in this work, but there are many wells drilled a long time ago from which no samples were received and in these cases use has to be made of the only available source of information, the drillers' logs.

The formations referred to in this report are the Queenston, Lorraine, Utica and Collingwood, Trenton and Black River, Chazy and Beekmantown. As regards the distinction between formations made as a result of examinations of samples, it should be noted that this is of necessity generally based on difference of colour and lithology. For this reason it is generally impossible to distinguish between the Utica and Collingwood formations, the Trenton and Black River formations, and the Trenton-Black River and Chazy limestones if no intervening sandstones or shales occur. As regards nomenclature the more general older terms have been retained even when recent work bas shown them to be not applicable to some parts of the area under consideration. The fact that all parts of the area have been compared would seem to make this proceeding necessary. Thus the term "Lorraine" is retained to describe the rocks lying between the Utica and the Queenston, although this assemblage has been subdivided and renamed in the Toronto area by Dr. W. A. Parks, as the subdivisions cannot generally be recognized in well samples and a comparison is here made with rocks occupying a similar stratigraphic position farther east than the Toronto area. The term "Utica" is also retained for the formation lying between the Collingwood or the Trenton and the Lorraine, although this formation has been renamed the Gloucester in the eastern part of the areas covered and there seems to be some doubt as to whether any true Utica is present in Canada. No attempt has been made to subdivide the Beekmantown into the Theresa and the Beauharnois, the lower limit of the Beekmantown being arbitrarily assumed to be where the lowest bed of dolomite occurs in the sandstone.

The term Queenston is used to include all rocks lying between the Silurian Medina-Cataract and the Lorraine shales. The lower limit of the Queenston is drawn where the change from red to grey occurs. Foerste ${ }^{1}$ has noted that the basal part of the Queenston up to a thickness of 50 feet may be blue and as such would be indistinguishable in well samples from the underlying Lorraine.

[^8]The area in question is naturally divisible into three subordinate areas. These are: the western, which includes that part of southern Ontario lying south and west of the Utica-Trenton contact between lake Ontario and Georgian bay; the central, which includes the triangular area between Ottawa and St. Lawrence rivers and is limited on the west by the western boundaries of Carleton and Grenville counties; and the eastern, which includes the part of Quebec lying between Montreal and Quebec city and limited on the north and west by the Precambrian and on the south and east by the mapped trace of the Champlain fault.

Information from wells drilled in the area between the Utica-Trenton contact north of lake Ontario and the Precambrian Frontenac axis to the east is of no value in the present discussion, as the only Palæozoic formations in this area are the Trenton-Black River limestones which rest on the Precambrian with only a thin basal sandstone between. The seas that deposited the Beekmantown and Chazy do not appear to have extended west of the Frontenac axis and these formations are, therefore, missing from the western area.

$$
\begin{gathered}
\text { THE "QUEENSTON" } \\
\text { Western Area }
\end{gathered}
$$

Some of the thicknesses as shown by well logs are:

| County | Well name | Thickness |
| :---: | :---: | :---: |
|  |  | Feet |
| Ersex. | Roslyn No. 1......................... | 250 |
| Kent. | Union No. 15........................ | 240 |
|  | Coste Nos. 7 and 15............... | 270 |
| Lambton. | Union No. 2. | 330 |
| Middlesex. | Delaware Development Co. | 355 |
| Oxford. | Beachville. | 450 |
| Perth. | St. Mary's Cement Co. | 366 |
| Wellington. | Puslinch............... | 455 |
| Halton.... | Suburban Gas Co., No. 1 | 410 |
| Welland. | Drillers' logs of aeveral wells... | 950 |

## Central Area

No data are available as to the thickness of the formation which occurs in small, detached areas in this district.

## Eastern Area

The "Queenston" here seems to be confined to certain synclinal areas, three of which have been mapped and named, from northeast to southwest, the Deschene, Nicolet, and Pierreville synclines. Well logs from some points outside these areas show the presence of "Queenston," but the information is not sufficiently complete to form a basis for outlining additional areas underlain by this formation. The greatest recorded thickness passed through in drilling is 1,620 feet in the case of the Canadian Natural Gas Company's No. 4 well in St. Hyacinthe district. The upper contact was not passed through, however, and the probability of faulting in this area renders this figure unreliable.

THE "LORRAINE"

Western Area
The result of well drilling indicates thickness as under:


## Central Area

No information is available as to total thickness, as no deep wells in the area have passed through the upper contact. The greatest recorded thickness is 510 feet from a well drilled near Vars, Cumberland township, Russell county. Another well in Russell township, Russell county, passed through 430 feet.

## Eastern Area

Drilling records indicate a great thickening of the Lorraine towards the east and southeast, although the possibility of duplication by faulting or of apparent thickening as a result of folding must be considered in the interpretation of well logs, more especially in that part of the area near the Champlain fault. The maximum thickness recorded was 3,415 feet with the lower contact not reached, in the log of the Canadian Natural Gas Company's No. 3 well in St. Hyacinthe district. This well is the most easterly of the group and the nearest to the mapped trace of the Champlain fault; the duplication by faulting, therefore, seems probable. All the other wells in St. Hyacinthe area passed through varying thicknesses of "Lorraine" up to 1,637 feet without reaching the lower contact. At Three Rivers a thickness of 900 to 1,000 feet is recorded. At the two wells of the Quebec Fuel Company near Verchères a thickness of 1,735 to 1,775 feet was reported with the upper contact not found. Near Yamaska the Quebec Fuel Company's well reported a combined thickness for the "Lorraine" and "Utica" of 2,490 feet, with the lower contact not reached. Of the wells in Nicolet county none records a definite thickness of the "Lorraine," the well at Nicolet College is recorded as entering this formation at 110 feet and as not reaching the Trenton at 2,270 feet, so that a combined thickness of "Lorraine".""Utica" of over 2,160 feet is indicated.

From surface indications the thickness of the "Lorraine" in a section exposed on Nicolet river was calculated by Foerste ${ }^{1}$ to be 2,513 feet from the contact with the Queenston, but with the lower contact not seen. Faulting, however, may have complicated the section. Logan ${ }^{2}$ estimates it to be about 2,000 feet in the district between rivière Ste. Anne and rivière à la Rose.

## "UTICA" AND COLLINGWOOD WHEN LATTEER IS PRESENT

## Western Area

The following wells passed through the "Utica."

| County | Well name | Thickness |
| :---: | :---: | :---: |
|  | Roslyn No. |  |
| Kent. | Union No. 15. | 170 |
|  | Coste No. 7. | 150 |
| Perth. | St. Mary's Cement Co. | 68 |
| Wellington.. | Puslinch........................ | 75 |
|  | Pennsylvania Oil and Gas Co....... | 175 |
| Wentworth | Woodly farm.............. | 210 |
| York... | Vuburban Oir and Gas Co. No. 1.... | ${ }_{116}$ |
| York. | Dr. McCormick, Toronto. | 100 |
| York... | Swansea...... | 96 |

## Central Area

No very reliable data are available from surface outcrops. The wells drilled in the vicinity of Ottawa also provide no information as to thickness, with the exception of a well at Ramsayville, Gloucester township, which records a thickness of 75 feet of "Utica".

The following wells in Russell county farther east passed through the "Utica".

| Well | Thickness in feet |
| :---: | :---: |
| Russell, Ottawa Dairy Company. | 265 |
| Portlance farm, Vars.. | 200 |
| Vars................ | 190 |

## Eastern Area

Montreal District. Field evidence gives a thickness of about 300 feet. No data are provided by well records as the upper contact was not penetrated.

La Prairie. The La Prairie Brick Company's well is reported as passing through 1,500 feet of shale before striking limestone. Map No. 571, Montreal sheet, shows La Prairie as being underlain by the Utica. This thickness seems to be so much greater than any other recorded in the area that it must be regarded with suspicion. No other records of deep wells are available in the vicinity and no samples were received from this well. The difficulty of mapping formation contacts in this vicinity makes it possible that this well started in the "Lorraine."

[^9]L'Assomption. The experimental farm well near this point recorded thicknesses of 165 and 195 feet separated by igneous rock 100 feet thick. These relations would tend to make the total thickness, 360 feet, rather questionable.

Three Rivers. The well drilled near this town passed through 400 to 500 feet of "Utica" without apparently reaching the lower contact.

Although many of the deeper wells passed into the "Utica," no distinction between it and the "Lorraine" seems to have been made and no data for formation thicknesses is thus provided. Field evidence shows a thickness of about 300 feet at isle d'Orleans a little outside the area under discussion and 318 feet between rivière Ste. Anne and rivière à la Rose.

## TRENTON AND BLACK RIVER

Western Area


## Central Area

Ottawa District. The well at Ramsayville records a thickness of 600 feet, of which the lower 100 feet is described as Black River. A well at Carlsbad Springs east of Ottawa recorded a thickness of 640 feet.

Russell County. The Ottawa Dairy Company's well at Russell passed through 485 feet of limestone of Trenton and Black River age without reaching the lower contact.

## Eastern Area

Montreal District. Field evidence shows a thickness of about 600 feet. Cumming ${ }^{1}$ estimates a minimum thickness of 695 feet as recorded by well borings. The lower contact of the Black River with the Chazy limestone, however, is in general impossible to determine in well samples, and estimates of thickness are of necessity only approximate.

L'Assomption District. The Experimental Farm well recorded a thickness of 900 feet of limestone between the "Utica" above and the Chazy sandstone below; examination of the samples failed to discover any evidence of the contact between the Black River and Chazy limestones.

[^10]Assuming a thickness of about 300 feet for the Chazy limestones, 600 feet would be left for the remainder of the Trenton-Black River. No further information as to thickness is obtainable from well logs. Surface indications show a thickness of 600 feet at rivière St. Charles and of over 600 feet at Baie-St.-Paul.

## CHAZY

This formation consists of an upper limestone member and a lower sandstone-shale member. These have been distinguished as separate formations in Ottawa district, but as comparison is made with formations in a similar stratigraphic position farther east the lithological distinction only will be given when it is available. In Ottawa district the limestone member is quite subordinate in thickness to the underlying sandstone and shale, but as the formation is traced easterly the relative thickness of the limestone increases until in the eastern area the sandstones and shales are quite subordinate.

## Central Area

| Well name | Limestone | Sandstone and shale | Total |
| :---: | :---: | :---: | :---: |
| Ottawa Dairy Company. | 40 | 165 | 205 |
| J. R. Booth.... |  |  | 210 |
| Somerset and Bay streets. | 37 | 165 | 202 |
| Union Station, C.N.R | 60 | 270 | 330 |
| Y.M.C.A..... | 30 | 140 | 170 |
| Ramsayville..... | 70 |  | 150 |
| Carlsbad Springs. | 70 | 180 | 250 |

The abnormal thickness at the Union Station may possibly be due to faulting.

Glengarry County. A well at Alexandria recorded 46 feet of limestone and 145 feet of sandstone.

## Eastern Area

Montreal District. Field measurements indicate a thickness of about 300 feet. Well records show 785 feet, but this is based on rather uncertain data and the generally disturbed conditions at Montreal also render it rather unreliable.

L'Assomption District. The Experimental Farm well passed through 900 feet of limestone and 60 feet of sandstone in the interval between the Beekmantown below and the "Utica" above. The contact between the limestone of the Chazy and of the Black River was not shown by the well samples, but assuming that the thickness of the Trenton-Black River is 600 feet this leaves 300 feet of limestone and 60 feet of sandstone to be assigned to the Chazy. This figure agrees fairly well with estimates of thickness made in the field.

## BEEKMANTOWN

## Central Area

The logs of some of the well records indicate the presence of a sandy phase towards the base of the Beekmantown. This is recorded in cases where it is shown, but no attempt is here made to make a definite separation from the upper dolomitic or limestone phase.

## Ottawa District

| Well name | Dolomitic phase | Sandy dolomitic phase | Total |
| :---: | :---: | :---: | :---: |
| Somerset and Bay streets, Ottawa | 211 | 10 | 221 |
| Union Station, C.N.R., Ottawa... | 195 | 90 | 285 |
| J. R. Booth, Ottawa., | 190 | 40 | 230 |
| Ramsayville. |  |  | 200 |
| Y.M.C.A., Ottawa.. |  |  | 275 |

In a well near Carlsbad Springs 340 feet of Beekmantown was passed through without reaching the base of this formation. Tests of the solubility in acid of all samples show that the entire section is sandy, the upper 90 feet apparently being much more sandy than the lower 250 feet, the average percentages of insoluble material, chiefly sand grains, in the two sections being about 40 per cent and 20 per cent respectively.

Dundas County. A well at Chesterville passed through 470 feet, of which the last 175 feet were sandy.

## Eastern Area

Field measurements give a general thickness of 300 to 400 feet. The Montreal Gas Company's well at Hochelaga ${ }^{1}$ is considered to have passed through 1,065 feet of this formation without reaching the lower contact. No other information is available from well records, the Experimental Farm well at L'Assomption up to date passing through only 70 feet of this formation.

## SUMMARY

"Queenston." In the western area the thickness increases eastward from 250 feet in the southwestern counties to 400 to 450 feet in the central and south-central ones. A great thickening occurs in the southwestern part, about 1,000 feet being recorded from Welland county and Niagara district.

No data are available as to the central area. If the thicknesses given in St. Hyacinthe district in the eastern area are not complicated by folding or faulting there is a great thickness in this area in the synclines, at least 1,600 feet being recorded.

[^11]"Lorraine." In the western area the thickness in Essex and Kent counties is about 300 feet, eastward and northeastward this increases to about 500 feet in Middlesex, Perth, and Grey counties. Farther north in Wellington county it is 700 feet. In the south-central counties it is about 600 feet. In the central area the "Lorraine" is at least 510 feet thick. In the eastern area available information is far from complete. Disregarding the maximum thickness of 3,415 feet shown in St. Hyacinthe district it seems probable that 2,000 to 2,500 feet is a fair estimate of thickness south of the St. Lawrence. This agrees fairly well with Logan's estimate of 2,000 feet in the Rivière-St.-Anne and Rivière-à-la-Rose district. North of the St. Lawrence, 900 to 1,000 feet is reported from the Three Rivers well. This may be due to faulting or to thinning out towards the northern shoreline.
"Utica" and Collingwood When Present. The thickness is 150 to 175 feet in the southwest counties of the western area, about 75 feet in the central part, 175 feet farther north in Grey county, and in Wentworth county a little over 200 feet. A little farther east, however, in Halton and York counties, the thickness is only about 100 feet.

## Central Area

One well in Ottawa district shows 75 feet; farther east in Russell county there is considerable thickening to 200 to 250 feet. In the eastern area information is very scanty. The only available drill records are those of the Three Rivers well and the L'Assomption Experimental Farm well, 400 to 500 , and 360 feet, respectively. Field measurements show about 300 feet both in the eastern and western parts of the area. A thickness of 300 to 400 feet, therefore, seems probable for the northern part, some thickening towards the south, however, may occur.

Trenton-Black River. In the western area these formations with their basal sandstones lie directly on the Precambrian and, therefore, their thickness would be expected to vary with the relief of the old Precambrian land surface. In the southwestern part of the area thicknesses of 800 to 950 feet are recorded, but over the remainder of the area well logs available show 550 to 700 feet with an average of about 600 feet. A well in Perth county and another in Wentworth county, however, record 800 feet.

In the central area an average of about 600 feet seems applicable. For the eastern area no definite data are provided by well logs. Cumming ${ }^{1}$ estimates 695 feet as a minimum for Montreal, but estimates here are not very reliable. It seems probable that the figures reported from field relations, 600 feet, would be about correct; this figure corresponding both with the thicknesses in the central area and with that estimated in the L'Assomption well.

Chazy. In the central area the Ottawa wells show an average of 150 to 200 feet, the upper 30 to 40 feet being limestone. Farther east at Carlsbad Springs a slight thickening to 250 feet is found, the limestone about doubling in thickness. In Glengarry county southeast of Carlsbad Springs 200 feet is recorded.

[^12]In the eastern area information is entirely confined to two wells, the Turkish Bath well at Montreal and the Experimental Farm well near L'Assomption. The estimated thickness in the Montreal well was 785 feet, that of Experimental Farm well was 360 feet. The field relations show 300 feet, so it is considered that the Experimental Farm well probably represents about the true thickness.

Beekmantown. Central area figures give 200 to 230 feet for Ottawa district. Eastward thickening is shown by a figure of 340 feet for Carlsbad Springs and 470 feet for the Chesterville well in Dundas county.

In the eastern area the only available well record is one at Montreal ${ }^{1}$ which gives a figure of 1,065 feet without reaching the lower contact. This is so much greater than the field estimate, 300 to 400 feet, that it is of very doubtful value. In Lake Champlain region a thickness of 1,800 feet is reported, so that thickening towards the south in the region generally is to be expected.
${ }^{1}$ Geol. Surv., Canada, Mem. 72, p. 24.

# HEAVY MINERALS IN THE BASAL ORDOVICIAN SANDSTONES OF ONTARIO AND QUEBEC 

By F. J. Fraser

## Illustration

## Page <br> 137 <br> Plate I. Tabular anatase from basal Ordovician sandstone. Quarry near Eagleson <br> Corners, near Ottawa

Heavy minerals from various Palæozoic sandstones in North America have been mentioned or described by Colony, Cordry, Dake, Lamar, and Wallace and McCartney. The object of this paper is to record the similarity of the heavy minerals in the basal Ordovician sandstones of eastern Ontario and Quebec to those in some other North American Palæozoic sandstones and to note the occurrence of naturally etched tourmalines which may have some significance in determining the age of the sandstone from well samples.

Both Colony and Dake agree that the heavy mineral suites of the St . Peter sandstone, and the Potsdam from which it is presumably derived, are restricted ones, but give no specific data. Lamar describes the heavy minerals in the St. Peter sandstone of Illinois, and gives useful comparative data regarding shape, size, and relative abundance. The suite is restricted to well-rounded zircons and tourmalines as the principal minerals, with fresh anatase variable. Wallace and McCartney found similar zircons and tourmalines in the Winnipeg Ordovician and Basal Silurian sandstones of Manitoba. Cordry examined about 100 samples representing sandstones of Cambrian, Ordovician, and Carboniferous age in Missouri. All these contain well-rounded zircon and tourmaline as principal heavy minerals, and well-developed euhedral anatase in some samples. Edson ${ }^{1}$ shows (Plate I) a suite of minerals from the Simpson sandstone which is typical of a coarse-grained Palæozoic sandstone.

Examination of heavy minerals from samples collected from exposures, Lower Beekmantown or Potsdam in age, at Eagleson Corners about 10 miles southwest of Ottawa, gave the following results:
No. 1 Sample. Collected from contorted mass. Hand specimen is white, compact, mediumgrained, granular, and non-calcareous sandstone.
Zircon. Abundant. Grains large and well rounded; may be equidimensional, but tend to be elongate. Size 0.1 to 0.2 mm . (Sizes refer to maximum diameter throughout).
Tourmaline. Few, large and well rounded. Size commonly 0.1 mm . diameter.
Anatase. Colourless, tabular. Size 0.04 to 0.08 mm . diameter.
No. 2 Sample. Collected from upper part of exposure 100 yards to east of No. 1. Hand specimen is brown, compact, dolomitic, and contains well-rounded quartz grains very irregularly distributed; some parts are almost free from quartz. In the mass, crystalline aggregates (?dolomite-not collected) occur sporadically.
Residue after hot acid is about 30 per cent, and the sample is, therefore, a sandy dolomite. The size of grains that make up the insoluble residue is of the order:

Greater than 0.5 mm ., dia. 6
Less than 0.5 , Greater than 0.2 mm ., dia. 43
Less than 0.2 , Greater than 0.1 mm ., dia. 20
Less than 0.1 mm ., dia. 31 per cent
All grains greater than 0.2 mm . diameter are well rounded and frosted. Grains smaller than 0.2 mm . diameter are angular or subangular.

[^13]Zircon. Large and well rounded. Size 0.04-0.2 mm., 0.1 mm . common.
Tourmaline. Large and well rounded. Size $0.1-0.5 \mathrm{~mm}$., with some smaller.
Rutile. Occasional grains.
The heavy minerals also include well-rounded, opaque grains, commonly 0.1 mm . diameter.
No. 3 Sample. Collected from non-calcareous zone underneath No. 2. Hand specimen is a much weathered, white, medium-grained sandstone; grains are subangular, but many are rounded and show frosted surface. Yield of heavy minerals poor.
Zircon. Well rounded; grade very variable. Size 0.04-0.07.
Tourmaline. Well rounded and tend to be large - up to 0.2 mm . Smallest grains around 0.04 mm .
Anatase. Colourless tabular. Size commonly 0.07 mm . Other grains noted: well fractured garnet; hornblende.
No. 4 Sample. Collected from exposure west of Nos. 1, 2, and 3, and nearest to road. Hand specimen, white, compact, and dense, and is a medium to fine-grained sandstone.
Zircon. Well rounded. Size $0.04-0.2 \mathrm{~mm}$. Grains 0.1 mm . common.
Tourmaline. Very few. Size commonly 0.1 mm . All well rounded.
Anatase. Colourless, tabular. Size commonly 0.07 mm .
There are also occasional well-rounded rutile, and a few opaque grains.
No. 6 Sample. Collected from quarry. Hand specimen is a slightly weathered, white, coarse to medium-grained sandstone. The rock is compact by reason of the very fine-grained quartz as a matrix.
Zircon. Large and well rounded. Size 0.07-0.2 mm.
Tourmaline. Scarce. Large and well rounded up to 0.2 mm , diameter.
A natase. Colourless, tabular. Size commonly 0.07 mm .
Occasional rutile grains are present.
Comparable with the foregoing are two samples collected by Mr. D. C. Maddox from Smiths Falls. One of these contains carbonates; 7 per cent is soluble in hot acid. Heavy minerals in the insoluble residue are barite, well rounded zircon and tourmaline, and tabular anatase. The rounded grains measure up to 0.2 mm .; grains of 0.1 mm . are common.

A sample of Potsdam sandstone from St. Julienne, Quebec, collected by Mr. M. Mahoney, contains well-rounded zircons.

Two Potsdam samples from well cuttings have been examined for heavy minerals; one from the Somerset Street well, Ottawa, from a depth of 1,365 feet, and the other from the Eva Shail well at Carleton Place, Ontario, from a depth of 78 feet. Both samples show well-rounded zircon and tourmaline up to 0.2 mm .

The zircons in all the samples examined range from stumpy to elongate, and in Canada balsam show a very pitted surface. The size of these grains is noteworthy in that the size of the original euhedral zircon grains must have been considerably greater than is usual in a detrital rock, even taking into account the coarseness of the bulk grains with which they are associated. If these zircon crystals have been derived from a provenance, some of which still remains exposed (as would be the case if they were derived from the Precambrian), investigations similar to those carried out by Dr. A. W. Groves and other workers in Great Britain, will throw light on the origin of those types of sandstones with which this paper is concerned. In spite of the amount of thought and labour that has been put into unravelling the complexities of the Precambrian rocks, we have no systematic records of the heavy accessory minerals they contain, and until such investigations are carried out, progress as to sources of many sedimentary rocks in North America must be slow. This type of work is considered of sufficient interest to justify a list of papers dealing with this subject (See page 60).

The tourmalines show rounding comparable with that of the zircons, but have a smoother surface, due to lower refractive index. The grains are strongly pleochroic, are commonly olive green, occasionally brown-yellow, rarely pink. Of special interest in some of the samples is the roughened appearance at one end only of the caxis. The appearance under a high power suggests that the etching has taken place along planes parallel to rhombohedral planes, giving rise to a scaly network which becomes thinner in the direction of the middle of the grain, and forms a "cap" through which the unaltered periphery of the mineral may be sharply focused. The maximum depth of the alteration is uniformly about one-eighth of the total length of the grain; the altered zone is colourless (suggesting leaching of iron), and the extinction and optical character is in continuity with the original crystal. The internal angle of the secondarily developed planes is about 130 degrees, which corresponds closely with that in a well-developed crystal. The open character of the sandstones in places would leave adequate passage for circulating waters responsible for the etching.

The anatase grains are always very fresh and tabular (See Plate I), and show good bevelled edges and corners. The habit of these grains, especially in contrast with that of the zircon and tourmaline, leaves no doubt as to the secondary nature of the anatase. It may be that the tourmaline was etched by similar agencies that deposited the anatase.

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# SILICA DEPOSITS AT LEITCH CREEK AND SKYE MOUNTAIN, CAPE BRETON, N.S. 

By E. A. Goranson<br>Hlustration<br>Figura 5. Leitch Creek silica quarries, Cape Breton county, N.S....................... ${ }_{62}$

INTRODUCTION
During the summer of 1930 , the writer examined the Leitch Creek silica deposit and that of Skye mountain, Cape Breton. Both deposits are quartzite. The Leitch Creek deposit has been operated for a number of years by the Dominion Steel and Coal Corporation, Limited; the Skye Mountain deposit is as yet undeveloped.

The writer wishes here to express his indebtedness to Mr. W. B. Gillis for statistical data on the Leitch Creek silica deposit and for the analysis of the quartzite used in making silica brick at Sydney. In the field, W. Longley proved a capable assistant.

## LEITCH CREEK SILICA DEPOSIT

The deposit is about 15 miles from Sydney and lies on the south side of George river in the low rolling valley between Boisdale hills directly on the north, and Coxheath hills about 4 miles to the south.

The rocks from which the pure quartzite at the Leitch Creek deposit is quarried belong to the George River series of Precambrian age. The George River series consists of two members, a quartzose member and a carbonate member. The quartzose member includes pure and impure quartzite, quartz-muscovite-biotite schists, metamorphosed arkoses, quartz-sillmanite-andalusite schists, and similar rocks. Some of the rocks are definitely schistose, others granulose, massive, or gneissose. Amphibolites of unknown origin are associated with this member and are probably metamorphosed diorites or more basic igneous rocks. The rocks are cut by dykes and large bodies of granite and by other, more basic, igneous types.

The quartzose rocks in the vicinity of the deposit underlie a small area on the south flank of Boisdale hills. They extend from a point slightly north of the junction of Crane creek and George river to approximately one mile south of the quarries. Carbonate rocks lie on the north and south, granite on the west, and Carboniferous sediments on the east. Five quarries and other workings have been opened in them along a stretch of 2,300 feet following the general strike of the strata, which here is slightly south of west. Except at the quarries, outcrops are few and, therefore, the distribution of the various rock types remains unknown. The strata are presumed to be tightly folded since that is the general structure of the George River series. The beds dip at angles of 70 to 85 degrees.

The easternmost quarry is an opening extending southerly into the hillside and is about 100 feet long with a maximum breadth of about 50 feet. A high silica quartzite is exposed in the southwest corner and, on the line of strike, along part of the east face. The high-grade quartzite in the

Figure 5. Leitch Creek silica quarries, Cape Breton county, Nova Scotia. Rock outcrops shown by crosses. 整
southwest corner has a breadth of about 20 feet. It is bounded on the north by a shear striking south 87 degrees east (magnetic) and dipping 69 degrees north. A narrow, basic dyke, considerably sheared, follows the shear; to the north of it along the west wall of the quarry the rocks are schistose impure quartzites, etc., cut, at near the quarry entrance, by an altered diabasic dyke. The high-grade quartzite in the southwest corner and that in the east face is bounded on the south side by another shear striking north 47 degrees east (magnetic), dipping 80 degrees south, and separating the purer quartzite from impure quartzite.

The next quarry to the west is about 400 feet from the first and no rocks are exposed between them. This quarry consists of two benches: a lower about 100 feet in diameter; and an upper 20 feet higher, and extending 80 feet west from the west side of the lower. The entrance to the lower bench is from the north and along it are exposed a basic igneous rock, quartz-mica schist, and impure quartzite. These are separated by a shear from a body of comparatively pure quartzite in which the quarry lies, but the south faces are of impure quartzite separated by a shear from the purer quartzites to the north. The area of purer quartzite displayed is about 200 feet by 90 feet.

A third quarry opens directly on a road paralleling George river and lies about 900 feet west of the second described quarry. The third quarry opening is 225 feet long and 80 feet broad. Directly south of this quarry are two pits. The rock in the quarry varies from a fairly pure to an impure and spotted quartzite. A flat-lying, pinkish grey granite dyke cuts the quartzite for nearly the entire length of the quarry face with smaller, steeply dipping dykes at its eastern termination. The large dyke pinches and swells along the face, attaining a maximum thickness of 10 feet. Large, black, irregular patches and streaks are distributed in places around the dyke walls and prove on microscopic examination to be impure quartzite consisting of quartz, biotite, sericite, apatite, zircon, and a little pyrite. The flat-lying dyke at the western end of the quarry shows local pegmatitic phases. The quarry face averages 20 feet in height.

The fourth quarry is a few yards west and south of the western end of the third quarry. The main part of the fourth quarry has a diameter of about 75 feet. The west wall of the entrance from the north shows impure quartzite on the north in contact with, on the south, a flat-lying granite body. The granite is not exposed on the east wall. The south contact of the granite is with a greenish quartzose rock which extends for about 25 feet south along the west wall of the quarry to where it is in contact with pure quartzite. Farther south along the west wall of the quarry a granite dyke striking north 65 degrees east (magnetic) and dipping 58 degrees south, cuts the pure quartzite. Pure quartzite continues for 50 feet on the south wall of the quarry where it is cut by another granite dyke parallel to the first. The second granite dyke extends east along the south face and continues a short distance beyond to a small knoll of white weathered quartzite where it ends abruptly and probably has been faulted off. A few yards south of the dyke white weathered quartzite is exposed in two outcrops. The east quarry wall is of quartzite much like that visible in the adjoining quarry to the east.

A fifth quarry lies about 200 feet west of the fourth. It shows very little quartzite of commercial grade. The working consists of a long face from which comparatively little rock has been removed. At the centre of the working fairly pure quartzite is exposed for a distance of 35 feet. On the south side the quartzite has a shear contact with fine-grained, altered diabase; on the north it has similar relations with impure quartzite. North of the impure quartzite a highly gneissose amphibolite is exposed on the road and north of the amphibolite, granite. Near the southern end of the working is a small trench exposing slightly impure quartzite.

In hand specimens the commercial quartzite is a glistening, white, compact, equigranular, medium-grained rock in which the individual grains can readily be seen with the unaided eye. In thin section the rock is seen to be composed of large, usually equidimensional, anhedral grains of quartz with slightly serrated interlocking borders. The average diaemeter of the grains is 0.5 mm . The grains are slightly strained, giving rise to a weak, wavy extinction under crossed nicols. Original structures, such as former grain size and bedding, are not present. Numerous minute inclusions of an opaque, undeterminable material are dotted through the quartz grains in fine bands and in haphazard manner. The main impurity is sericite in small shreds usually at the boundaries of the quartz grains. Other impurities are present only in small amount and include rutile, rounded small grains of apatite, shredded brown biotite, faint green chlorite, pyrite in small cubes, iron oxide, and minute prisms of an undetermined mineral with weak birefringence and moderate indices. A mean of a number of Rosiwal determinations of the average commercial quartzite in thin section gave 97 per cent quartz and 3 per cent impurity. Pyrite is a widespread constituent in the quartzose member, but only in small amount. A soft green, serpentine mineral is found in some places along the shears in the quartzite.

The overburden is comparatively light in the vicinity of the quarries, being mainly soil and averaging 3 to 4 feet in thickness. In places where the surface was of a pockety character till accumulated up to 10 feet or more in thickness. The quartzite deposit is considerably fissured and sheared, greatly aiding the quarrying of the rock. Owing to the lack of outcrops in the intervening ground between the quarries it is impossible to trace the beds or to find their displacement along the shears.

The deposit is worked during the summer and autumn months and gives employment to about 20 men in the quarries and 4 men hauling the rock. At the time of the writer's visit only the first two quarries were being worked. The tonnage of quartzite quarried annually is dependent on the requirements of the steel plant at Sydney. For the years 1925 to 1930 inclusively, the tonnages produced are as follows:


The total production from the beginning of operations in 1921 to the end of the 1930 season is 50,830 tons.

An analysis of the average grade of quartzite used in making silica brick at Sydney is as follows:


The best-grade rock is the white-weathered, surface quartzite and runs about $98 \cdot 5$ per cent $\mathrm{SiO}_{2}$.

The entire output of quartzite is made into silica brick at the plant of the Dominion Steel and Coal Corporation, Limited, in Sydney, to supply a part of their requirements.

For a systematic development of the deposit considerably more structural data should be obtained and this is possible only either by surface stripping at many points to expose the bedrock or by core drilling. A combination of the two, stripping and short-core drill holes, would give valuable information. The geology indicates that a considerable quantity of quartzite remains to be quarried.

## SKYE MOUNTAIN QUARTZITE DEPOSIT

A brief visit was paid to the quartzite deposit on Skye mountain. George Campbell of Iron Mines kindly acted as guide. The deposit is still in the prospect stage, although some development work has been done on it. The main showing consists of a long, almost continuous outcrop at the summit of Skye mountain.

Skye mountain, the extreme eastern end of Craignish hills, includes that part of the hills north of the village of Iron Mines which runs in a general southwest and northeast direction towards Whycocomagh, sloping down steeply towards St. Patrick channel. The elevation of the upland surface bordering the channel is about 1,000 feet above sea-level. The southeast slope of the mountain is mainly forested by an open hardwood growth; the upland surface is covered by closely growing, small scrub spruce.

The quartzite cropping is about $1 \frac{1}{2}$ miles northwest of Iron Mines and at approximately 975 feet above sea-level. A footpath leads up the mountain slope from Iron Mines to within a few hundred feet of the eastern end of the outcrop.

Along the trail leading from Iron Mines up to the quartzite body, massive, white, crystalline limestone or dolomite is first encountered on the mountain slope. Farther up, quartz-mica schist, impure metamorphosed sandstones, and other associated metamorphosed sediments outcrop. About a mile up the trail from Iron Mines, angular white quartzite becomes quite conspicuous and the guide stated that several pits and trenches were dug at various points exposing white quartzite. The pits and trenches are now almost completely filled with soil and debris.

The main outcrop presents a ledge 10 to 20 feet high at about the summit of Skye mountain. The quartzite may be traced as an almost continuous outcrop for 750 feet, the maximum uncovered width being about 175 feet. Large, angular blocks of white quartzite are found farther west evidently in place. The general trend of the outcrop is northwest (magnetic).

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The surface quartzite is a milky, white, fairly fine-grained, fissile rock somewhat stained by iron oxide and organic material. The fissility planes are spaced about one-eighth of an inch apart and may correspond to the original bedding of the rock. The strike of the fissility is south 32 degrees east (magnetic) and the dip 80 degrees northeast.

A small pit in the quartzite cropping near its eastern extremity exposes the comparatively fresh rock. The unweathered quartzite is a faint greengrey, somewhat sheared rock with a fissility not as pronounced as in the weathered surface quartzite. Very fine-grained pyrite is distributed through the rock in slight amount, more or less oxidized. In thin section the rock is seen to be composed of composite quartz grains with extremely serrated borders and with a fine-grained quartz mosaic around the boundaries. The composite grains are made up of individual grains so arranged optically that under the low power of the microscope they appear as a single grain with undulous extinction. The composite grains average 0.14 mm . in width and 0.52 mm . in length and their longer axes are in a general parallel alinement. The main impurity is actinolite, colourless in thin section, randomly oriented in ragged individuals or aggregates of prismatic grains. Other impurities present are epidote in clusters of small grains, alkali feldspar in small blebs interstitial to the augens, and cubes of pyrite partly altered to red-brown iron oxide. A Rosiwal determination in thin section gave 93 per cent quartz and 7 per cent impurity. The white-weathered, surface quartzite was carefully ground and examined in immersion oils under the microscope. The amount of impurity seemed to be practically nil.

No attempt was made to sample the unweathered quartzite. If the microscopic analysis of the unweathered rock at the eastern extremity of the cropping be any criterion, the quartzite does not possess the high degree of purity demanded in making silica brick and other high-silica products. The white-weathered quartzite appears to be only a foot or so thick, grading into the impure, unweathered rock. This opinion is based only on information gathered at the eastern end of the outcrop and cannot be regarded as final.

For a quartzite deposit of moderately high silica content, this deposit offers exceptional opportunities for exploitation. A large tonnage is undoubtedly available and transportation facilities are favourable. Orangedale, a point on the Canadian National railway, is about 6 miles southeast of Iron Mines by road; tidewater lies near the deposit, at the foot of Skye mountain.

For most commercial purposes, the content of silica must be high and the physical characters uniform; the percentage of silica and the kind and amount of impurities allowable vary with the different industrial uses. The chief properties that make quartzite important commercially are hardness and resistance to heat and ordinary chemical action.

For complete descriptions of the uses of quartzite the reader is referred to the following publications: Cole, L. Heber: "Silica in Canada"; Part 1. Eastern Canada; Dept. of Mines, Canada (1923). McDowell, J. Spotts: "A Study of the Silica Refractories"; Trans. Am. Inst. Min. Eng., vol. 57 (1917). Sosman, R. B.: "The Properties of Silica"; 1927. Weigel, W. M.: "Technology and Uses of Silica and Sand"; U.S. Bureau of Mines, Bull. 266, 1927.

# DEEP BORINGS IN ONTARIO, QUEBEG, AND THE MARITIME PROVINCES 

By W. A. Johnston<br>(Chief, Division of Pleistocene Geology, Water Supply, and Borings)

The importance of obtaining dependable supplies of water for cities, towns, and rural districts, and the increasing necessity of providing information as to the possibility of obtaining additional supplies of water from underground sources as the population of Canada increases both in numbers and density have led to the formation of the Division of Pleistocene Geology, Water Supply, and Borings. The work of the Borings Division being so closely related to that of the new division it was considered advisable to include it in the newly formed division. The work which the Borings Division has been carrying on for over twenty years, involving the collection of samples and records from wells drilled for oil, gas, and water, will continue unaltered, and it is to be hoped that all drillers and owners of water wells will co-operate with the division in the collection of samples and data from wells put down. If the division is advised that a well is going to be put down arrangements can be made whereby samples can be taken from the commencement of operations.

Acknowledgments are due to Col. R. B. Harkness, Gas Commissioner of Ontario, for logs of wells drilled in 1928 and 1929 and for co-operation in securing samples from wells. 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 Scotsburn well put down by that company. Dr. J. A. L. Henderson and Mr. J. Crichton of the New Brunswick Gas and Oilfields, Limited, kindly forwarded samples and logs from wells put down in Moncton district. The Layne Canadian Water Supply Company forwarded several logs of wells put down by them for water. The Alexander Diamond Drilling Company forwarded logs of some drill holes put down in James Bay district. Results of drilling operations for gypsum in Aspy Bay district, Victoria county, N.S., were supplied by the Atlantic Gypsum Products Company. The Sussex Mineral Springs Company of Sussex, N.B., sent a detailed analysis of water from their deep well. Through the courtesy of Mr. E. W. G. Chapman of the Canadian National railways records and samples from several wells drilled by that railway were received. Dr. W. J. McCormick of Toronto forwarded samples from his well covering the "Utica"-Trenton contact.

The only deep test for oil and gas in Nova Scotia was made by the Imperial Oil Company near Scotsburn, Cumberland county. This well was abandoned at 1,980 feet and another one was commenced $2 \frac{1}{2}$ miles south of Amherst, Cumberland county.

In New Brunswick some drilling for oil and gas was done in Moncton district where the New Brunswick Gas and Oilfields, Limited, deepened wells Nos. $7,48 \mathrm{~A}, 82$, and 86 and drilled new wells Nos. 89 and 90.

Records of drilling in the province of Quebec are given in this report. Samples from two wells in Ontario were received, these wells being in districts in which little was known as to the character of the formations at depth. The geological logs of these wells, the Pennsylvania Oil and

Gas Company's well, and that of the Brimblecombe well near Harriston are given. Another well of considerable interest was a diamond drill hole put down in the Bothwell field by the Imperial Oil Company. The $\log$ of the well, together with the report on fossils found in it, is also given. Some drilling for oil and gas was undertaken in James Bay district. Dr. W. S. Dyer of the Ontario Department of Mines examined the samples.

Further work was done by D. C. Maddox on samples of bentonite from the Robert Cherry well at Collingwood. Dr. Marshall Kay of Columbia University, to whom some of the material was sent, reports that he submitted some to Dr. Kerr who advised that X-ray diffraction studies showed it to be a potash bentonite, or metabentonite, and generally similar to the Hounsfield metabentonite found at Medonte and Uhthoff quarries between Orillia and Coldwater.

The province of Ontario, as in previous years, yielded the largest number of records of water wells. The deepest well drilled for water was that at L'Assomption, Quebec, which has not obtained a suitable supply to date. In the Maritime Provinces samples were received from a well put down at Dalhousie, Restigouche county, N.B., to a depth of 300 feet entirely in igneous rock. The names of other wells and names of the drillers will be found in the tabulated list.

Work on samples obtained from wells in eastern Canada was confined to the following.

The well drilled for salt near Gautreau, N.B., 256 samples being examined and bottled.

The well drilled near L'Assomption and the well drilled in Montreal by the Guaranteed Pure Milk Company, 119 samples in all. Wells in southwestern Ontario drilled for oil and gas, 610 samples from four wells were examined and bottled.

Welis in Ottawa district (Carleton, Russell, and Dundas counties); 1,006 samples from 26 wells were examined and bottled, the work being done to determine thickness of formations for the use of geologist's working in the area. In the case of the Beekmantown of this area it is of interest to note the rapid change in magnesian content within short distances. The results of rapidly made, rather approximate effervescence tests in cold acid, are given below. Relative rates of effervescence are indicated in this table by the numerals 2 to 7 ( 2 being the lowest, and 7 the highest, rate); the figures in the columns headed by these numerals are, in the case of each well, the percentages of the total number of samples examined that exhibited effervescence at the various relative rates.

| Well name | Thickness | 2 | 3 | 4 | 5 | 6 | 7 |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | Feet |  |  |  |  |  |  |

The most marked contrast seems to be between the Somerset and Bay Streets' well, which is entirely dolomitic, and the Y.M.C.A. well, which is practically entirely limestone.
Ontario: Wells Drilled for Oil_and Gas

Ontario: Wells Drilled for Oil and Gas-Continued


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| $\varnothing$ |  |  | 오요여용 <br>  <br>  |  <br>  쇼오 |  $\qquad$ |
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Ontario: Wells Drilled for Oil and Gas-Continued






Ontario: Wells Drilled for Oil and Gas-Continued


Ontario: Shallow Wells
RECORDS RECEIVED, 1930



Log of Pennsylvania. Oil and Gas Company Well, Lot 29, Con. IX, St. Vincent Tp., Grey Co., Ont.

| Depth (in feet) | - | Rate of effervescence with acid |  | Notes |
| :---: | :---: | :---: | :---: | :---: |
|  |  | Cold | Hot |  |
| 0- 60 | Shale, red. . | 3 | - | Trace of green shale |
| 60-75 | Limestone, grey and red. | 4 | 6 | Considerable red and green shale. Fossiliferous at 60-65 feet |
| 75-80 | Limestone, medium grey. | 4 | 6 |  |
| 80- 95 | ، | 5 | 6 | Considerable grey shale |
| 95-105 | lomite groy and | 5 | 6 | " red and green shale |
| 105-110 | Dolomite, grey and red... | 3 | 6 |  |
| 110- 120 | Shale, red and green-grey.. | 3 | 5 | " limestone |
| 120- 125 | " red................. | 2 | 4 | Calcareous |
| 125- 145 | " red and green-grey. | 2 | 4 | " |
| $145-155$ $155-160$ | " " " | 3 2 | 4 | Considerable dolomite |
| $\begin{array}{ll}155-160 \\ 160 & 170\end{array}$ | " ${ }_{\text {" }}$ grey....... | 2 | 5 | Considerable dolomite |
| $160-170$ $170-190$ | " green-grey. | 2 | 5 4 | Calcareous |
| 290-430 | " " | 1 | 3 |  |
| 430-630 | " " | 1 | 2 |  |
| 630-660 | - " dark grey. | 1 | 2 |  |
| [ 665 | "، " | 2 | 4 | Calcareous 6 ce 690 and 700 fet |
| 665-700 | " " | 1 | 2 | " at 690 and 700 feet |
| 705-705 | " " | 3 | 5 | Considerable brown limestone |
| 705-715 | " Limestone, medium grey. | 2 | 3 |  |
| $720-725$ | Limestone, medium grey. | 3 | 5 | Considerable dark grey shale |
| $730-740$ | " ${ }^{\text {a }}$ | 4 | 5 | A. little grey shale |
| $750-845$ $850-870$ | " ${ }^{\prime}$ | 5 | 6 | " " |
| $870-890$ | " | 5 | 6 |  |
| 895-950 | " " | 5 | 6 | A little green-grey shale |
| 955-960 | " " | 5 | 6 |  |
| 965-1,015 | " " | 5 | 6 | " " |
| 1,020-1,045 | " " | 5 | 6 |  |
| Stratigraphic interpretation: |  |  |  | Depth |
| Cabot Head. |  |  |  | Feet $0-60$ |
| Manitoulin dolomite |  |  |  | 60- 110 |
| Queenston; |  |  |  | 110-155 |
|  |  |  |  | 155-630 |
| UticarCollin |  |  |  | 630-815 |
|  |  |  |  | 815-1,045 |

Log of Goodyear Farm Well, Imperial Oil Company, Bothwell Field, Lot 6, Con. VIII, Zone Tp., Kent Co., Ont.

| Depth | - | Rate of effervescence with acid |  | Notes |
| :---: | :---: | :---: | :---: | :---: |
|  |  | Cold | Hot |  |
| 180 ft .6 ins. -182 ft . | Limestone, brown-grey........ | 4 | 5 | Considerable shaly residue after acid |
| 184 ft . | Shale, brown-grey.............. | 3 | 4 |  |
| 185 ft . | Limestone, brown-grey......... | 4 4 | 5 5 | 25 per cent insoluble in acid Shaly |
| 188 ft . -192 ft . | Shale, brown-grey. | 4 | 5 | Calcareous |
| 192 ft . -204 ft . | Limestone and shale, browngrey | 4 | 5 | Grades into calcareous shale at 204 feet |

Log of Goodyear Farm Well, Imperial Oil Company, Bothwell Field, Lot 6, Con. VIII, Zone Tp., Kent Co., Ont.-Continued

| Depth (in feet) | - | Rate of effervescence with acid |  | Notes |
| :---: | :---: | :---: | :---: | :---: |
|  |  | Cold | Hot |  |
| $\begin{array}{r} 204 \mathrm{ft.} 6 \text { ins. }-206 \mathrm{ft} . \\ 208 \mathrm{ft} . \end{array}$ | Limestone, brown-grey . | 5 | 6 | Residue after acid 30 per cent |
|  | Shale, brown-grey............. | 3 | 4 | Residue after acid 60 per cent |
| $\begin{array}{r} 209 \mathrm{ft} . \\ 209 \mathrm{ft} .-210 \mathrm{ft} .8 \mathrm{ins} . \\ 211 \mathrm{ft} . \end{array}$ | Limestone, brown-grey | 5 | 6 | Residue after acid 22 per cent |
|  | " " ...... | 4 | 5 | Residue after acid 35 per cent |
|  | medium grey...... | 4 | 5 | Considerable shaly residue after acid |
| $212 \mathrm{ft} .-213 \mathrm{ft}$. | Shale, dark brown............. | 3 | 4 | Calcareous. Bituminous. Oil by distillation |
| $213 \mathrm{ft}$.8 ins . | Limestone, medium brown.... | 5 | 6 |  |
| $215 \mathrm{ft} .-216 \mathrm{ft}$. | " light brown...... | 3 | 6 | Bituminous. Oil by distillation. Dolomitic |
| 217 ft . -218 ft . | " . dark brown....... | 3 | 7 | Bituminous |
| 219 ft . | " light brown....... | 6 | 7 |  |
| 221 ft . 2222 ft . | " dark brown....... | 5 | 6 | Slightly bituminous |
| 221 ft . -222 ft . | " light brown. | 5 | 6 |  |
| 223 ft 224 ft . | " dark brown. | 3 | 6 | Dolomitic |
| $225 \mathrm{ft} .-234 \mathrm{ft}$. | "" light brown....... | 4 | 5 |  |
| 225 ft . 230 ft . | Dolomitic limestone, light brown | 4 | 6 | Bituminous at 229 feet |
| 231 ft . | Limestone, dark brown. . . . . . | 4 | 5 | Slightly bituminous |
| 232 ft . | Dolomite, dark brown........ | 2 | 5 |  |
| 233 ft . | Limestone, dark brown. | 5 | 7 | Bituminous. Oil by distillation |
| $234 \mathrm{ft}$. . | " brown-grey. | 4 | 6 | Dolomitic |
| 235 ft . | "، dark brown. | 4 3 | 6 | " Bituminous |
| 237 ft .-238 ft. | " light brown. | 4 | 6 | * |
| $239 \mathrm{ft} .-247 \mathrm{ft}$. | " | 3 | 6 | " |
| 248 ft . -251 ft . | " | 4 | 6 |  |
| 252 ft . | " | 5 | 7 |  |
| - 253 ft . | medium brown.... | 5 | 7 |  |
| 254 ft . -255 ft . | " light brown. | 3 | 6 | Dolomitic |
| 257 256 ft . | " dark brown. | 3 | 5 | " |
| 257 ft . -277 ft . | " light brown. | 4 | 6 | * |
| 278 ft . -284 ft . | ¢ | 5 | 6 |  |
| 285 ft . -287 ft . | " " ${ }^{\prime \prime}$...... | 5 | 7 |  |
| 288 ft . 297 ft . | " " | 4 | 7 | Dolomitic |
| 298 ft . -302 ft . | " " $"$ "..... | 6 | 7 |  |
| $303 \mathrm{ft} .-307 \mathrm{ft}$. | " " | 4 | 6 | " |
| $308 . \mathrm{ft}$. -311 ft . | "" " | 5 | 7 |  |
| 313 ft . -312 ft . | " " | 5 | 6 | Dolomitic |
| $313 \mathrm{ft} .-314 \mathrm{ft}$. | " | $\stackrel{4}{5}$ | 5 7 | Dolomitic |
| 316 ft . -319 ft . | " medium brown.... | 5 | 7 |  |
| 320 ft . -338 ft . | "" light brown....... | 5 | 6 |  |
| 339 ft . | " | 5 | 7 |  |
| $340 \mathrm{ft} .-343 \mathrm{ft}$. | " very light brown. | 5 | 7 |  |
| 344 ft . -352 ft . | " light ${ }_{6}$ brown....... | 4 | 7 | " |
| 353 ft . -354 ft . | 6 | 5 | 7 |  |
| $356 \mathrm{ft}-355 \mathrm{ft}$. | Chert, light brown.... | 2 | 3 |  |
| 356 <br> $358 \mathrm{ft} .-357 \mathrm{ft}$. <br> 63 ft | Dolomite, light brown. | 3 | 7 |  |
| 358 ft. -363 ft . | Limestone, light brown. | 4 | 7 | " |
| $365 \mathrm{ft}-365 \mathrm{ft} 764 \mathrm{ft}$. | Dolomite, light brown. | 2 | 7 |  |
| $365 \mathrm{ft} .-365 \mathrm{ft} .7 \mathrm{ins}$. | Limestone, light brown | 4 | 7 | " |
| $365 \mathrm{ft} .7 \mathrm{ins} .-388 \mathrm{ft}$. $388 \mathrm{ft}-392 \mathrm{ft}$. ins |  |  |  |  |
| 388 ft . -392 ft .6 ins. | Dolomite, light brown........ | 2 | 7 |  |

Core recovery complete except for section 192-204 feet; porous at 223-224 feet; decidedly sandy towards the base.
The fossils present as identified by Mr. E. M. Kindle and his stratigraphic interpretations follow:
Feet
Chonetes deflecta ..... 181
Chonetes sp. and Platyceras sp ..... 183
Phacops sp ..... 184
Leiorhynchus laura ..... 185
Chonetes deflecta ..... 186
Chonetes deflecta. ..... 197 to 204
A trypa reticularis ..... 206
Spirifer mucronatus ..... 209
Styliolina fissurella ..... 210
Rhipidomella cyclas and Chonetes deflecta. ..... 211
The species above listed represent the Hamilton portion of the"well section. The fauna below 211 feet, listed in order of depth, includes the following:Feet
Stropheodonta sp. ..... 218
Atrypa reticularis ..... 225
Spirifer cf. manni ..... 227
Chonetes cf. hemisphericus. ..... 228
Camarotoechia sp. and Spirifer sp ..... 235
Spirifer ef. manni ..... 236
Pholidostrophia iowensis. ..... 237
Rhipidomella sp ..... 239
Spirifer cf. varicosus ..... 242
Spirifer cf. varicosus. ..... 250 and 251
Rhipidomella sp ..... 258
Pholidostrophia iowensis. ..... 257
Camarotoechia cf. carolina ..... 266
Atrypa spinosa ..... 275
Platyceras sp ..... 291
Spirifer cf. medialis ..... 301
Stropheodonta demissa ..... 303
Atrypa spinosa ..... 310
Styolites well developed at ..... 312
Camarotoechia sp. and cone-shaped bryozoa (Fenestella?) ..... 317
Fenestella? sp. and Productella sp ..... 318
Productella sp. ..... 321
Atrypa reticularis ..... 323
Camarotoechia tethys ..... 328
Intermandibular tooth of a small Onychodus, probably O. Sig- moides Newberry (Middle and Upper Devonian) ..... 329
Crinoid stems ..... 330
Atrypa reticularis? ..... 331
Chonetes sp. ..... 334

81d
Log of H. Brimblecombe Well, Harriston, Wellington County, Ont.


82D
Log of H. Brimblecombe Well, Harriston, Wellington County, Ont.-Continued

| Depth <br> (in feet) | - | Rate of effervescence with acid |  | Remarks | $\underset{\text { minosity }}{\text { Bitu- }}$ | $\begin{aligned} & \text { Insoluble } \\ & \text { residue } \\ & \text { after HCl } \end{aligned}$ | Precipitate with barium chloride |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Cold | Hot |  |  |  |  |
| 325 | Dolomite, medium ${ }_{\text {cs }}$ brown. | 1 | 7 | Selenite, P. |  | Low | Trace |
| 330 335 | " brown-grey .... | 1 | 7 |  |  |  |  |
| 335 340 |  | 0 | 7 |  |  | High | Medium |
| 345 | " dark grey | 1 | 7 | Selenite, |  | " | " |
| 350 | " ${ }_{\text {" }}$ | 1 | 7 |  | B | " | Trace |
| 355 360 | " light " | 3 |  |  | B S | " | Hir |
| 370 | " light ${ }_{\text {grey }}$ | ${ }_{3}^{3}$ | 7 | Much gypsum | $\stackrel{\text { SB }}{\text { SB }}$ | " | High |
| 375 | Dolomitic limestone, dark grey | 4 | 7 | Gypsum, P.. | SB | " ${ }^{\text {a }}$..... | 'Trace |
| 880 385 | " " " $\quad$ " | 4 | 7 | " | $\stackrel{\text { SB }}{\text { SB }}$ | Medium... | " |
| 390 400 | Dolomite, grey-brown. | 0 | 7 | Much gypsum.. | SB | Very low. | High |
| 400 410 | " " | 1 | 7 | Little gypsum and selenite. | SB | Low.... | Present |
| 415 | Dolomitic limestone, dari grey | 4 | 7 | Much gypsum. Pyrite, P. | ${ }_{B}$ | High. | High |
| 420 |  | 4 | 7 | Little gypsum. | SB |  | Medium |
| 425 430 | Limestone, dark grey......... | 5 | 7 |  | ${ }_{\text {B }}^{\text {B }}$ | Medium. | Trace 0 |
| 440 | " " | 6 | 7 | Little gypsum | B | Low. | Medium |
| 450 | " | 6 | 7 |  | B | Medium. | Trace |
| 460 | " | ${ }_{5}^{6}$ | 7 | Little gypsum | B |  | Present |
| 470 480 | "" " | 5 | 7 |  | ${ }_{B}^{B}$ | Low | ${ }_{0}^{0}$ |
| 490 | " " $\ldots$...... | 6 | 7 |  | 13 | ": | 0 |
| 495 | mottled, light and | 6 | 7 | Much gypsum and selenit | B | Medium | High |
|  | " dark grey " |  |  | " ${ }^{\text {a }}$ |  | Very high | " |
| 505 | " ${ }^{\text {" }}$ " ${ }^{\text {a }}$ " ${ }^{\text {a }}$ | ${ }^{6}$ | 7 |  | B | Medium... | Medium |
| 510 520 | "، " ${ }^{\prime \prime}$ " ${ }^{\text {" }}$ | 5 | 7 | Much gypsum and selenite. | $\stackrel{\text { SB }}{\text { SB }}$ | " $\quad$..... | High |
| 525 | " medium grey..... | 5 | 7 | Selenite, P. | B | " | Present |
| 530 | " | 7 | 7 |  | B | High. | Medium |
| 540 | " " ${ }_{\text {" }}$ | ${ }_{6}$ | 7 | Much gypsum and selenite. | B |  |  |
| 545 550 | " grey-brown | 6 | 7 7 |  | - ${ }_{\text {B }}$ |  | Trace |
| 560 | " ${ }^{\text {c }}$ | 7 | 7 |  | SB | Very 1 | 0 |
| 570 |  |  |  |  | SB | "\% |  |




Sulphates were tested for with barium chloride in acid solution.
Under column headed bituminosity, $\mathrm{B}=$ bituminous, $\mathrm{SB}=$ slightly bituminous; this test was also made on the acid solution.

The symbol P. means present in amounts of less than 1 per cent. The fossiliferous horizon at 730 to 740 feet was searched for fossils, but nothing very diagnostic was located.

Following is a generalized geological log of the well:

|  | Feet |
| :---: | :---: |
| Surface deposits. | 70 |
| Salina, dolomite gypsum, and shale | 345 |
| Guelph and Lockport, limestone... | 275 |
| Cabot Head and Manitoulin, limestone and shale. | 110 |
| Queenston, shale. . . . . . . . . . . . . . | 150 |
|  | 950 |

The chief point of interest in connexion with the well is that there is practically no sandstone at the horizon of the Grimsby or Whirlpool sandstone above the Queenston shale. The limestones as shown by the samples are only slightly dolomitic. No commercial quantities of gas were reported from the well.

# LOGS OF WELLS DRILLED FOR OIL AND GAS, IN QUEBEC 

By D. C. Maddox

With the exception of a few rather shallow test wells, little drilling for oil and gas was undertaken in the province of Quebec during 1930. The progress of the deep test for water being made near L'Assomption, by the Dominion Department of Agriculture, was watched with great interest, but no commercial yields of oil or gas have yet been obtained at this point. Renewed interest, however, was displayed during 1930, in the oil and gas possibilities of that part of the province of Quebec lying between Montreal and Quebec city and bounded on the north and east by the Precambrian and on the south and west by the Champlain fault. In view of the numerous inquiries received at this office for logs of wells drilled for oil and gas in this area it seems advisable to assemble and publish the available information.

In the list of wells are included some that were drilled for water. Though it is practically certain that these wells gave no indications of the presence of oil or gas they provide information regarding the porosity of the rocks, more especially of the Lorraine shales and Trenton and Black River limestones. Many of the water wells are located in areas in which the Trenton limestone outcrops at the surface, but some were drilled in areas where a more or less impervious shale overlies the limestone.

## MONTREAL AND VICINITY

The results of deep drilling for water in this district are described in Memoir 72, "The Artesian Wells of Montreal," by C. L. Cumming. This publication contains records of 179 wells covering depths up to 2,550 feet. In a few wells pockets of gas are recorded as occurring, but no commercial production was obtained. Stratigraphically, most of the wells started in the Trenton or Black River formations, a few commenced in the overlying Utica formation. The Chazy and Beekmantown were penetrated by some of the deeper wells, but the Potsdam sandstone was not reached. Since the date of issue of Memoir 72 the only $\log$ of a deep well received was of one put down on Aqueduct street by Wallace Bell for the Guaranteed Pure Milk Company. Records from this well cover a depth of 625 feet, all in dark grey limestone except for igneous rock, apparently dyke or sill material, at 410 and 500 feet. No oil or gas was recorded as occurring in the well.

## L'ASSOMPTION AREA

The log of the deep test for water at the Federal Experimental Farm located about one mile south of the town and near the west bank of L'Assomption river is No. 1 of the following list of logs. Two wells were drilled in the town of L'Assomption by Mons. Rioux the driller of the Experimental Farm well. One of these, 400 feet deep, was drilled for Mons. Parent, the other, 1,015 feet deep, for the town. In the absence of samples information about them is necessarily very indefinite, but the
interpretation of general descriptions by the driller of the rocks passed through and comparison with results obtained at the Experimental Farm well seem to show that the sequence was about as follows.

The town well, close to river bank, on west arm of horseshoe bend.

|  | Feet |
| :---: | :---: |
| Urica. | 140- ${ }^{0}$ - 140 |
| Trenton | $340-600$ |
| Igneous roc | $600-800$ |
| Trenton. | $8800-850$ |

Mons. Parent well, about 1,500 feet east 15 degrees south of the town well.

$$
\begin{aligned}
& \text { Driit. } \\
& \text { Igneous rock......................................................................... 120-240 } \\
& \text { Utica } \\
& \text { A little water was obtained, but no large flows of gas. } \\
& \text { st.-PAUL-L'ERMITE } \\
& \text { A well drilled for water found salt water at } 60 \text { feet. } \\
& \text { joliette county }
\end{aligned}
$$

In 1893 a well was drilled for water to a depth of 305 feet, it was reported as having passed into magnesian rocks at 300 feet, possibly into the Beekmantown dolomite. In 1890 another well, 160 feet from the above, was drilled to a depth of 125 feet. No oil or gas was obtained from either of these wells. Verbal communication by Mons. Rioux as to the results of his drilling operations in this general area were to the effect: that no commercial yield of gas was obtained; that at Lanoraie, a little gas was found in some wells, the deepest being 200 feet and the strata possibly being Lorraine; that at Roche d'Achigan a well 200 feet deep was drilled in what may be Trenton; that at St. Alexis drilling was to depths of 150 to 400 feet possibly in Trenton or Trenton and Chazy; that at St. Sulpice drilling was to a depth of 520 feet in, possibly, Utica.

## Louiseville area

In this area the Combustile Gas Company drilled a number of wells. ranging in depth from 295 to 695 feet. Gas in varying amounts, and salt water apparently from the Utica shales, are recorded from all of them.

## berthier

A well 899 feet deep was drilled for water for a distillery. Slightly saline water was obtained, but no large amounts of gas. No records are available. The strata at Berthier may be Lorraine about one mile from the contact with the "Utica", the possibility exists, therefore, that the well reached the Trenton formation.

## THREE RIVERS

In 1909 a well was drilled to 1,750 feet, at a point about 2 miles from the town. H.M.Ami who examined the few available samples reported the log as:

|  | Feet |
| :---: | :---: |
| Surface deposits | $0-150$ |
| Queenston. | $150-300$ or 350 |
| Lorraine. | 300 or $350-1,250$ or 1,350 |
| Utica. | 1,250 or 1,350-1,750 |
| A show of oil | feet was recorded. |

## YAMACHICHE AREA

The Canadian Gas and Oil Company drilled about 15 wells to depths up to 300 feet. A little gas with a good deal of salt water was obtained at or near the base of the drift.

## PORTNEUF COUNTY

Records of several wells drilled for water follow.
Grondines: Wells drilled by Mons. E. H. Guilbault.
No. 1, depth 125 feet; 100 feet limestone, 25 feet sandstone; gas at 45 to 115 feet drowned out by salt water at 115 feet.
No. 2, depth 155 feet; thin beds of sand in limestone recorded.
No. 3, depth 70 feet; a little gas and water at 43 feet.
Several other wells were drilled to depths of 30 to 40 feet, but no gas is recorded as occurring in them. The area is underlain by a thin veneer of limestone resting on the Precambrian.

St.-Marc-des-Carrieres. A number of wells were drilled for water, by the town. The records of seven of these, covering depths to 450 feet, indicate 20 to 65 feet of Ordovician limestone underlain by Precambrian granite and crystalline limestone. No gas is recorded as having been found.

Pointe-aux-Trembles. A well 395 feet deep was put down for the convent at this point. No large yield of gas was reported.

## CAP ROUGE

The condensed $\log$ of a well put down by the Federal Experimental Farm to a depth of 625 feet is No. 2 in the list of logs.

## QUEBEC CITY

The Shawinigan Engineering Company put down a well 1,050 feet deep at the terminal station, Orleans avenue. The log of this well is as follows:


Samples from 950 to 1,000 feet showed marked slickensides.

## LA PRAIRIE

A well drilled by the La Prairie Brick Company to a depth of 2,330 feet is reported as passing through 1,500 feet of shale and 800 feet of limestone. No records of oil or gas being found are on hand.

## VErchères

Two wells were drilled near the shore of the St. Lawrence by the Quebec Fuel Company in 1909 and 1910. No. 3, one mile below the village, on lot 27, Grande Côte, is 2,450 feet deep, and its log was reported as being:

|  | Feet |
| :---: | :---: |
| Surface deposits. | $0-125$ |
| Lorraine and Utica | 125-1,860 |
| Trenton. | 1,860-2,450 |

Gas reported at 1,860 feet, 250,000 cubic feet per day, pressure 240 pounds per square inch. No. 4 is half a mile above the village and its log was reported as being:

| as reported as being: | Feet |
| :---: | :---: |
| Surface deposits. | 0-125 |
| Lorraine and Utica. | $125-1,900$ |
| Trenton. | 1,900-2,200 |

Indications of gas, but not in paying quantities, 50,000 to 100,000 cubic feet per day.

## ST. HYACINTHE

Seven wells were put down in an area about 4 to 6 miles north of the town of St. Hyacinthe and west of Yamaska river and the town of St. Barnabé. Five of these were drilled by tne Canadian Natural Gas Company and two by the National Gas Company. The detailed logs of these wells and of one at Ste.-Madeleine, with a summary of the results obtained, are Nos. 3 to 10 in the list of logs. It is of interest to note that well No. 1 of the Canadian Natural Gas Company and well No. 1 of the National Gas Company reached the top of the red beds at 1,000 feet and 980 feet, respectively. The line joining these wells approximately corresponds in direction with the axis of the Pierreville syncline as mapped.

## ST. ROCH, RICHELIEU COUNTY

A well located about one mile west of Richelieu river was drilled by the Quebec Fuel Company to a depth of 2,800 feet to 3,000 feet. The Trenton limestone was penetrated for 200 feet, but no gas was found in it, though a little was reported as occurring in the shale.

## YAMASKA

The Quebec Fuel Company drilled a well about one mile south of the village to a depth of 3,060 feet. Alluvium to a depth of 180 feet and red shale from 180 to 570 feet are reported. The contact between the Lorraine and the Utica is not recorded, but the well was still in Utica at 3,060 feet.

## NICOLET COUNTY

A number of wells have been drilled. Some of the principal ones are as follows.

Nicolet Town Area. A well was put down to a depth of 2,270 feet close to the college. The Lorraine is recorded as occurring below 110 feet of drift and a little gas was found in this formation at 604 feet. The Trenton limestone was not reached.

St. Grégoire District. The $\log$ of the Trudel well on lot 501, concession of Beauséjour, is No. 11 of the following list of logs. The Canadian Gas and Oil Company sank wells near the Trudel well. Of these: No. 1 was drilled to about 1,400 feet passing into red shale at 485 feet; No. 2 was drilled to 801 feet passing into red shale at 450 feet; and No. 3 was drilled to 500 feet. No commercial yield of gas was reported from any of the three
wells. The log of Bergeron well located 2 miles west of St. Grégoire on Pointu concession is log No. 12 of the following logs. The Quebec Department of Mines Annual Report, part B, 1929, page 87, contains information on five other wells in this district, drilled to depths up to 3,000 feet. No detailed logs seem to be available. A little gas flow, not of commercial value, is reported in all but one. The position of the wells is such that it is not probable the Trenton limestone was reached. All these wells are now abandoned.

## LIST OF LOGS

Samples from all these wells, except Nos. 11 and 12, were examined by the division. To express tne relative quantities of subordinate constituents in the well samples, the following symbols have been used:
S.D. meaning superdominant and constituting 100 to 90 per cent of the minor constituents.
D. meaning dominant and constituting 90 to 50 per cent of the minor constituents.
V.H. meaning very high and constituting 50 to 25 per cent of the minor constituents.
H. meaning bigh and constituting 25 to $12 \frac{1}{2}$ per cent of the minor constituents.
M. meaning medium and constituting $12 \frac{1}{2}$ to $6 \frac{1}{4}$ per cent of the minor constituents.
L. meaning low and constituting $6 \frac{1}{4}$ to $3 \frac{1}{3}$ per cent of the minor constituents.
V.L. meaning very low and constituting $3 \frac{1}{3}$ to 1 per cent of the minor constituents.
P. meaning present and constituting less than 1 per cent of the minor constituents.

The numbers in the column under the heading "Rate of Effervescence" refer to the speed of effervescence of the material in dilute hydrochloric acids1: 4.

| 1 | meaning extremely slow. |  |
| :--- | :--- | :--- |
| 2 | " | very slow. |
| 3 | " | slow. |
| 4 | " | medium. |
| 5 | " | fast. |
| 6 | " | very fast. |
| 7 | " | extremely fast. |

It should be noted that an effervescent of rate 7 with cold acid implies that the rock is a pure limestone, the lower numbers implying a successively lower calcium carbonate content.

90D
Log No. 1, Dominion Experimental Farm Well, Near Bank of L'Assomption.
River, About 1 Mile South of L'Assomption

| Depth (in feet) | - | Rate of effervescence with acid |  | Remarks |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Cold | Hot |  |  |
| 25 | Clay, dark grey. | 0 | 0 | A little coarse sand Much coarse sand |  |
| 35- 110 | "4 medium grey | 3 | 4 |  |  |
| 120 | Shale, dark grey. | 2 | 1 |  |  |
| 125-275 |  | 0 | - |  |  |
| 285- 375 | Igneous rock, medium grey.... | 1 | 1 |  |  |
| 385- 425 | Shale, dark grey.............. | 0 | 1 |  |  |
| 435- 515 | " very dark grey. | 1 | 2 |  |  |
| $525-535$ | " ${ }^{\text {c }}$ | 2 | 3 |  |  |
| 535- $\begin{array}{r}590 \\ 590\end{array}$ | Samples missing |  |  |  |  |
| $\begin{aligned} & 590 \\ & 600 \end{aligned}$ | Igneous rock, dark grey....... | 3 | $\begin{aligned} & 4 \\ & 5 \end{aligned}$ | $\underset{\text { Much }}{\text { dark }}{ }_{\text {as }}$ grey shale |  |
| 610-620 | " dark brown-grey | 1 | 2 |  |  |
| 630 | Shaly limestone, dark grey .. | 4 | 5 |  |  |
| 640 | " | 4 | 5 | 30 per cent |  |
| 650 | " ${ }^{6}$ | 4 | 5 | $35$ |  |
| 660 | " " " | 4 | 5 |  |  |
| 670 | " " ${ }^{\text {a }}$ | 4 | 5 | 40 " |  |
| 680 | " " " | 4 | 5 | 25 " |  |
| 690 | " " | 5 | 6 | 30 " |  |
| 700 | " | 5 | 6 | 30 " |  |
| 710 | Limestone, dark grey. | 5 | 6 | 35 |  |
| 720 |  | 5 | 6 | 20 " |  |
| 730 | * | 5 | 6 | 20 " |  |
| 740 | " ${ }^{\prime \prime}$ ¢ $\ldots$..... | 5 | 6 | 30 " |  |
| 750-1,030 | dark brown-grey.. | 5 | 6 |  |  |
| 1,040-1,080 | " ${ }_{\text {" }}$ brown-grey....... | 6 | 7 | Considerable shale residue small |  |
| 1,090-1,170 | " dark brown-grey. | 6 | 0 | considerable |  |
| $1,180-1,200$ $1,210-1,250$ | "* dark brown-grey.. | 6 7 | 0 | considerable shaly residue |  |
| 1,260 | " brown-grey....... | 6 | 0 | very small <br> 10 per cent, fine sand and shale |  |
| 1,270 | " " | 6 | 0 |  |  |
| 1,280 | " " | 6 | 0 | 10 per cent, fine sand and shale |  |
| 1,290 | " " | 6 | 0 | 10 " | " $"$ |
| 1,300 | * | 6 | 0 | 30 " | " ${ }^{6}$ |
| 1,310 | " | 6 | 0 | 25 " | $" \%$ |
| 1,320 | " | 6 | 0 | 32 " | " $"$ |
| 1,330 | " " | 6 | 0 | 18 " | " |
| 1,340 | " " | 6 | 0 | 20 " | " |
| 1,350 | " " | 6 | 0 | 20 " | " " |
| 1,360-1,370 | " ${ }_{6}^{6}$ \% | 6 | 0 | very small |  |
| 1,380-1,410 |  | 6 | 0 | small |  |
| 1,420-1,430 | " " | 6 | 0 |  |  |
| 1,440-1,450 | " ${ }^{\prime \prime}$ " | 6 | 0 |  |  |
| 1,460-1,480 | " medium grey. | 6 | 0 | 50 per cent; shaly |  |
| 1,490 | " ${ }_{\text {" }}$ " | 5 | 0 |  |  |
| 1,500 | " | 5 | 0 | 30 " " |  |
| 1,510 | " ${ }^{\prime \prime}$ | 5 | 0 | 30 " " |  |
| 1,520 | " light grey. | 5 | 0 | 20 per cent; sandy |  |
| 1,530 1,540 | Sandstone, light grey.. | 5 4 | 0 | 606060 |  |
| 1,550-1,580 | " | 4 | 5 | Coarse grained, a few well-rounded quartz grains to 2 mm . |  |
| 1,590-1,610 | Shaly limestone, dark grey. | 4 | 6 |  |  |
| 1,620-1,630 | Limestone, dark brown-grey. . | 5 | 6 |  |  |
| Stratigraphic Interpretation: |  |  |  | Depth Thickness |  |
|  |  |  |  | O- $120 \quad 120$ |  |
| Utica shale...... |  |  |  | . 120-285 | 165 |
| Igneous rock |  |  |  | . ${ }^{\text {. }}$ 285- 385 | 100 |
| Utica shale. |  |  |  | . 385- 590 | 205 |
| Igneous rock. |  |  |  | .... 590-630 | 40 |
|  |  |  |  | .. 630-1,530 | 900 |
| Trenton, Black River, and Chazy limestoneChazy sandstone......................... |  |  |  | ... 1,530-1,590 | 60 |
| Beekmantown limestone. |  |  |  | .... 1,590-1,630 | 40 |

Mr. Montreuil, Farm Superintendent, has furnished the following information.

Water from a depth of 835 feet yielded on analysis:

|  | Parts per million |
| :---: | :---: |
| Common salt ( NaCl ) | 30,030 |
| Sulphate of lime ( $\mathrm{CaSO}_{4}$ ) | 112 |
| Carbonate of lime ( $\mathrm{CaCO}_{3}$ ) | 1,978 |
| Carbonate of magnesia ( $\mathrm{MgCO}_{3}$ ) | 161 |

Water from a depth of 845 to 850 feet had the same general character as that from a depth of 835 feet.

Water from a depth of 1,050 feet yielded on analyses:

|  | Parts per million |
| :---: | :---: |
| Common salt ( NaCl ) | 24,710 |
| Magnesium chloride ( $\mathrm{MgCl}_{2}$ ) | 2,435 |
| Calcium chloride ( $\mathrm{CaCl}_{2}$ ) . | 2,418 |

Between a depth of 90 to 100 feet, gas poured out of the well at a high pressure for about half an hour and then decreased to practically nothing.

On March 13, 1929, when the drill reached a depth of between 830 and 835 feet, gas began to pour out of the well at a very high pressure, blowing water and mud so high that this water and mud fell on the ground 900 feet away. On the next day, March 14, a valve was put on the well and the pressure of the gas was still 85 pounds per square inch. With the gas fairly large quantities of salty water were blown out of the well. On March 16, the flow of water discontinued and the pressure of gas was low. On March 18, at about 845 feet deep, a mixture of water and gas again blew out of the well. Large quantities of gas rose, but the flow of water was irregular. Sometimes the water rose for a while at the rate of 4 gallons per minute and then slowed down to 2 gallons. Some gas still comes out of the well but in very small quantities, just enough to keep burning when forced to pass through a $\frac{1}{2}$-inch opening.

## Log No. 2, Condensed Log of Well on Dominion Experimental Farm, Cap Rouge, Quebec

| Depth (in feet) | - | Rate of effervescence with acid |  | Remarks |
| :---: | :---: | :---: | :---: | :---: |
|  |  | Cold | Hot |  |
| 300-490. | Shale, grey. | 2 | 3 | Slightly calcareous, white calcite at $300-320$ feet, $375-380$ feet, and 400405 feet, probably vein filling |
| 495-570... | Shale, dark grey | 1 | 2 | Less calcareous than the above |
| 575-600... | Shale, dark grey.............. . | 1 | 2 | With a large proportion of greenish grey shale |

## St. Hyacinthe District: Wells Drilled by the Canadian Natural Gas Company and by the National Gas Company

| Well | Location | Depth | Thickness of red beds | Igneous rocks | Gas at depth |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | (in feet) | (in feet) | (in feet) | (in feet) |
| Gan. Natural Gas Co., | Lot 164, St.-Amable, | 1,880 | 980 | 1,105-1,110 | 1,860 |
| Can. Natural Gas Co., | North * | 2,907 | 1,270 | 1,200-1,210 | 2,900 |
| Can. Natural Gas Co., | Lot 227, St.-Amable, | 3,455 | 0 | 2,315-3,455 | 1,600 |
| No. 3 | South ${ }^{\text {S }}$ |  |  |  |  |
| Can. Natural Gas Co., No. 4 | Lot 982, St. Jude- Ste.-Rose | 2,380 | 1,620 | - | - |
| Can.Natural Gas Co., | Lot 160, St.-Amable, | 2,508 | 1,120 | 900-930 | 1,600 |
| National Gas Co., | Lot 1319, St.-André, | 2,050 | 1,000 | 1,000-1,040 | 1,510-1,520; 1,940- |
| No.1 1 | North " |  |  |  | ,510-1,520; 1950 |
| National Gas Co., No. 2 | " " " | 1,826 | 660 | 1,300-1,320 | 1,720 |

The thickness of the red beds in the case of Can. Nat. Gas Co., well No. 1, is taken from a $\log$ prepared by E. Dulieux; only 12 samples from this well were received.

The depth of Can. Nat. Gas Co., well No. 4 , is given as 3,000 feet, but samples received cover a depth of only 2.680 feet.

All wells passed through igneous rocks except Canadian Natural Gas Company well No. 4.
In all the wells evidences of faulting were found, this evidence consisting of slickensides and the presence of large amounts of vein calcite considered as filling in the fracture zones generally associated with faults.

The deepest well, Can. Nat. Gas Co., well No. 3, began in the Lorraine formation and apparently did not reach the underlying Utica shale. In this well 3,415 feet of dark grey shales were penetrated before igneous rock was struck. All samples from this well were subjected to distillation tests with negative results. The fact that the Utica shale is in general much more bituminous than the Lorraine shale would seem to make it very improbable that the Utica was reached. Close search for fossils in the last 200 feet of shale penetrated in this well was negative.

All the flows of gas are recorded as being small except that in the Can. Nat. Gas Co. well No. 1 , for which a pressure of 275 pounds was claimed to have been obtained. None of the wells is a commercial producer at the present time.

Log No. 3, Canadian Natural Gas Company, Well No. 1, Lot 164,

| Depth (in feet) | - | Rate of effervescence with acid Cold | Remarks |
| :---: | :---: | :---: | :---: |
| 350 | Sandy shale, reddish brown | 1 | Rounded quartz, P.; fibrous calcite, P. |
| 425 | " " " | 2 | Rounded quartz, L- ; green shale, $\mathrm{P}^{\text {P. }}$ |
| 575 | " " | 1 | Rounded quartz, $\mathrm{H}_{\text {; }}$; green shale, P . |
| ${ }^{980}$ | Shale, dull green............ | 2 | Red shale, L.: rounded quartz, P. |
| 1,106 | Igneous, dark ${ }_{\text {u }}$ grey.......... | 1 |  |
| 1,265 | Shale, dark grey | 4 | Vein calcite, V.H.; much slickensided |
| 1,285 | "" "4 | 5 | Vein calcite, V.H.; much slickensided |
| 1,860 | " medium grey....... | 4 | Vein calcite, V.H. |
| 1,860-1,863 | " light grey........... | 3 | Vein calcite, V.H. |
| 1,860-1,866 (sic) | " dark grey........... | 1 | Very well laminated |
| 1,880 | " green-grey.......... | 3 | Fine, calcareous sandstone, M. |

93D
Log No. 4, Canadian Natural Gas Company, Well No. 2, Lot 164, St.-Amable, North

| $\begin{aligned} & \text { Depth } \\ & \text { (in feet) } \end{aligned}$ | - | Rate of effervescence with acid Cold | Notes |
| :---: | :---: | :---: | :---: |
| 98 | Clay, light grey.... | 3 | Surface material |
| 98- 108 | Sandy shale, reddish brown....... | 2 | Quartz grains 0.2 to 0.5 mm ., L. |
|  |  | 2 |  |
| $118-128$ $128-138$ | " " ${ }_{\text {" }}$ " | 2 |  |
| 138- 148 | " " |  | " " 0.2 to 0.5 mm ., L L . ${ }^{\text {andstone, } \mathrm{L} \text {. }}$ |
| 148- 158 | " " | 2 | " " 0.2 to 0.5 mm ., L . |
| 158-168 | Sandstone, green-grey and red...... | 2 | Medium to coarse grained; red-brown shale, P. |
| 168-178 | Sandy shale, reddish brown...... | ${ }_{2}^{2}$ | Sandstone, H. V.E. |
| 188-198 |  |  | Missing |
| 198- 208 | Sandy shale, reddish brown...... | 2 | Medium to coarse-grained sandstone, V.H. |
| 208- 218 | Sandstone, green-grey and reddish | 2 | Red brown, sandy shale, V.H. |
| 218- 2288 | Sandy shale, reddish brown....... | $\stackrel{2}{2}$ | Green-grey, fine sandstone, V.L. |
| 238-248 |  |  | Missing |
| 245- 255 | Sandstone, greenish grey. | 2 | Fine to coarse-grained, green-grey shale, H. |
| 265-275 | Sandy shale, reddish brown....... | 2 | Green-grey sandstone. Fine to medium grained, |
| 275-285 | " " " | ${ }_{2}^{2}$ | " " V |
| $285-295$ $295-305$ | Shaly sandstone, reddish brow | ${ }_{2}^{2}$ | Fine grained; green-grey sandstone, fine to medium grained, M |
| 305-317 | Sandstone, reddish brown......... | 2 | Fine grained; green-grey sandstone, fine to medium grained, |
| 317-327 | Sandy shale, reddish brown | 2 | Green-grey, sandy shale, V.L.; fine, red sandstone, M. Missing |
| ${ }_{337-}^{327-} 341$ | Sandstone, reddish brown |  | Fine grained; green-grey sandstone, V.L.; rounded quartz grains to 0.5 mm ., V.I |
| 341-351 | " | 3 | Fine to medium grained; green-grey sandstone, fine to coarse grained, V.L.; roun ed quartz grains to 0.5 mm ., V.L. |
| 351-361 | " " | 2 | Fine to coarse grained; green-grey sandstone, fine to coarse grained, L.; rounded quartz, V.L. |
| 361-371 | " " | 2 | Fine to medium grained; green-grey sandstone, fine to coarse grained, V.L.; round. ed quartz, V.L. |
| 371- 381 |  |  | ed quartz, V.L. Missing |
| 381-391 | brown-red | 2 | Fine to medium grained; green-grey sandstone, fine to coarse grained, M.; rounded quartz, V.L. Fibrous vein calcite, P. |

Log No. 4, Canadian Natural Gas Company, Well No. 2, Lot 164, St.-Amable, North-Continued

| Depth (in feet) | - | Rate of effervescence with acid Cold | Notes |
| :---: | :---: | :---: | :---: |
| 391-401 | Sandy shale, reddish brown. | 2 | Greenish grey shale, M.; fibrous vein calcite, M. |
| 401-411 | " brownish red. | 3 | " "\% L.; " " L. |
| 411- 421 | " ${ }_{\text {" }}$ ¢ ${ }^{\text {cownish grey.. }}$ | ${ }^{3}$ | " " L.; " " L. |
| 421- 431 |  | 3 | Fibrous vein calcite, $\mathrm{P}^{\text {Preenish }}$. . fibrous vein calcite, L |
| ${ }_{441-}^{451}$ | "، reddish ${ }^{\text {" brown. }}$ | 3 |  |
| 451- 463 | Sandstone, greenish grey. | 3 | Very fine grained; fibrous vein calcite, M.; one large fragment shows considerable porosity similar to the weathered surface |
| $463-475$ | Sandy shale, reddish " brown. | 3 3 | Fibrous vein ealcite, V.L. |
| 485-497 | " " | 3 | ". " L.; quartz grains 0.2 to 0.5 mm ., L. |
| 497- 500 |  |  | Missing Very fine-grained sandstone L. |
| 510-520 | " " | 2 | Very fue-grained sandstone, L. |
| 520-530 | " " | 2 | Greenish grey, fine-grained sandstone, L.; fibrous vein calcite, V.L.; quartz grains 0.2 to 1.0 mm ., V.L. |
| 530-540 | " " | 1 | Quartz grains 0.2 to 0.5 mm ., L. |
| $540-550$ $550-560$ | "، " | ${ }_{2}^{2}$ | Greenish grey, fine-grained saydstone, L.; fibrous vein calcite, L. Fibrous vein calcite, L. |
| 560- 570 | " " | 3 | Greenish grey, fine-grained sandstone, L.; fibrous vein calcite, L. |
| 570-580 | " " | 3 | Fibrous vein calcite, M. |
| ${ }_{580-590}^{500}$ | " " | 2 | Greenish grey, fine-grained sandstone, L. |
| ${ }_{600-610} 6$ | " ${ }^{\text {a }}$ | ${ }_{2}^{2}$ | Fibrous vein calcite, V.L. ${ }_{\text {Greenish grey, fine-grained sandstone, V.L.; fibrous vein calcite, M.; quartz grains }}$ |
| 610-620 | " " | 2 | 0.2 to 0.5 mm ., $L$. |
| 620-630 | " " | 2 | Fbrous vein calcite, P.L. |
| 630-640 | " " | 1 | Greenish grey, fine-grained sandstone, V.H.; fibrous vein calcite, L. |
| $640-650$ | " " | 2 | Fibrous vein calcite, V.L.; white gypsum, $P$. |
| $650-660$ $860-670$ | " " | ${ }_{2}^{2}$ | Greenish grey, fine-grained sandstone, V. L.; fibrous vein calcite, P. Greenish grey, fine-grained sandstone, fine to coarse grained, |
|  |  |  | calcite, P.; gypsum, P. |
| 670-680 | " " | 2 | Greenish grey, fine-grained sandstone, fine to coarse grained, V.L.; fibrous tein calcite, V.L. gypsum, P. |
| 680-690 | " " | 3 | Greenish grey, fine-grained sandstone, fine to coarse grained, L.; fibrous vein calcite, M |

Greenish grey sandstone, medium to coarse grained, M.; fibrous vein calcite, L.
Greenish grey sandstone, fine to coarse grained, V.L.; fibrous vein calcite, P.;
Greenish grey sandstone, ine to coarse grained, V.L.; fibrous vein calcite, P.;
gypsum, $P$.
Fibrous vein calcite, $P$.
Rounded quartz sand, L.; fibrous vein calcite, $P$.
Rounded quartz sand, P.; greenish grey, fine-grained sandstone, $P . ;$ fibrous vein
Medium sand, M.; greenish grey, fine-grained sandstone, P.; fibrous vein cal-
Rounded, medium-grained sand, L.; greenish grey, fine-grained sandstone, P.; Medium fibrous vein calcite, P.; gypsum, P.

Quartz grains 0.2 to 0.5 mm ., $\mathrm{L}_{\text {. }}$; fibrous vein calcite, $\mathrm{L}_{\text {. }} ;$ gypsum, $\underset{\text { s }}{\mathrm{P}} \mathrm{P}$.
Fibrous vein calcite, V.L.; gypsum, V.L.
Quartz grains 0.2 to $0.5 \mathrm{~mm} ., M_{\text {. ; greenish grey sandstone, fine to medium grained; }}$
Quartz grains 0.2 to 0.5 mm ., V.L.; greenish grey sandstone, fine to medium grained, V.H.
Fibrous vein calcit
Quartz grains 0.2 to 0.5 mm . V.L.; greenish grey sandstone, fine to medium Quartz grains 0.2 to 0.5 mm ., L.; gypsum, $L$.
Quartz grains 0.2 to 0.5 mm ., L.; greenish grey sandstone, fine to medium grained; Quartz grains 0.2 to 0.5 mm ., V.L. Greenish grey sandstone, fine to medium grained, V.H.; gypsum, P. $0.1 \mathrm{~mm} .$, L.; greenish grey sandstone, fine to medium grained, L.;
0.1 mm ., M.; greenish grey sandstone, fine to medium grained, $\mathrm{I}_{\text {. }}$; 0.1 mm . M.; green-grey, P .
$0.1 \mathrm{~mm} ., \mathrm{M}$; ; green-grey, sandy shale, M.; gypsum, P . $0.1 \mathrm{~mm} .$, M.; green-grey, sandy shale, L.; gypsum, P.
$0.5 \mathrm{~mm} .$, L.; green-grey sandstone, M.; Eypsum, P.
$0.5 \mathrm{~mm} ., \mathrm{V} . L . ;$ brown-red sandstone, V.L.; gypsum, P.
0.5 mm ., V.L.; green-grey, sandy shale, L.
0.5 mm ., V.L.; green-grey sandstone, V.L.; green-grey shale, M.; gypsum, $P$.
" : $\div=$ $\because=$ $\because:$ $\approx$ Missing

Log No. 4, Canadian Natural Gas Company, Well No. 2, Lot 164, St.-Amable, North-Continued

| Depth (in feet) | - | Rate of effervescence with acid Cold | Notes |
| :---: | :---: | :---: | :---: |
| 1,053-1,063 | Sandy shale, red-brown. | 1 | Quartz grains 0.5 mm ., M.; green-grey sandstone, V.L. |
| 1,063-1,073 |  | 2 | " 0.5 mm ., V.H.; green-grey, sandy shale, V.L.; gypsum, P. |
| 1,073-1,083 | " green-grey | 2 | " $0.5 \mathrm{~mm} ., \mathrm{V} . \mathrm{L} . ;$ brown-red, sandy shale, V.H. |
| 1,083-1,093 | " red-brown. | 2 | " $0.5 \mathrm{~mm} ., \mathrm{V} . \mathrm{L} . ;$ green-grey, sandy shale, V.H.; gypsum, V.L. |
| 1,093-1,105 | " ، | 1 | $" 0.5 \mathrm{~mm} ., \mathrm{V} . \mathrm{L} . ;$ green-grey, sandy shale, L.; gypsum, V.L. |
| 1,105-1,115 | " " | 1 | " $0.1 \mathrm{mm}$. . V.L.; green-grey, sandy shale, V.L.; gypsum, P. |
| 1,115-1,125 | " | 1 | 0.5 mm ., V.L.; green-grey shale, V.H. |
| 1,125-1,135 | " | 1 | " $0.5 \mathrm{mm}$. . V.L.; green-grey shale, V.L.; gypsum, P. |
| 1,135-1,145 | * | 1 | " $\quad 0.5 \mathrm{~mm} ., \mathrm{V} . \mathrm{H} . ;$ green-grey shale, P.; gypsum, P. |
| 1,145-1,150 | $" 3$ | 1 | $0.5 \mathrm{~mm} ., \mathrm{V} . \mathrm{L} . ;$ green-grey, sandy shale, V.L.; gypsum, P. |
| 1,150-1,160 | " " . | 1 | $0.5 \mathrm{mm.}, \mathrm{V.L.;} \mathrm{green-grey} ,\mathrm{sandy} \mathrm{shale}, \mathrm{V.H}$. |
| 1,160-1,170 | red-brown and greengrey | 1 | 0.1 mm ., V.L. |
| 1,170-1,180 | "، red-brown.......... | 2 |  |
| 1,180-1, 190 | "، " | 1 |  |
| 1,190-1, 200 | " " | 1 |  |
| 1,200-1,210 | Igneous, dark grey.......... | 1 | Red-brown shale, H. |
| 1,210-1,220 | Sandy shale, redaish brown. | 1 | Rounded quartz grains to 0.5 mm ., V.L. ${ }^{\text {c }}$; greenish grey, sandy shale, H. |
| 1,220-1,230 | "، greenish grey. | 2 |  |
| $1,230-1,240$ $1,240-1,250$ | " " | 2 1 |  |
| 1,250-1,260 | " " | 1 |  |
| 1,260-1,270 | " " | 2 | " " 0.5 mm ., V.L. |
| 1,270-1,280 | Shale, dark grey | 3 | Brownish grey limestone, M. |
| 1,280-1,290 |  | 3 | Impure limestone, L . |
| 1,290-1,300 | " " | 3 | " H.; fibrous vein calcite, $P$. |
| 1,300-1,310 | " " ${ }^{\text {" }}$ | 3 |  |
| 1,310-1,320 | " "\% ................ | 3 |  |
| 1,320-1,330 | " " | 3 |  |
| 1,330-1,340 | " " ${ }^{\text {" }}$ | 3 3 | "" " $\quad$ H. $\quad$. |
| $1,340-1,350$ $1,350-1,360$ | " | 3 | Missing " grading to calcareous shale, V.H. |
| 1,360-1,370 | Limestono, dark grey | 4 | Dark grey shale, V.H.; dark grey limestone, grading to calcareous shale, V.H. |
| 1,370-1,380 | Shale, dark grey..... | 4 | Very impure limestone, V.H.; slickensides |
| 1,380-1,390 | Impure limestone, dark grey | 4 | Grading to calcareous shales; slickensides |
| 1,390-1,400 | Shale, dark grey.. | 3 | Very impure limestone, M, |
| 1,400-1,410 | " $\%$,..........,.... | 3 | ¢ ${ }^{\text {¢ }}$ |


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Log No. 4, Canadian Natural Gas Company, Well No. 2, Lot 164, St.-Amable, North—Continued


$\infty \infty \infty \infty$

Log No. 4, Canadian Natural Gas Company, Well No. 2, Lot 164, St.-Amable, North-Continued

| Depth (in feet) |  |  |  | Rate of effervescence with acid Cold | Notes |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2,790-2,800 | Shale, very dark grey.. |  |  | 32332221222 | Fine, grey, calcareous sand, M.; vein calcite, P. <br> Vein calcite, P. <br> Grey, calcareous sandstone, $P$. <br>  <br> Grey, calcareous sandstone, H. |
| $\stackrel{2,800-2,810}{ }$ |  |  |  |  |  |
| 2,820-2,830 | " | " |  |  |  |
| 2,830-2,840 | " | " |  |  |  |
| $\stackrel{2,840-2,850}{2} 850$ | " | " |  |  |  |
| $2,850-2,860$ $2,860-2,870$ | " | " |  |  |  |
| 2,870-2,880 | " | " |  |  |  |
| 2,907 | " | " |  |  |  |

Insoluble Residues after Treatment with Hot HCl

| Sample from | Amount of residue Per cent | Character |
| :---: | :---: | :---: |
| 1,360-1,370 | 60 | Sandy shale, high; dark shale, low |
| 1,370-1,380 | 68 | Fine-grained, white sandstone, high; dark shale, low |
| 1,650-1,660 | 80 | Sandy shale, low; dark shale, high |
| 1,660-1,670 | 80 | "\% "، "* ${ }_{\text {c }}$ |
| 1,670-1,680 | 82 | " " " " " |
| $1,680-1,690$ $1,690-1,700$ | ${ }_{66}^{68}$ | " " " " " |
| 2,500-2,510 | 80 | " " " " |
| 2,520-2,530 | 62 | Fine-grained, white sandstone, high; dark shale, low |

[^14] stone rather than thin limestone bands.
Log No. 5, Canadian Natural Gas Company, Well No. 3, Lot 227, St.-Amable, North

| Depth (in feet) | - | Rate of efferwith acid Cold | Notes |
| :---: | :---: | :---: | :---: |
| $75-85$ | Shale, dark grey. | 1 | Vein calcite, P.; slickensides; coarse sand, P. |
| $85-$ <br> 95 <br> 95 <br> 95 <br> 105 | " "، $\quad$ "....... | ${ }_{2}^{2}$ | " ${ }_{\text {¢ }}$ P.; coarse sand, P.; grey, sandy \%hale, P. |
| 105-115 | Sandy shale, dark grey... | 3 | " P.; slickensides; rounded quartz grains 0.2 to 0.50 mm., $P$. |
| 115-125 |  | 3 |  |
| 125-135 | "، " | 3 |  |
| $135-145$ <br> $145-155$ <br> 150 | "" " | 3 |  |
| 145-155 | " $:$ :. $\cdot$ | ${ }_{3}^{3}$ |  |
| 165-175 | " ${ }_{\text {" }}$ | 3 | " ${ }^{\text {P.; }}$ " " 0.2 to 0.5 mm ., $\mathrm{L}_{\text {. }}$; " P . |
| 185-195 | " | 3 | "" P.; slickensides; rounded quartz grains 0.2 to 0.5 mm ., L. |
| $195-205$ $205-215$ | " ${ }^{\prime \prime}$ " $\quad . . .0$ | ${ }_{3}^{3}$ | " <br>  |
| 215-225 | " "، $\quad$ ".... | 3 |  |
| 225-235 | " ${ }_{\text {" }}$ | 3 | " P.; " ${ }^{\prime \prime}$ " 0.2 to 0.5 mm ., L . |
| ${ }^{235-} 245$ | " | 3 |  |
| 245- 255 | " | 3 |  |
| 265- 275 | " " $\quad$..... | 3 |  |
| 275-285 | " " ${ }_{\text {" }}$ | 3 | " ${ }^{\text {c/ }}$.; rounded quartz grains 0.2 to 0.5 mm ., M. |
| 285- 395 | " ${ }_{\text {" }}{ }^{\text {a }}$ | 0 |  |
| 295- 305 | " " | 1 |  |
| 315-325 | " " | 3 | V.L.; " " 0.2 to 0.5 mm ., V.L. |
| 325-335 | " ${ }_{\text {" }} \times$ | 2 | " L.; " " 0.2 to 0.5 mm ., V.L. |
| 335-345 | " | 2 | " V.L.; slickensides; rounded quartz grains 0.2 to 0.5 mm ., P. |
| 345- 355 <br> $355-365$ | " " | 3 | " L.L.; rounded quartz grains 0.2 to 0.5 mm ., P. |
| 365-375 | " | 3 | " M.; " " 0.2 to 0.5 to mm ., L . |
| 375-385 | " | 3 | Rounded quartz grains 0.2 to 0.5 mm ., H. |
| $385-395$ <br> $395-405$ | " " | ${ }_{2}^{2}$ | " " 0.2 to 0.5 mm ., H.; 1 grey garnet |
| $395-405$ $405-415$ | " " | 3 | Vein calcite, L.; rounded qusrtz grains 0.2 to 0.5 mm ., H. Rounded quartz grains 0.2 to 0.5 mm ., H. |
| 415-425 | "" " | 3 | Vein calcite, L.; rounded quartz grains 0.2 to 0.5 mm ., M. |
| $425-435$ $435-445$ | " " | 3 | V.L.: " 0.2 to 0.5 m |
| 445-455 | " " | 2 |  |

Log No. 5, Canadian Natural Gas Company, Well No. 3, Lot 2.97, St.-Amable, North-Continued




Lug No. 5, Canadian Natural Gas C'ompany, Well No. 3, Lot 297, St.-Amable, North-Continued







Log No. 5, Canadian Natural Gas Company, Well No. 3, Lot 227, St.-Amable, North—Continued









Log No. 5, Canadian Natural Gas Company, Well No. 3, Lot 297, St.-Amable, North-Continued


| Insaluble Residues after Treatment with Hot HCl |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Sample from | $\begin{aligned} & \text { Amount } \\ & \text { of } \\ & \text { residue } \end{aligned}$ | Sample from. | Amount of residue | Sample from | $\begin{aligned} & \text { Amount } \\ & \text { of } \\ & \text { residue } \end{aligned}$ | Sample from | Amount of residue | Sample from | $\begin{gathered} \text { Amount } \\ \text { of } \\ \text { residue } \end{gathered}$ |
|  | Per cent |  | Per cent |  | Per cent |  | Per cent |  | Per cent |
| 145-155 | 40 | 495-505 | 85 | 795-805 | 75 | 1,145-1,155 | 80 | 2,045-2,055 | 80 |
| 205-215 | - 75 | 545-555 | 70 | 845- 855 | 75 | 1,235-1,245 | 80 | 2,095-2,105 | 80 |
| 315-325 | 75 | 595-605 | 75 | 895-905 | 80 | 1,345-1,355 | 75 | 2,295-2,305 | 80 |
| 345-355 | 90 | 645-655 | 75 | 945-955 | 85 | 1,385-1,395 | 75 | 2,355-2,365 | 80 |
| 395-405 | 80 | 705-715 | 70 | 995-1,005 | 80 | 1,445-1,455 | 90 |  |  |
| 455-465 | 70 | 745-755 | 70 | 1,105-1,115 | 75 | 1,945-1,955 | 80 |  |  |

With the exception of the residue from the sample obtained from 145 to 155 feet, the residues are mainly shaly and nearly always contain round-
ed and angular, coarse sand. There appears to be very little sand of medium or coarse grains in the samples examined from 945 to 1,455 feet ( 8 samples). The residue for the sample from 145 to 155 feet contains much secondary silica in the form of well-developed quartz crystals.

Log No. 6, Canadian Natural Gas Company, Well No. 4, Lot 989, St.-Jude-Ste.-Rose

| Depth (in feet) | - | Rate of effervescence Cold | Notes |
| :---: | :---: | :---: | :---: |
| 120-120 | Shale, green-grey. | 1 | Quartz pebbles and fine sand, P.; red shale, P. |
| 120-130 | " | $\frac{1}{1}$ |  |
| 140-150 | No sample |  |  |
| $150-160$ |  |  |  |
| 170-180 | Shale, green-grey and red.. | 2 | Quartz pebbles and fine sand, P. |
| 180- 190 | " " ${ }_{\text {" }}$ | ${ }_{2}$ |  |
| $190-200$ $200-210$ | " " ${ }_{\text {" }}$ | 2 2 | " ${ }_{\text {" }}$ |
| 210-220 | " red. | 1 | Green-grey shale, M. |
| 220-230 | Sandy shale, red. | 1 | Quartz pebbles and fine sand, P .; green-grey shale, M. ${ }^{\text {M }}$. ${ }^{\text {a }}$, |
| $230-240$ 240 250 | " ${ }^{\text {" }}$ | 1 |  |
| 250-260 | " " | , | Pyrite, P.; white quartz pebbles, P.; green-grey shale, P. |
| 260- 270 | Sandstone, green, shaly ......... | ${ }_{2}^{2}$ | Fine grained; red, shaly sandstone, L.; green shale, P.; red shale, P. |
| -270-280 | Shale, red .............. | ${ }_{1}^{2}$ | Green, sandy shale, P.; white effervescence |
| 290- ${ }_{200}^{290}$ | Sandy shale, red and green.. | 1 | " " D.; ", sandy shale, H. |
| 300-310 | " green, grey, and red | 1 | Green-grey, sandy shale, D.; red, sandy shale, H. |
| 310-320 | " red.. | 2 |  |
| $330-330$ <br> $330-340$ | " green-grey and red. | 2 |  |
| ${ }^{340-350}$ | red. | 2 | " " $\quad$ L. ${ }^{\text {c }}$ |
| $350-360$ $360-370$ | " ${ }^{\text {" }}$ green-grey and red. | $\stackrel{2}{2}$ | " " D.; " $\quad$ " $\quad$ H.; fine sandstone, L. |
| 370-380 | " | 2 | " L. |
| 380-390 | " " | 1 | L. |
| 390- 400 | " " ${ }^{\text {" }}$ | 1 | " " ${ }^{\text {" }}$ " M.; fine, red sandstone, P . |
| 410-420 | " " $\ldots$................ | 1 | " " $\quad$ M.; green-grey sandstone, $P$ P ${ }^{\text {a }}$, red and green, fine sandstone, $P$. |
| 420-430 | Shaly sandstone, green-grey...... | 2 | Red, sandy shale, L.; fine grained |
| $430-440$ $440-450$ | Sandstone, green-grey........... | 1 | Red sandstone, P.; red, sandy shale, L.; fine grained Red, sandy shale, L.; fine grained; coarse sandstone, $P$. |

M.
Fine sand H ; green shale H.; red shale, H.; subangular quartz 0.5 mm . coarse, rounded quartz, $P$.

## $\underset{6}{\text { coarse sand, }} \underset{P}{P}$.

subangular quartz, $P$.

H.i.
 Green-grey shale, M.; green-grey sandstone, L.
sandy shale, M. green-grey sandstone, L.
 Grey, sais "4, H.; greenish grey, fine-grained sandstone, L.
Greenish grey, sandy shale, V.H. Reddish brown, sandy shale, red shale,

## 5 mm. .5 mm. .5 mm. .5 mm. .5 mm. .5 mm. .5 mm. brous, b. .5 mm.

0.5 mm . g
102
0 gig
g
0.00 병 \%0000000040
 $==$

Log No. 6, Canadian Natural Gas Company, Well No. 4, Lot 982, St.-Jude-Ste.-Rose—Continued










Log No. 6, Canadian Natural Gas Company, Well No. 4, Lot 982, St.-Jude-Ste.-Rose-Continued


Log No. 7, Canadian Natural Gas Company, Well No. 5, Lot 160, St.-Amable, North


The above samples are represented by very small quantity, most of the material being washed through 200 -mesh sieve.
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Log No. 7, Canadian Natural Gas Company, Well No. 5, Lot 160, St. Amable, North-Continued





Nors. The above samples are represented by very small quantity, most of the material being washed through 200 -mesh sieve.
Log No. 7, Canadian Natural Gas Company, Well No. 5, Lot 160, St.-Amable, North—Continued


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[^15]Log No. 7, Canadian Natural Gas Company, Well No. 5, Lot 160, St. Amable, North-Continued
Insoluble Residue after Treatment with Hot HCl

| Samples from | $\begin{gathered} \text { Amount } \\ \text { of } \\ \text { residue } \end{gathered}$ | Samples from | $\begin{aligned} & \text { Amount } \\ & \text { of } \\ & \text { residue } \end{aligned}$ | Samples from | Amount of residue | Samples from | Amount of residue | Samples from | Amount of residue |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Feet | Per cent | Feet | Per cent | Feet | Per cent | Feet | Per cent | Feet | Per cent |
| 630-640 | 80 | 1,340-1,350 | 90 | 1,790-1,800 | 90 | 2,050-2,060 | 95 | 2,280-2,290 | 85 |
| 770-780 | 90 | 1,390-1,400 | 85 | 1,840-1,850 | 95 | 2,090-2,100 | 95 | 2,390-2,400 | 95 |
| $880-890$ | 85 | 1,490-1,500 | 80 | 1,940-1,950 | 95 | 2,140-2,150 | 95 | 2,400-2,410 | 85 |
| 1,030-1,040 | 90 | 1,560-1,570 | 95 | 2,000-2,010 | 85 | 2,190-2,200 | 90 | 2,420-2,430 | 90 |
| 1,190-1,200 | 75 | 1,690-1,700 | 85 | 2,040-2,050 | 90 | 2,240-2,250 | 95 |  |  |

The residues are mainly sandy shale. Below 1,700 feet the residues are probably more sandy than shaly. Nearly all samples contain angular
and rounded sand grains, but the bulk of the material is a fine sand from which the carbonate content has been removed by the acid.
Log No. 8, National Gas Company, Well No. 1, Lot 1819, St.-André, North

Log No. 8, National Gas Company, Well No. 1, Lot 1319, St.-André, North-Continued


| * | * | 6 | * | L.; | yps | P. |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| * | * | 6 | 6 | L.; |  | $P$ |
| 4 | * | * | c | L.; | 4 | $\mathbf{P}$ |
| 6 | * | 6 | 6 | L. |  |  |
| " | * | * | * | L.; | 4 | $\underset{P}{P}$ |
| 6 | * | 6 | ${ }^{6}$ | L.; | 4 | P. |
| 6 | 6 | 6 | 6 | 工.; |  |  |
| * | * | * | * | L. |  |  |
| * | ${ }^{6}$ | * | 6 | $\underline{L}$ |  |  |
| 6 | 6 | 6 | * | L. |  |  |
| ، | ${ }^{6}$ | * | * | L. |  |  |
| " | ${ }^{6}$ | ${ }_{6}$ | * | L. |  |  |
| ${ }^{6}$ | ${ }^{6}$ | ${ }_{6}$ | ${ }^{6}$ | L. |  |  |
| Rounded sandstone, $\mathrm{L}_{6} \mathrm{~L}_{*} ;$ red-brown, sand \% $_{6}$ shale, $\frac{\mathrm{H}}{\mathbf{M}}$. |  |  |  |  |  |  |
| ${ }^{6}$ | ${ }_{6}$ | 6 |  | 6 | M. |  |
| " | " | ${ }^{6}$ |  | \% | H. |  |
| Red and green shale, $\mathbf{P}$. |  |  |  |  |  |  |

Red shale, P. coarse sandstone, $P$.
Medium grit, $P$.
Medium-grained, gritty sandstone, $P$ P.
Fine-grained, gritty sandstone, P.; fibrous calcite, $P$.; slickensides, P. Fine-grained, gritty sandstone, L.; vein calcite, $P$.
Fine, calcareous sandstone, M.; micaceous shale, $P$.
Calcite vein 5.00 mm . width; pyrite nodule 2.00 mm . diameter
Pyrite, $\mathbf{P}$.



Log No. 8, National Gas Company, Well No. 1, Lot 1319, St.-André, North-Continued

| Depth (in feet) | - | Rate of effervescence with acid Cold | 4 Notes |
| :---: | :---: | :---: | :---: |
| 1,300-1,310 | Shale, medium grey | 3 | Vein calcite, H.; calcareous shale, H. |
| 1,310-1,320 |  | 3 | " L.; " " P. |
| $\begin{aligned} & 1,320-1,330 \\ & 1,330-1,340 \end{aligned}$ | Misging ${ }_{\text {Shale, }}$ | 3 | " P.; " " L. |
| 1,340-1,350 | "" medium grey | 4 | " L.; " " ${ }^{\text {H. }}$ |
| 1,350-1,360 | " dark grey.... | 4 | " P.; " " L. |
| 1,360-1,370 | " green-grey | 4 | Calcareous shale, L. |
| $\begin{aligned} & 1,370-1,380 \\ & 1,380-1,390 \end{aligned}$ | " | 3 3 | Vein calcite, L.; calcareous shale, ${ }_{\text {\% }}^{\text {P }}$. |
| 1,390-1,400 | " | 3 | Calcareous shale, L . |
| 1,400-1,410 | " | 3 | " " H. |
| 1,410-1,420 | " " . | 3 | " " L . |
| $1,420-1,430$ $1,430-1,440$ | " " | ${ }_{3}^{3}$ | " " ${ }^{\text {\% }}$ |
| 1,440-1,450 | 碞 | 3 | " " L . |
| 1,450-1,460 | " | 4 | " " H. |
| 1,460-1,470 | " " | 3 | Calcareous, sandy shale, H. |
| 1,470-1,480 | " ${ }_{\text {" }}$ " | 3 | " " $\quad$ H. fosils, $P$ |
| $1,480-1,490$ $1,490-1,500$ | ، | ${ }_{3}^{3}$ | Vein calcite, P.; calcareous, sandy shale, H.; fossils, P. |
| 1,500-1,510 | " " | 3 |  |
| 1,510-1,520 | " " | 4 | " L.; " " M.; hand specimen showing slip |
| $1,520-1,530$ $1,530-1,540$ | " " | 3 | Calcareous, sandy shale, H.; ${ }_{\text {\% }}$ \% ${ }^{\text {\% }}$ |
| 1,540-1,550 | " " | ${ }_{3}^{3}$ |  |
| 1,550-1,560 | " " | 3 | " " M.; limestone, P.; slickensides |
| 1,560-1,570 | " " | 2 | " " M. |
| $1,570-1,580$ $1,580-1,590$ | " " | $\stackrel{2}{2}$ | Vein calcite, P. P.; calcareous, sandy shale, H. |
| 1,590-1,600 | " " | 2 | Calcareous, sandy shale, H.; vein calcite, P . |
| 1,600-1,610 | " " | 3 | " ${ }^{\text {\% }}$, |
| 1,630-1,640 | " | 2 | " " M ${ }^{\text {\% }}$ |
| $1,640-1,650$ $1,650-1,660$ | " " | $\stackrel{2}{3}$ |  |







31400-9

Log No. 9, National Gas Company, Well No. 2, Lot 1319, St.-André, North




Log No. 9, National Gas Company, Well No. 2, Lot 1319, St.-André, North-Continued

| Depth (in feet) | - | $\left\|\begin{array}{c}\text { Rate of } \\ \text { offor- } \\ \text { vescence } \\ \text { withacid } \\ \text { Cold }\end{array}\right\|$ | Notes |
| :---: | :---: | :---: | :---: |
| 950-960 | Limestone, dark grey. | 3 | Dark grey shale, M.; vein calcite, V.L.; shows shell impression; slickensides |
| 970-980 | Shale, dark grey. | ${ }_{3}^{2}$ |  |
| 980-990 | Limestone, dark grey. | 3 |  |
| $990-1,000$ $1.000-1.010$ | " "، | 3 | " " V.L.; " ${ }_{\text {L }}$ |
| 1,010-1,020 | " " | 3 |  |
| 1,020-1,030 | " | 3 | Dark grey limestone, V.H.; vein calcite, L. |
| 1,030-1,040 | Shale, dark grey | 3 |  |
| $1,040-1,050$ $1,050-1,060$ | " " | 3 3 3 |  |
| 1,060-1,070 | " |  | " " H.; " L.; a little brown, glassy material |
| 1,070-1,080 | " " | 3 | " " L.; " L. |
| 1,080-1,090 | " |  | " " H.; " L. |
| 1,090-1,100 | " | 4 | Pyrite, P.; dark grey limestone, H.; white calcite, L. |
| 1,110-1,120 | "" " | 3 | Grey limestone, H.; white calcite, V.L. |
| 1,120-1,130 | " " | 3 | " M.; "* " |
| 1,130-1,140 | " " | 3 |  |
| 1,140-1,150 | " | $\stackrel{2}{2}$ |  |
| 1,160-1,170 | " | 2 | " M.; " " |
| 1,170-1,180 | " " |  | " I.; " " ${ }^{\text {c }}$ |
| 1,180-1,190 | " " . | 2 | " H.; " " ${ }^{\text {\% }}$ " |
| 1,190-1,200 | " " | $\stackrel{2}{2}$ |  |
| ${ }_{1}^{1,200-1,210}$ | " | 2 | " M.; " " P. |
| 1,220-1,230 | " |  | " L L.; " " P. |
| 1,230-1,240 | " |  | " L.; " " V.L. |
| 1,240-1,250 | " |  | " M.; " " V.L |
| ${ }_{1}^{1,250-1,260}$ | " | ${ }_{3}^{2}$ |  |
| 1,270-1,280 | " " | 3 | White calcite, P.; grey limestone, H. |
| 1,280-1,290 | " " | ${ }_{3}^{3}$ | Vein cailcite, P.; grey limestone, V.H. |
| $1,290-1,300$ $1,300-1,310$ | " " ${ }^{\text {" }}$..... | 3 | Dyke rock V.L.; " H. |
| ${ }_{1}^{1,300-1,310}$ | Igneous, medium grey. | 1 | Dyke rock |
| 1,320-1,330 | Shale, dark grey..... | 1 | Vein calcite, P.; limestone, P. |



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Log No. 10, Ste.-Madeleine Well, Lot 93, Ste.-Madeleine, Quebec


# Lot No. 11, Bergeron Well, Ernest Rheault Lot, Pointu Concession, Bécancour Seigniory, Nicolet County 

|  |  |
| :--- | :--- | :--- | :--- |

Lot No. 12, Trudel Well, Lot 501, Roquetaillade Seigniory, Nicolet County

| - | Thickness | Depth |
| :---: | :---: | :---: |
|  | Feet | Feet |
| Blue loam with thin layers of sand. | 47 | 47 |
| White sand; emanations of gas. | 5 | 52 |
| Gravel; emanations of gas and water | 15 | 67 |
| Black sand, dense; water, but no gas. | 7 | 74 |
| Sandstone, somewhat calcareous, oily oozings. | 80 | 154 |
| Same as preceding, but harder and finer grained | 60 | 214 |
| Red shale. | 75 | 289 |
| Red shale, lighter colour. | 10 | 299 |
| Shale, nearly black........... | 16 | 315 |
| Shale, blackish brown, not hard; abundant and sudden flow of gas, having a strong smell of kerosene. | 54 | 369 |
| Red shave; emanation of gas... | 105 | 474 |
| Red shale, somewhat greyish | 50 | 524 |
| Softer red shale............... | 55 | 579 |
| Red shale; another strong flow of gas. | 60 | 639 |
| Impure calcareous rock apparently containing magnesia. Another vein of gas. | 20 | 659 |
| Calcareous rocks. | 60 | 719 |
| Oily, calcareous rock | 100 | 819 |
| Black shale; flow of gas. | 40 | 859 |
| Black shale, compact. | 225 | 1,084 |
| Depth of well.. |  | 1,115 |

## OTHER FIELD WORK

## Geological

T. L. Tanton. Mr. Tanton completed the geographical and geological mapping of Shebandowan 1-mile quadrangle, Ontario (latitudes $48^{\circ} 30^{\prime}$ to $48^{\circ} 45^{\prime}$, longitudes $90^{\circ} 00^{\prime}$ to $90^{\circ} 30^{\prime}$ ). Mr. Tanton also examined parts of the Manitou 4-mile map-area with a view to revising the geology for preparation of an 8 -mile map of a part of western Ontario.
A. F. Matheson. Mr. Matheson, under the supervision of T. L. Tanton, continued geographical and geological mapping of Michipicoten 1-mile quadrangle, Ontario (latitudes $47^{\circ} 45^{\prime}$ to $48^{\circ} 00^{\prime}$, longitudes $84^{\circ} 30^{\prime}$ to $85^{\circ} 00^{\prime}$ ).
H. M. Bannerman. Mr. Bannerman completed geographical and geological mapping of Horwood 1-mile quadrangle, Ontario (latitudes $47^{\circ} 45^{\prime}$ to $48^{\circ} 00^{\prime}$, longitudes $82^{\circ} 00^{\prime}$ to $82^{\circ} 30^{\prime}$ ).
W. H. Collins. Mr. Collins, with T. C. Phemister, completed geological mapping of Copper Cliff 1-mile quadrangle, Ontario (latitudes $46^{\circ} 15^{\prime}$ to $46^{\circ} 30^{\prime}$, longitudes $81^{\circ} 00^{\prime}$ to $81^{\circ} 30^{\prime}$ ).
T. T. Quirke. Mr. Quirke completed geological mapping of a 1-mile quadrangle east of Parry Sound, Ontario (latitudes $45^{\circ} 15^{\prime}$ to $45^{\circ} 30^{\prime}$ longitudes $79^{\circ} 30^{\prime}$ to $80^{\circ} 00^{\prime}$ ).
M. E. Wilson. Mr. Wilson continued the geological mapping of Perth 1-mile quadrangle, Ontario (latitudes $44^{\circ} 45^{\prime}$ to $45^{\circ} 00^{\prime}$, longitudes $76^{\circ} 00^{\prime}$ to $76^{\circ} 30^{\prime}$ ).

Alice E. Wilson. Miss Wilson spent part of the season mapping the Ottawa 1-mile quadrangle, Ontario and Quebec (latitudes $45^{\circ} 15^{\prime}$ to $45^{\circ} 30^{\prime}$, longitudes $75^{\circ} 30^{\prime}$ to $76^{\circ}$ ).
J. B. Mawdsley. Mr. Mawdsley, with A. H. Lang, commenced geological mapping of Chibougamau 1-mile quadrangle, Quebec (latitudes $49^{\circ} 45^{\prime}$ to $50^{\circ} 00^{\prime}$, longitudes $74^{\circ} 00^{\prime}$ to $74^{\circ} 30^{\prime}$ ).
T. H. Clark. Mr. Clark completed geological mapping of Sutton 1-mile quadrangle, Quebec (latitudes $45^{\circ} 00^{\prime}$ to $45^{\circ} 15^{\prime}$, longitudes $72^{\circ} 30^{\prime}$ to 73), and commenced geological mapping of Memphremagog 1-mile quadrangle (latitudes $45^{\circ} 00^{\prime}$ to $45^{\circ} 15^{\prime}$, longitudes $72^{\circ} 00^{\prime}$ to $72^{\circ} 30^{\prime}$ ).
E. Poitevin. Mr. Poitevin continued a systematic mineralogical study of the serpentine-asbestos belt in southern Quebec.
G. W. Crickmay. Mr. Crickmay, under the supervision of F. J. Alcock, concluded the study of the geology of Matapedia valley from Chaleur bay towards Amqui.
F. J. Alcock. Mr. Alcock continued geological mapping of the country bordering Chaleur bay both in Gaspe and New Brunswick.
C. H. Kindle. Mr. Kindle, under the supervision of E. M. Kindle, continued the geological study of the coastal part of Gaspe from Port Daniel to Percé.
A. Anrep. Mr. Anrep examined a number of the larger peat bogs in southern Quebec that appear to be suitable for the manufacture of peat litter products.
G. W. H. Norman. Mr. Norman commenced geological mapping of Hillsborough 1-mile quadrangle, New Brunswick (latitudes $45^{\circ} 45^{\prime}$ to $46^{\circ} 00^{\prime}$, longitudes $64^{\circ} 30^{\prime}$ to $65^{\circ} 00^{\prime}$ ).
G. F. Flaherty. Mr. Flaherty, under the supervision of G. W. H. Norman, commenced geological and geographical mapping of the New Brunswick part of Chignecto 1-mile quadrangle (latitudes $45^{\circ} 30^{\prime}$ to $45^{\circ} 45^{\prime}$, longitudes $64^{\circ} 30^{\prime}$ to $65^{\circ} 00^{\prime}$ ).
W. A. Bell. Mr. Bell, with E. A. Goranson, continued geological mapping of the Sydney 1-mile quadrangle, Nova Scotia (latitudes $46^{\circ} 00^{\prime}$ to $46^{\circ} 15^{\prime}$, longitudes $60^{\circ} 00^{\prime}$ to $60^{\circ} 30^{\prime}$ ).
E. R. Faribault. Mr. Faribault continued geological mapping of Sissiboo 1-mile quadrangle, Nova Scotia (latitudes $44^{\circ} 15^{\prime}$ to $44^{\circ} 30^{\prime}$, longitudes $65^{\circ} 30^{\prime}$ to $66^{\circ} 00^{\prime}$ ), and commenced geological mapping of Church Point quadrangle (latitudes $44^{\circ} 15^{\prime}$ to $44^{\circ} 30^{\prime}$, longitudes $66^{\circ} 00^{\prime}$ to $66^{\circ} 30^{\prime}$ ).

## Topographical

A. G. Haultain. Mr. Haultain continued topographical mapping of four 1-mile quadrangles that include the Sudbury copper-nickel mineral area, Ontario.
H. N. Spence. Mr. Spence ran control surveys in two 1-mile quadrangles in Ontario: Rabbit Lake quadrangle (latitudes $46^{\circ} 45^{\prime}$ to $47^{\circ} 00^{\prime}$, longitudes $79^{\circ} 30^{\prime}$ to $80^{\circ} 00^{\prime}$ ), and Wanapitei quadrangle (latitudes $46^{\circ} 30^{\prime}$ to $46^{\circ} 45^{\prime}$, longitudes $80^{\circ} 30^{\prime}$ to $81^{\circ} 00^{\prime}$ ).
A. C. Tuttle. Mr. Tuttle ran control surveys in three 1-mile quadrangles in Rouyn district, Quebec.
J. V. Butterworth. Mr. Butterworth ran control surveys for a detail map on a scale of 800 feet to 1 inch, of the mining area between Thetford and Black Lake.
R. C. McDonald. Mr. MeDonald ran control surveys in two 1-mile quadrangles in New Brunswick: Chignecto quadrangle (latitudes $45^{\circ} 30^{\prime}$ to $45^{\circ} 45^{\prime}$, longitudes $64^{\circ} 30^{\prime}$ to $65^{\circ} 00^{\prime}$ ), and St. Stephen quadrangle (latitudes $45^{\circ} 30^{\prime}$ to $45^{\circ} 45^{\prime}$, longitudes $64^{\circ} 30^{\prime}$ to $65^{\circ} 00^{\prime}$ ).
S. C. McLean and K. G. Chipman. Messrs. McLean and Chipman commenced a detailed survey, on a scale of 800 feet to 1 inch, of the coalmining area at Sydney, Nova Scotia.

Tabular anatase from basal Ordovician sandstone. Quarry near Eagleson Corners, near Ottawa.

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[^0]:    (b) Along the axis of the Sacre-Coeur-de-Marie anticline, between the Thetford-Broughton boundary and lot 14, range VII, Thetford town-

[^1]:    ${ }^{1}$ Le Platine et les Gites Platinifères de L'Oural et du Monde. Louis Duparc et Marguerite N. Tikonowitch, pp. 64-65.

[^2]:    ${ }^{1}$ Mawdsley, J. B.: "The Eagle River Area, Abitibi County, Quebec"; Geol. Surv., Canada, Sum. Rept. 1927, pt. C, p. 23.
    ${ }^{2}$, Geol. Surv., Canada, Ann. Rept., vol. IX, pt. A, p. 71 (1898).
    s O'Sullivan, Henry: 'Report of Progress of Exploration in the Country between Lake St. John and James Bay"; Dept. of Colonization and Mines, Quebec, 1898 and 1901.
    ${ }^{4}$ Low, A. P.: "Geological Report on the Chibougamau Mining Region"; Geol. Surv., Canada, Pub. No. 923 (1906).
    ${ }^{5}$ Mining Operations in the Province of Quebec, pp. 50-83 (1908).

[^3]:    1 "Report on the Geology and Mineral Resources of the Chibougamau Region, Quebec"; Dept. of Colonization, Mines, and Fisheries, Quebec, 1911.
    ${ }^{2}$ Cooke, H. C.: "Basins of the Nottaway" and Broadback Rivers"; Geol. Surv., Canada, Sum. Rept. 1914, p. 95; 1915, p. 170." "Some Stratigraphical and Structural Features of the Pre-Cambrian of Northern Quebec"; Jour. Geol., vol, 27, pp. 65-78, 180-203, 263-274, 367-382 (1919).
    ${ }^{2}$ Mawdsley, J. B.: "Lake David Area"; Geol. Surv., Canada, Sum. Rept. 1927, pt. C, p. 1.
    4 Tolman, C.: "Obatogamau River Area, Abitibi Territory, Quebec"; Geol. Surv., Canada, Sum. Rept. 1929, pt. C, p. 20.

[^4]:    1 Geol. Surv., Canada, Map. 190A; "Nottaway Sheet, Quebec".

[^5]:    1 Tolman, C.: "Obatogamau River Area, Abitibi Territory, Quebeo"; Geol. Surv., Canada, Sum. Rept. 1929, pt. C, p. 26.

[^6]:    31400-3

[^7]:    ${ }^{1}$ Mawdsley, J. B.: "Lake David Area, Chibougamau District, Quebec"; Geol. Surv., Canada, Sum. Rept. 1927, pt. C, pp. 7 et seq.

[^8]:    ${ }^{1}$ Geol. Surv., Canada, Mem. 83, p. 142.
    31400-43

[^9]:    ${ }^{1}$ Geol. Surv., Canada, Mem. 83, p. 39.
    Geol. Surv., Canada, Rept. of Progress 1863.

[^10]:    ${ }^{1}$ Geol. Surv., Canada, Mem. 72, p. 24.

[^11]:    ${ }^{1}$ Geol. Surv., Canada, Mem. 72, well No. 61.

[^12]:    ${ }^{1}$ Geol. Surv., Canada, Mem. 72, p. 24.

[^13]:    ${ }^{1}$ Criteria for the Recognition of Heavy Minerals Occurring in the Mid Continent Field"; Oklahoma Geol. Surv., Bull. 31 (1925).

[^14]:    The residues in general are either dark shale or very fine sandstone which probably merges into a sandy shale too fine to be a sand, and too The character of the residues and the carbonate content at 1,360-1,370,1,380-1,390, and 2,520-2,530 suggest a very fine-grained, calcareous sand-

[^15]:    Note. The above samples are represented by very small quantity, most of the material being washed through 200-mesh sieve.

